Quantifying mucosal blood volume fraction from multispectral images of the colon

Ela Claridge[a], Džena Hidović-Rowe[a], Tariq Ismail[b] and Phillipe Taniere[b]

[a]School of Computer Science, The University of Birmingham, U.K.
[b]Birmingham University Hospital, Birmingham, U.K.

Background

Angiogenesis – the formation of new blood vessels – is one of the common physiological changes associated with cancer. In the colon the first tissue to be affected is mucosa. Standard endoscopy, using RGB imaging, may be ineffective in visualising the resulting changes in colouration. This is because the reddening of the tissue due to the increased blood contents can be visually suppressed through the increased scatter originating from the structural tissues affected by cancer. Multispectral images provide a richer information and are more appropriate for representing subtle changes in colouration. Moreover, the use of image interpretation methods based on physics of image formation provides the means for deriving quantitative information from the imaged data.

Purpose

The purpose of this work is to derive quantitative estimates of the blood contents of the mucosa from multispectral images of the colon, and to determine whether the derived quantities show significant statistical differences between the normal and the cancerous colon tissue.

Methods

As the first step we construct a forward model which predicts reflectance spectra associated with specific instances of colon tissue. The model uses a Monte Carlo simulation of photon propagation through the three main layers of the colon tissue: mucosa, submucosa and smooth muscle. The optical properties of each layer are characterised by a number of constant parameters (the absorption and the scatter coefficients as a function of wavelength) and a number of variable parameters (blood volume fraction, haemoglobin saturation, the size of scattering particles, their density and the layer thickness) which characterise specific instances of the tissue. The latter are varied across their entire physiological ranges to create a cross-reference between their values and the reflectance spectra. The model spectra are computed for 33 wavelengths in the range of visible light from 450nm to 700 nm and validated by comparison with the experimental data acquired in vivo.

The quantitative estimates of the blood contents are obtained through “model inversion”, i.e. in contrast to the forward model, we compute the parameter values from the image spectra. In a multi-spectral image each pixel represents a spectrum. Using optimisation, we derive a set of parameter values such that a spectrum generated from the parameters using the Monte Carlo simulation provides the best match to the measured spectrum. Parametric maps of the blood contents are created by storing at every pixel the blood volume fraction value recovered through the model inversion.

We acquired multispectral images of ex-vivo samples of the colon from 8 patients. The samples were placed immediately in a fixative and images were obtained within no more than 1 hour from the excision. Multispectral data was acquired at 33 wavelengths using a computer controlled LCD filter (VarSpec, C.R.I.) interfaced to a monochrome 12 camera

(Retiga Exi, QImaging). The samples contained histologically confirmed instances of adenocarcinoma (7), necrotic tissue (1), neoplastic polyp (1), hyperplastic polyp (1), adenomateous polyp (2) and normal tissue (12). 1000 points were selected (smaller number in some small polyps) from each class in the parametric map of the blood contents of each sample. A Mann-Whitney test with Bonferroni correction was carried out to determine whether there is a statistical difference between the blood contents in the pathological and the adjacent normal tissue in each sample.

Results

The parametric maps of the blood volume fraction show distinctly the increased blood contents in the cancerous regions (see Fig. 1 for one of the examples). In all the cases, adenocarcinoma shows the significant increase in blood volume fraction (75% in comparison to the normal tissue; 13% of the entire histological range of values). The blood contents in the necrotic region is lower (as expected) than in the surrounding tissue. All the adenomateous polyps shows a small increase in the blood contents. Plot in Fig. 2. shows the results for all the samples. The Mann-Whitney test shows that all but one differences are significant ($p<0.00015$). The exception (B9(P), $p>0.05$) is a benign neoplastic polyp

Conclusions

To our knowledge this is the very first time that the values of the blood volume fraction for the colon were computed from multispectral images, and demonstrated to show statistically significant differences between normal and the cancerous tissue. Although the reported values are for an excised tissue, and therefore are likely to be different than those in the in vivo samples, the differences between the blood volume fraction are likely to be similarly distinct in the living tissue.

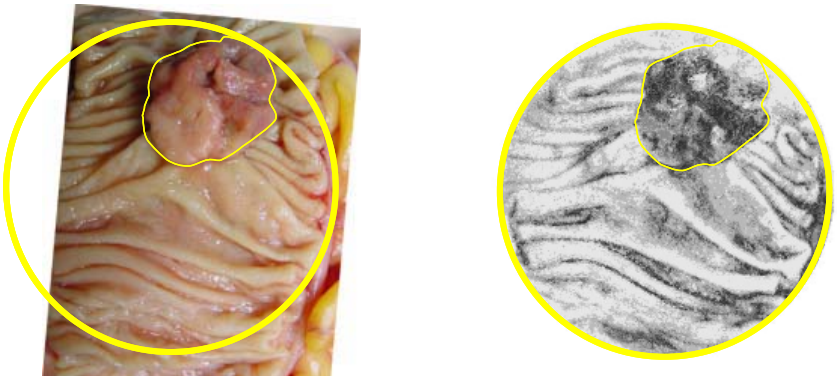
Other publications

The optical model of the colon is described in [1]. The method for the parameter recovery is presented in [2]. The paper in a local conference proceedings [3] shows parametric maps for two samples in a way of a demonstration; there is no statistical analysis.

1. Hidovic D, Claridge E (2005) Modelling and validation of spectral reflectance for the colon. *Physics in Medicine and Biology* 50, 1071-1093.

2. Hidovic D, Claridge E (2005) Model based recovery of histological parameters from multi-spectral images of the colon. Medical Imaging 2005: Physics of Medical Imaging, Proceedings of SPIE Vol. 5745. Flynn MJ (Ed), 127-137.

3. Hidovic-Rowe D, Claridge E, Ismail T, Taniere P (2006) Analysis of multispectral images of the colon to reveal histological changes characteristic of cancer. Medical Image Understanding and Analysis MIUA 2006, Manchester, U.K., July 2006.



(a) (b)

Figure 1: (a) Colour image of an excised tissue sample; the cancer outlined in yellow. (b) Parametric map of the blood volume fraction (darker = more).

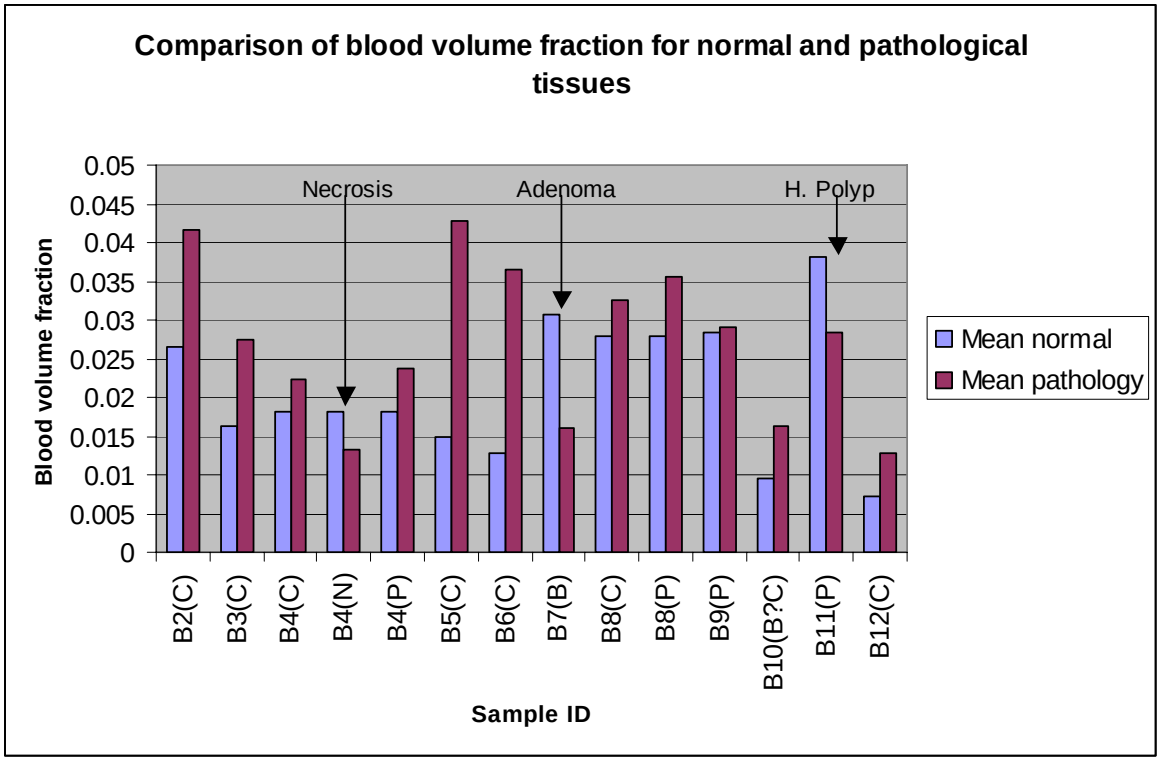


Figure 2: Comparison of blood volume fraction (BVF) values for normal and pathological colon tissues. The sample number (B<N>) is followed by a pathology code: C = cancer, P = polyp, N = necrosis; B?C = tubulo-villeous adenoma – a tumour which can potentially develop into a cancer. The arrows point to the exceptions where BVF is smaller within the pathological region than within the surrounding normal tissue. The total (histologically valid) range of the BVF represented in the model is 0 – 0.1 (0% - 10%).