HYPERSPECTRAL IMAGING OF THE HUMAN RETINA: OXIMETRIC STUDIES

D.J. Mordant¹, I. Al-Abboud², A.R. Harvey², A.I. McNaught²

PHOTOGRAPHIC DEPARTMENT, CHINTERFACE GROUP; AND SCHOOL OF ENGINEERING AND PHYSICAL SCIENCES, HERIOT-WATT UNIVERSITY, EDINBURGH, UNITED KINGDOM.

Purpose

Hyperspectral imaging of the human retina is a relatively new concept that has the potential to determine the metabolic status of the retina. Oximetric studies have been the main focus of previous research as the differential spectral characteristics of the two functional haemoglobin derivatives may be exploited to determine the oxygen saturation in the blood vessels. This study aims to demonstrate the ability to detect oximetric variations in the retinal circulation amongst normal subjects and in patients with retinal arteriopathy and glaucoma using hyperspectral imaging and spectral analysis techniques.

Methods

A hyperspectral retinal imaging system consisting of a modified commercial fundus camera, a liquid crystal tunable filter and a low-noise CCD detector (figure 1) was used to capture sequential hyperspectral images of the human retina. A hyperspectral data cube with a spectral bandwidth of 500nm to 700nm and a spectral resolution of 10nm at wavelength steps of 2nm were obtained for each subject. Normal subjects (n = 11) were examined and compared to subjects with retinal arterial occlusion (n = 3) and advanced primary open angle glaucoma (POAG) (n = 1).

Pre-processing algorithms were used to dark calibrate and co-register the raw retinal images. A further image processing algorithm produced a reflectance optical density map of the retina for each wavelength (figure 2).

Linear spectral unmixing is used in spectral imaging to determine the relative abundance of materials (endmembers) in each pixel of a scene through the analysis of its spectral characteristics. An average spectral profile of the arteries in the optic disc were calculated from all normal eyes (figure 3). This spectral profile was used to represent a pure endmember of arterial blood. In addition, a region within the optic disc cup was included into the analysis and represents a relatively non-oxygenated and spectrally inert endmember. Linear spectral unmixing, performed in ENVI 4.1 (ITT Visual Information Solutions), incorporating these two endmembers was used to produce a qualitative abundance map of oxygenated blood in the retina.

Results

Linear spectral unmixing produced consistent oximetric maps of the retina in normal subjects (figure 4) where oxygenated blood (red) has been identified within the arteries and arterioles. In subjects with arterial occlusions and advanced POAG, this technique was able to detect changes in the oximetric status of the retinal circulation. Figure 5 illustrates one of these subjects with arterial retinal vasculopathy caused by giant cell arteritis. The oximetry maps demonstrate an improvement in oxygenation of the retinal vasculature and retina following treatment with intravenous methylprednisolone. Figure 6 illustrates the oximetric variation in the retinal circulation of a patient with advanced POAG which corresponds with the severity of visual field loss.

Conclusions

Hyperspectral imaging is capable of detecting oximetric changes in the retina and monitoring its response to treatment. However, the sequential technique of capturing retinal images described here is heavily dependent on other factors such as accurate co-registration of the images. This limitation will be addressed in poster 2582/B659 where we will describe the development of a “snapshot” spectral retinal camera.

Linear spectral unmixing offers a powerful and visually useful method of producing semi-quantitative oximetric maps of the retina, but to increase the effectiveness in detecting changes caused by diabetic retinopathy and early glaucoma increased and absolute accuracy is required. This requires the incorporation of a physical model for light propagation in the retina into the calculation of oxygenation – as is described in poster 2581/B658.

References