Visible Light OCT-Based Quantitative Imaging of Lipofuscin in the Retinal Pigment Epithelium

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Abstract

Lipofuscin, a by-product of the vision cycle of photoreceptors, is the major source of the fundus auto-fluorescence (FAF) in the Retinal Pigment Epithelium (RPE). In other words, a complex mixture of partially digested lipids and protein components in the retinal pigment epithelium (RPE) cells, is a major source of fundus autofluorescence (FAF). FAF hence is a natural biomarker that carries the information of lipofuscin content, and quantification of FAF signal could be used to assess the amount of lipofuscin in the RPE for diagnosis and monitoring disease progression. FAF imaging has been used in ophthalmology clinics for many years. For example, hyper-autofluorescence is positively correlated with the progression of AMD and Stargate's macular dystrophy. In the case of geographic atrophy (GA), the late stage of dry AMD, advanced RPE alterations exhibit clinically recognizable patterns of hyper-autofluorescence, which is positively correlated with the rate of GA progression and can be analysed semi-automatically with newly developed software by non-expert graders.

Mechanisms were discussed. We also looked at some Lipofuscin accumulates with aging and in certain pathological disorders and is thus a biomarker for degenerative retinal diseases. Therefore, quantification of lipofuscin is important in the diagnosis, progression monitoring, and treatment evaluation. Lipofuscin quantification is challenging because light is attenuated by the media anterior to the RPE which is subject to inter-individual and intra-individual differences. Further, various illumination power and detection sensitivity of different imaging systems can also affect the readings of the detected FAF.

We developed a technology to provide simultaneous VIS-OCT and AF of the retina and a reference standard target at the intermediate retinal imaging plane with a single broadband visible light source. Since both OCT and AF images are generated from the same group of photons the OCT probe light experiences attenuation by the same ocular layers.

The technology is able to eliminate the varying pre-RPE attenuation factor in AF imaging using the simultaneously acquired VIS-OCT image. To quantitatively bridge the OCT and AF detection systems thus eliminate the effects of illumination power and detector sensitivity, a standard reference target with known reflectivity and fluorescence efficiency was implemented into the system. Using the standard reference, similar to the one used by Deloria AF and reflectance signals are normalized to a known reference value that are independent from the exposure power and detection gain. The system was calibrated and tested in vivo.

A VIS-OCT-FAF system was built for the study. The VIS-OCT-FAF system integrated a spectral-domain VIS-OCT, a spectral-domain near-infrared (NIR) OCT, and a confocal FAF detection channel on a single platform. The system used a supercontinuum light source for both VIS-OCT and FAF excitation. The filtered output of the light source had a centre wavelength and a bandwidth. The axial resolution and sensitivity at a path-length difference VIS-OCT were measured. The signal roll-off at a depth was measured, which was compensated in quantification of the FAF intensities. The system acquires spatially registered VIS-OCT and FAF images simultaneously at a speed, determined by the line rate of the CCD camera of the OCT spectrometer. The NIR-OCT was used for alignment and identifying the retinal area of interest (AOI). Upon activation of data acquisition, the visible light is turned on and scanned across the AOI. The VIS-OCT and FAF images were acquired simultaneously and streamed to a computer.

Biography

Dr. Shuliang Jiao research interest is mainly focused on the development of innovative technologies for imaging and treatment of eye diseases. His current research includes the technological development and application of Optical Photoacoustic Microscopy, Optical Coherence Tomography, and Multimodal Functional Imaging for the early diagnosis of age-related macular degeneration, diabetic retinopathy, and glaucoma.

Dr. Shuliang Jiao received his Ph.D. from the department of Biomedical Engineering of Texas A&M University in 2003. He joined the faculty of Bascom Palmer Eye Institute of University of Miami as an assistant professor after graduation. He is currently a professor in the Department of Biomedical Engineering, Florida International University.

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