位相非感受型光コヒーレンス血管造影

Phase-insensitive Optical Coherence Angiography

○洪暎周^{1,2)}, 卷田修一¹⁾, 山成正宏¹⁾, 三浦雅博^{1,3)}, 金秀鉉²⁾, 谷田貝豊彦¹⁾, 安野嘉晃¹⁾○Youngjoo Hong^{1,2)}, Shuichi Makita¹⁾, Masahiro Yamanari¹⁾, Masahiro Miura^{1,3)}, Soohyun Kim²⁾, Toyohiko Yatagai¹⁾, and Yoshiaki Yasuno¹⁾COG¹⁾, 韓国科学技術院²⁾, 東京医科大学³⁾Computational Optics Group in the University of Tsukuba¹⁾, Korea Advanced Institute of Science and Technology²⁾, Department of Ophthalmology, Tokyo Medical University³⁾

E-mail: hongyoungjoo@kaist.ac.kr

A non-invasive, phase-insensitive optical coherence angiography method has been demonstrated for *in vivo* human retina based on high-speed spectral-domain optical coherence tomography at 840nm center-wavelength. Three-dimensional choroidal vasculature was obtained by segmenting choroidal vessels by using threshold values from the intensity distribution in each depth plane relative to the retinal pigment epithelium layer. A vascular projection image was obtained by integrating the segmented choroidal vasculature. The segmented vascular image was compared with the images obtained using existing invasive methods such as indocyanine green angiography (ICGA), to check the feasibility of the alternative method.

1. Introduction

Examination of ocular vascular integrity is important for the diagnosis of ophthalmic diseases, because the eye receives its nutrient supply through the ocular vessels. Fluorescein angiography (FA) and indocyanine green angiography (ICGA) are frequently used methods for ocular vessel imaging. Although it is possible to obtain satisfying images of the vasculature with FA and ICGA methods, there are some adverse allergic reactions due to the injection of the dye. These reactions range from skin rash and itching, which are mild, to rare but severe reactions like anaphylaxis, which may prove to be life threatening. Therefore, one of the requirements for non-invasive ocular angiography is to avoid allergic reactions.

Optical coherence tomography (OCT) is a low-coherence interferometer-based noninvasive medical imaging method that can provide high-resolution, sectional images of biological tissues. The recently developed Fourier domain (FD) OCT makes it possible to obtain high resolution images with high speed. Additionally, the volume flow dynamics characteristic of blood vessels can be obtained by Doppler OCT. Blood flow can be measured from the phase change between adjacent A-lines [1]. However, to measure the phase change, dense scanning between A-lines is necessary with phase-sensitive technique. The dense scanning is expensive for measurement time, especially for three-dimensional measurement, and it is difficult for some patients to endure a long measurement time and to avoid eye movements during the measurement.

Therefore we developed a phase-insensitive optical coherence angiography (OCA) method using light absorption and the scattering property of blood for choroidal vessel segmentation based on spectral domain (SD) OCT. Three-dimensional choroidal vasculature and two-dimensional images of similar quality to that of ICGA are obtained.

2. System

A standard SD-OCT system is employed to obtain three-dimensional retinal OCT images. A super-luminescent diode (SLD) which has a center wavelength of 840nm and a FWHM spectral bandwidth of 50nm was used as a light source. Polarization

controllers were used after the SLD, and before the reference and sample arms. An optical isolator was used to prevent re-incident light from entering the source. A 20/80 fiber coupler was used to split the beam; 80% for the reference arm and 20% for the sample arm. A 78D lens was used to focus on the posterior of the human eye and the measured axial resolution was 6.4μm in the tissue. The optical probing power was 700μW. A transparent diffractive grating of 1200 lines/mm was used to separate the coherent light in the spectrometer. 18.7 kHz line scan rate CCD was used for the detection; the exposure time of one A-line was 53.1 μs. The sensitivity of this system was measured to be 99.3 dB at a 100 μm depth and 92.9 dB at a 2 mm depth.

3. Phase-insensitive optical coherence angiography

A three-dimensional (3D) human retinal structure could be obtained with high-speed SD-OCT. Fig. 1 describes the process of choroidal vessel segmentation. First, the anterior boundary of the retina was determined by an algorithm similar to that of Mujat *et al* [2], but excluding the snake algorithm. Next, a highly reflective layer, the retinal pigment epithelium (RPE) and the choriocapillaris, were determined as the maximum gradient position lower than 122.5 μm (25 pixels) from the anterior boundary. In our method, the position of RPE is used as a reference depth layer.

Fig. 1. Process of choroidal vessel segmentation