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Case Report Open Access

Doppler Optical Coherence Tomography Imaging of Feeder Vessels in Exudative Macular Disease

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Abstract

We evaluated the three-dimensional vascular architecture of feeder vessels in exudative macular disease. A case of polypoidal choroidal vasculopathy with choroidal neovascularization was examined with Doppler optical coherence tomography (OCT), and the three-dimensional architecture of the feeder vessels could be clearly visualized in the Doppler OCT angiography image, showing the site of growth of the feeder vessels passing through Bruch's membrane. Together, the results demonstrated in this case report that Doppler OCT was useful for the noninvasive assessment of feeder vessels in exudative macular disease.

Keywords: Choroidal neovascularization; Polypoidal choroidal vasculopathy; Feeder vessel; Doppler; Optical coherence tomography

Introduction

Exudative macular diseases, including polypoidal choroidal vasculopathy (PCV) and age-related macular degeneration, are the major causes of severe loss of central vision among older people in developed countries [1]. Investigation of feeder vessels of choroidal neovascularization (CNV) is important for the diagnosis and treatment of exudative macular diseases, and evaluation of the three-dimensional (3-D) architecture of these feeder vessels could be useful in understanding the development of neovascular vessels [2-4]. In previous studies of living human eyes, indocyanine green angiography (ICGA) has been used to detect feeder vessels in exudative macular disease [2,3]. However, ICGA, occasionally based on scanning laser ophthalmoscopy, provides poor resolution of the depth of vascular lesions in exudative macular disease [5]. This poor axial resolution of ICGA prevents accurate evaluation of the 3-D structure of the feeder vessels.

Recently, a functional extension of optical coherence tomography (OCT) technology for 3-D vascular imaging was developed. This technique was first reported using Doppler OCT and was named optical coherence angiography [6]. Following this development, various 3-D vascular imaging techniques [7-13] were reported, and were collectively called OCT angiography. In this case report, using Doppler OCT angiography, we evaluated the 3-D architecture of feeder vessels and the neovascular network, to characterize the pathophysiology of exudative macular disease in an 82-year-old male patient.

Methods

The prototype Doppler spectral-domain OCT system was built by the Computational Optic Group at the University of Tsukuba [7]. The light source was a superluminescent diode with a central wavelength of 1,020 nm and bandwidth of 100 nm (Superlum, Carrigtwohill, Republic of Ireland). A high-speed InGaAs line-scanning camera with 1,024 pixels (Goodrich, Charlotte, NC, USA) was used as the detection system. The measurement speed was 47,000 depth scans/second, and the measured depth resolution was 4.3 μm deep in the tissue. A raster scanning protocol with 1,500 depth scans × 128 B-scans covering a 6.0 × 6.0 mm region on the retina was used for volumetric scans. The scanning depth was 1.3 mm and the acquisition speed of each measurement was 4.1 seconds/volume. The Doppler shift of OCT signals was calculated using the phase difference between the adjacent depth scans where the phase difference was obtained by complex division of adjacent depth scans. The minimum detectable axial velocity was expected to be 0.44 mm/second. A color Doppler image was created by overlaying a bidirectional Doppler signal on its corresponding standard OCT. For 3-D visualization of Doppler OCT, the power of Doppler shift was volume-rendered, where the power of Doppler shift was defined as the squared power of the bidirectional Doppler signal. For a layer-by-layer analysis, the internal limiting membrane line was automatically segmented, whereas the retinal pigment epithelium (RPE) line and the Bruch's membrane line were manually segmented. Based on this segmentation, the Doppler OCT angiography volume was separated into three parts: retina (from the internal limiting membrane to the RPE), the space between the RPE and Bruch's membrane (from the RPE to Bruch's membrane), and choroid (beneath Bruch's membrane). En face projection of the Doppler OCT angiography was overlaid on ICGA, where the Doppler signal at the retina, choroid, and RPE–Bruch's membrane space were represented by blue, green, and red, respectively. All measurements were approved by the Institutional Review Boards of the University of Tsukuba and Tokyo Medical University, and the experimental protocol followed the tenets of the Declaration of Helsinki. Informed consent for the study was obtained from all participants.

Case Report

A case of PCV with CNV was examined with Doppler OCT. An 82-year-old male patient noticed a gradual decrease of vision in his left eye. Best-corrected visual acuity in his left eye was 20/50, and macular

evaluation revealed a grayish subfoveal membrane and orange-red spot near the vascular arcade (Figure 1A). The early phase of ICGA showed the ingrowth site of a feeder vessel near the optic disk (Figure 1B). The late phase of ICGA showed subfoveal CNV and large branching vascular networks with polypoidal lesions (Figure 1C). The en face projection of the Doppler OCT angiography clearly depicted the feeder vessel and branching vascular network (Figure 2).

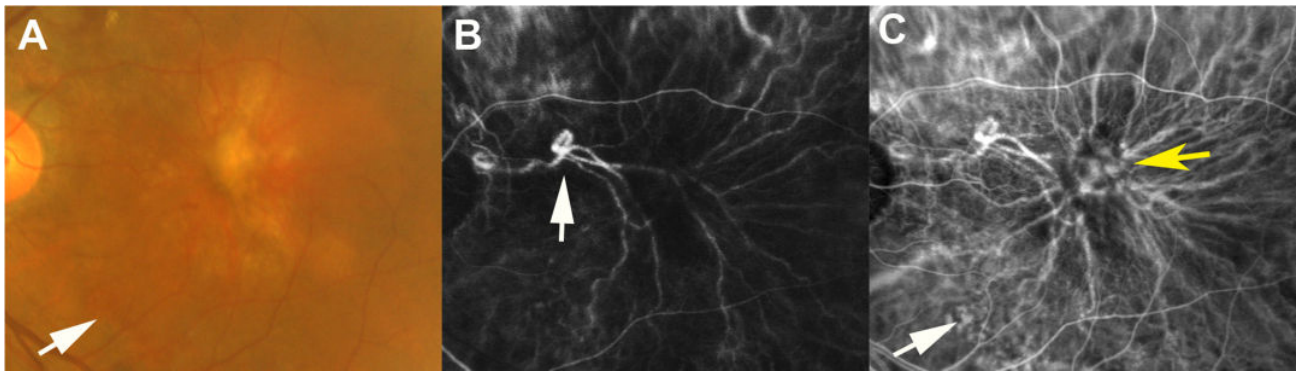

Figure 1: A color fundus photograph (A) shows a grayish subfoveal membrane and an orange-red spot near the vascular arcade (white arrow). The early phase of ICGA (B) shows a feeder vessel near the optic disk (white arrow). The late phase of ICGA (C) shows subfoveal CNV (yellow arrow), and large branching vascular networks with polypoidal lesions (white arrow).

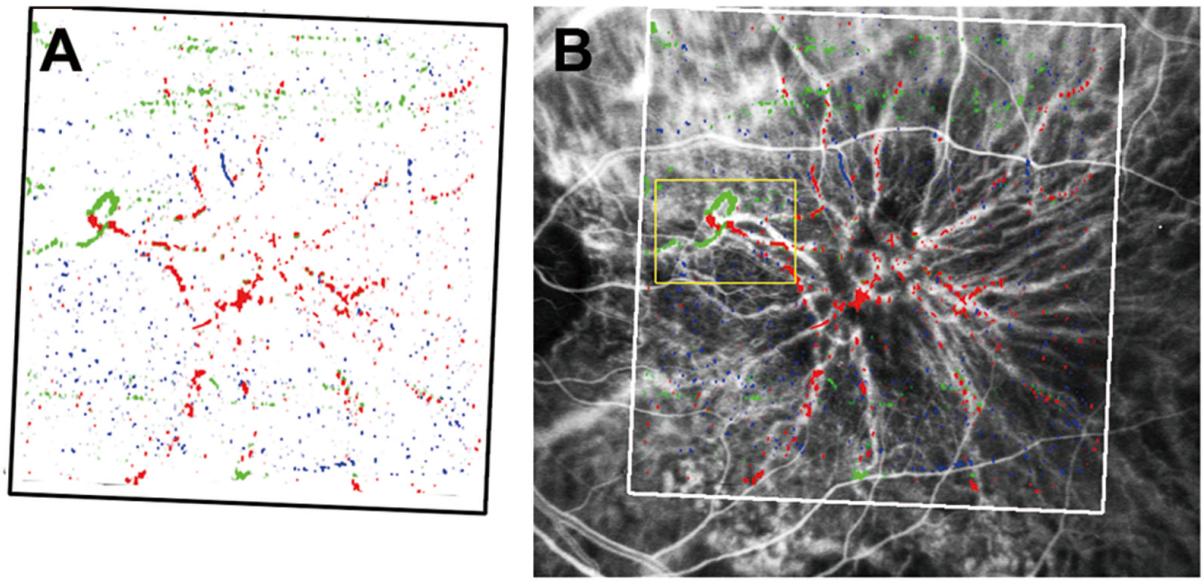

Figure 2: In the en face projection of Doppler OCT angiography (A), the distribution of Doppler signals from the retina, choroid, and the space between the RPE and Bruch's membrane are color-coded with blue, green, and red, respectively. The Doppler OCT angiography image superimposed on the ICGA image (B) shows the extensive distribution of Doppler signals between the RPE and Bruch's membrane. The white box in the ICGA image (B) indicates the area of OCT imaging, and the yellow box indicates the area of the high-magnification image in Figure 3.

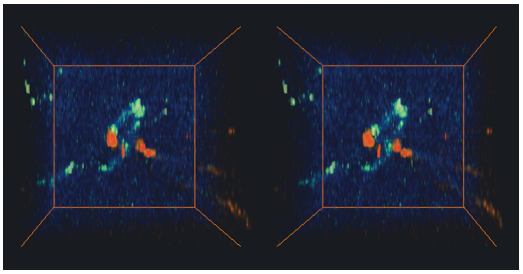

Figure 3: A stereoscopic image of high-magnification Doppler OCT angiography of the feeder vessel. A pair of images is presented for crossed-eye viewing. The distribution of the Doppler signals from the retina, choroid, and the space between the RPE and Bruch's membrane are color-coded with blue, green, and red, respectively.

Distribution of blood flow between the RPE and Bruch's membrane corresponded well with the pattern of the branching vascular network. With the high-magnification view of Doppler OCT angiography, the 3-D structure of the feeder vessels could be clearly depicted (Figures 3 and 4). The feeder vessel originated near the optic disk, and formed the abnormal vascular network after a single bend.

At the origin of the feeder vessels, Doppler signals were located beneath Bruch's membrane. At the site of the bend in the feeder vessels, the Doppler signals moved to the space between the RPE and Bruch's membrane. A series of color Doppler OCT images clearly showed penetration of the feeder vessel across Bruch's membrane (Figure 4). This transition point represents the ingrowth site of the feeder vessels passing through Bruch's membrane.

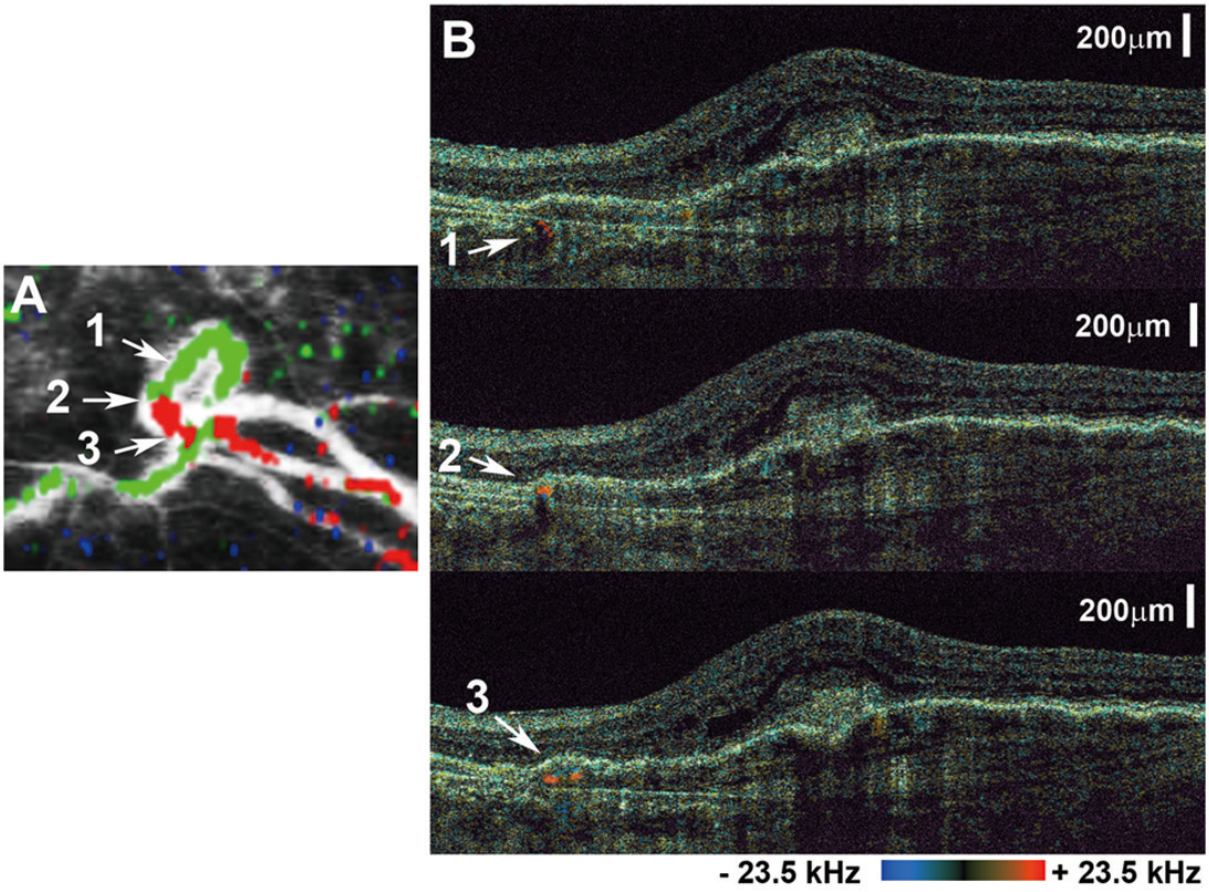

Figure 4: Doppler OCT images of the feeder vessel. In the high-magnification Doppler OCT angiography image of the feeder vessel (A), the distribution of Doppler signals from the retina, choroid, and the space between the RPE and Bruch's membrane are color-coded blue, green, and red, respectively. The transition point from green to red represents the penetration site of the feeder vessels through Bruch's membrane. A series of colored Doppler OCT images (B) show penetration of the feeder vessels across Bruch's membrane, and arrows indicate the position of Doppler signals in the colored Doppler OCT images.

Discussion

In this study, a Doppler OCT angiography clearly showed the 3-D structure of the feeder vessels and neovascular vessel. A feeder vessel penetrated Bruch's membrane near the optic disk, and extended into the space between the RPE and Bruch's membrane. The feeder vessel diverged in a radial fashion at the macula, and CNV occurred in conjunction with PCV at the center of this diversion. A part of the feeder vessel in the space between the RPE and Bruch's membrane was apparently a neovascular vessel, and the site of penetration through Bruch's membrane could be considered the beginning of the neovascular complex. Costa et al. studied PCV lesions using ICGA and suggested that the vascular network contains one single large neovascular complex arising from one major ingrowth site [3]. The distribution of PCV vascular lesions found in this study by Doppler OCT angiography supported this hypothesis.

In previous studies with OCT and ICGA, a similarity of PCV vascular lesions to type 1 CNV was reported [3,7,14]. The Doppler OCT angiography finding from this study supported this similarity. However, the 3-D architecture of the feeder vessel observed in this study differed from typical CNV feeder vessels. CNV feeder vessels were thought to be located in Sattler's layer [4], while the feeder vessel noted in this study was located in the space between the RPE and Bruch's membrane. This specific vascular location suggested that the development of PCV feeder vessels might be different from typical CNV feeder vessels, which could be a key element in understanding the clinical disparity between PCV and CNV [15].

In this study, Doppler OCT angiography could detect only some parts of the choroidal or retinal vasculature; hence, ICGA and fluorescein angiography are still required to thoroughly evaluate the entire structure of vascular lesions. However, clinical applications of ICGA and fluorescein angiography have been restricted because of patient discomfort and relatively long measurement times. Doppler OCT angiography has the advantage of being a noninvasive technique with a short measurement time. Together, the results of this case report demonstrated that investigation of the 3-D architecture of the neovascular network using Doppler OCT angiography can better characterize the development of exudative macular disease, and can potentially function as an adjunct tool to fluorescein angiography and ICGA in assessing macular diseases.

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