

Association of Focal Choroidal Excavation With Age-Related Macular Degeneration

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Submitted: May 2, 2014

Accepted: August 24, 2014

Citation: Kuroda Y, Tsujikawa A, Ooto S, et al. Association of focal choroidal excavation with age-related macular degeneration. *Invest Ophthalmol Vis Sci.* 2014;55:6046–6054. DOI: 10.1167/iovs.14-14723

PURPOSE. To study the prevalence, tomographic features, and clinical characteristics of focal choroidal excavation (FCE) in eyes with exudative age-related macular degeneration (AMD).

METHODS. We examined 243 consecutive eyes with exudative AMD with a prototype swept-source optical coherence tomography (OCT) system. Three-dimensional images of the macular area, covering $6 \times 6 \text{ mm}^2$, were reconstructed by segmentation of the outer surface of the retinal pigment epithelium.

RESULTS. Three-dimensional swept-source OCT revealed 15 excavations in 12 eyes (4.9%); 10 had a single excavation and 2 had multiple excavations (2 and 3 excavations, respectively). In multiaveraged scans, unusual choroidal tissue was found beneath 5 excavations, bridging the excavation with the outer choroidal boundary. Additionally, the suprachoroidal space was observed beneath 7 excavations—the outer choroidal boundary appeared to be pulled inward by this bridging tissue. In 9 excavations, color fundus photographs showed pigmentary disturbance. Fourteen excavations (93.3%) were located within or adjacent to the choroidal neovascularization area. Compared with eyes without FCE, in eyes with FCE, the mean age was significantly higher ($P = 0.040$) and mean visual acuity was significantly better ($P = 0.014$). In addition, polypoidal lesions were observed in 8 of 12 eyes with FCE, but they appeared to have a limited effect on either the rate of FCE ($P = 0.44$) or the clinical characteristics of the eyes.

CONCLUSIONS. While FCE may be partially related to the choroidal neovascularization associated with exudative AMD, other factors may also influence this association.

Keywords: focal choroidal excavation, exudative age-related macular degeneration, swept-source optical coherence tomography

Focal choroidal excavation (FCE) is a newly recognized clinical entity. It was first identified in 2006 by Jampol et al.¹ by using time-domain optical coherence tomography (OCT). Focal choroidal excavation is characterized by an intrachoroidal concavity in the macula, without posterior staphyloma or scleral ectasia. Subsequent studies using spectral-domain OCT have elucidated the clinical and morphological characteristics of FCE.^{2–12} Initially, FCE was considered a stable choroidal abnormality and an incidental finding in patients with metamorphopsia or blurred vision.¹⁰

Recently, it has been suggested that FCE may form the basis of choroidal neovascular diseases. Kobayashi and associates⁷ reported a case of FCE accompanied by polypoidal choroidal vasculopathy (PCV). Xu et al.¹² found choroidal neovascularization (CNV) at the bottom or slope of the excavations in 15 eyes (12 patients). In addition, Lee and Lee⁹ studied eight patients, aged over 50 years, who had CNV around the excavations. In older people, age-related macular degeneration (AMD) is the most common choroidal neovascular disease.^{13,14} On the basis of these previous reports, we hypothesized that FCE may be involved in the development of CNV associated with exudative AMD. To date, however, because these reports are single case reports or small case series, the prevalence and

clinical characteristics of complications associated with FCE remain unknown.

In recent years, swept-source OCT with a longer-wavelength light source has provided better views of the choroid because of improved light penetration into the choroid.^{15–19} In addition, the tunable laser source of swept-source OCT shows lower signal decay with increasing depth, further improving visibility of the choroidal features. Furthermore, the high imaging speed allows for dense scanning and subsequent three-dimensional (3-D) image reconstruction of the posterior pole. In the current study, we prospectively examined the macular area in consecutive eyes with exudative AMD by using 1- μm -wavelength swept-source OCT to study the prevalence and clinical and tomographic features of FCE and the possible association of FCE and CNV with exudative AMD.

METHODS

The Ethics Committee at Kyoto University Graduate School of Medicine approved this prospective study, which was conducted in accordance with the tenets of the Declaration of Helsinki.

Written informed consent was obtained from each subject before any study procedures or examinations were performed.

We used 3-D swept-source OCT imaging to prospectively examine 243 eyes of 217 consecutive exudative AMD patients who presented to the macula clinic at Kyoto University Hospital between October 2010 and March 2013. All the study subjects were Japanese. They underwent a comprehensive ocular examination, including autorefractometry, best-corrected visual acuity measurement with a Landolt C chart, slit-lamp biomicroscopy, intraocular pressure measurement, fundus photography (TRC-NW8F; Topcon Corp., Tokyo, Japan), 3-D swept-source OCT imaging with a prototype system (Topcon Corp.), and simultaneous fluorescein angiography (FA) and indocyanine green angiography (ICGA) by using the Spectralis HRA+OCT (Heidelberg Engineering, Heidelberg, Germany). Several patients underwent an additional OCT scan using RS-3000 OCT (Nidek, Gamagori, Japan) or Spectralis OCT (Heidelberg Engineering). The exclusion criteria included other macular abnormalities, for example, pathologic myopia, angioid streaks, retinal angiomatous proliferation, idiopathic CNV, other secondary CNV, intraocular inflammation, history of ocular trauma, poor image due to a thick subretinal hemorrhage, or history of vitrectomy.

The prototype swept-source OCT used in the current study has been reported previously.^{20,21} It uses a light source of a wavelength-sweeping laser centered at 1050 nm with a tuning range of 100 nm. This system has a scanning speed of 100,000 A-scans per second and a scan window depth of 2.6 mm. The axial and transverse resolutions are 8 μm and 20 μm in tissue, respectively. The optical power incident on the cornea is less than 1 mW, which meets the safety requirements for this laser class according to the American National Standards Institute.

Swept-source OCT examinations were performed by trained examiners after pupil dilation. In each subject, 3-D volumetric scans were acquired in 0.8 seconds, with 512 (horizontal) \times 128 (vertical) A-scans (total, 65,536 axial scans/volume). Each 3-D volumetric scan consisted of 128 B-scans and covered an area of 6 \times 6 mm², centered on the fovea. Pupil centration during the scan was achieved by using an internal fixation target and confirmed by a built-in camera within the swept-source OCT system. Owing to the high speed and invisible-wavelength scanning light, eye movements during the 3-D image acquisition were minimal. To decrease speckle noise, each image was denoised by the weighted moving average of three consecutive original B-scans.

On OCT, focal excavation was identified when Bruch's membrane line was excavated into the choroid focally, without any history of trauma, infection, posterior uveitis, or choroidal vascular disease. The excavations were divided into two types: conforming and nonconforming. Conforming excavations implied that the photoreceptor tips were attached to the retinal pigment epithelium (RPE). In nonconforming excavations, the photoreceptor tips were detached from the RPE.⁴

In eyes with FCE, 3-D topographical images were reconstructed from the OCT scans, by segmentation of the line of the outer surface of the RPE, to highlight the shape of the excavation. In each B-scan, the outer surface of the RPE line was automatically determined by the software, and manual corrections were made as necessary using the built-in segmentation-modifying tool. The excavation depth and width were measured manually from the 3-D dataset, using the scan that showed the greatest dimensions.

Polypoidal choroidal vasculopathy was diagnosed based on ICGA, which showed branching vascular networks that terminated in polypoidal lesions.^{22,23} In the current study, the angiographic features in the area of the excavations were examined. Additionally, the correlations between the locations of the excavations, the area of CNV, and areas of choroidal

vascular hyperpermeability in ICGA were analyzed. Choroidal vascular hyperpermeability was defined as multifocal areas of hyperfluorescence with blurred margins within the choroid in the mid to late phase of ICGA.²⁴

The retinal and choroidal thicknesses at the center of the fovea were manually measured with a built-in caliber tool. Retinal thickness was defined as the distance between the vitreoretinal interface and the outer border of the RPE, and choroidal thickness was defined as the distance between the line corresponding to the Bruch's membrane beneath the RPE and the choriocleral interface. When the excavation was located within the foveal center, choroidal thickness was measured as the distance between the supposed line of Bruch's membrane and the choriocleral interface.

All values are presented as mean \pm standard deviation. The measured visual acuity was converted to the logarithm of the minimum angle of resolution (logMAR) for statistical analyses. Mann-Whitney tests were used to compare numerical variable means, and Fisher's exact tests were used to compare the distribution of categorical variables. Statistical significance was indicated when the *P* value was less than 0.05.

RESULTS

Two hundred forty-three eyes of 217 consecutive patients with exudative AMD were examined by swept-source OCT. Fluorescein angiography showed CNV within the macular area in all the eyes, and ICGA revealed polypoidal lesions in 136 eyes. Of the 243 eyes with exudative AMD, 12 (4.9%) were found to have FCE. Of the 12 eyes with FCE, polypoidal lesions were seen in 8 eyes. Focal choroidal excavations were found in 5.9% of eyes with PCV and in 3.7% of eyes with AMD without polypoidal lesions. Table 1 shows the clinical characteristics of eyes with FCE associated with AMD. The mean age of eyes with FCE was 69.7 \pm 9.2 years (range, 57–83 years). Five eyes were myopic, and the mean spherical equivalent was -0.63 ± 3.25 diopters. The mean foveal retinal thickness was 255.7 \pm 124.8 μm (range, 111–588 μm), and the mean foveal choroidal thickness was 257.5 \pm 92.3 μm (range, 146–467 μm).

The 3-D scanning protocol of swept-source OCT allowed the detection of excavations in the macular area and visualization of their morphology (Fig. 1). Of 12 eyes with FCE, 10 had a single excavation and 2 had multiple excavations (2 and 3 excavations, respectively). Six excavations were classified into the conforming type, and nine were of the nonconforming type. The mean depth of the excavations was 53.3 \pm 19.6 μm (range, 22–106 μm), and the mean width of the excavations was 799.7 \pm 404.5 μm (range, 388–1986 μm). The inner retinal layers appeared normal, and even when the excavation was located subfoveally, the foveal contour remained nearly well preserved. In 13 (86.6%) excavations, the line of the external limiting membrane was preserved. In 3 (20.0%) excavations, the line forming the junction between the inner and outer segments of the photoreceptors remained continuous. The RPE line was intact in all the eyes, despite some thinning or attenuation (Table 2).

Swept-source OCT also allowed visualization of the choroidal structures. Multiaveraged scans often showed an inner choroidal layer with medium-diameter blood vessels and an outermost choroidal layer with larger-diameter blood vessels. In five excavations (33.3%), unusual choroidal tissue devoid of large vessels was detected beneath the excavation, bridging the bottom of the excavation with the outer choroidal boundary (Fig. 2). In addition, the suprachoroidal space was observed beneath seven excavations (46.7%)—the outer choroidal boundary appeared to be pulled inward by the bridging tissue

TABLE 1. Clinical Characteristics of Eyes With Focal Choroidal Excavation Associated With Age-Related Macular Degeneration

Patient	Age, y	Sex	Visual Acuity‡	Refractive Error Spherical Equivalent, Diopters	Excavation				FRT, μm	FChT, μm	Previous Treatment	Duration of Follow-Up With OCT Examination, mo
					Location	Type	Depth, μm	Width, μm				
1	83	F	0.08	0	Extrafovea	Conforming	45	465	111	205	PC	65
2	57	M	1.0	-1.25	Extrafovea	Nonconforming	50	540	174	327		2
3	83	M	1.2	3.25	Extrafovea	Nonconforming	67	865	258	340		3
4*	58	M	1.5	-4.0	Extrafovea	Conforming	77	1033	216	155	IVR	18
					Extrafovea	Conforming	51	836				
					Extrafovea	Conforming	22	388				
5	77	M	0.2	2.5	Extrafovea	Conforming	54	714	588	321	0	1
6	61	M	1.5	1.0	Extrafovea	Nonconforming	49	681	234	467	0	60
7	75	M	0.9	5.0	Subfovea	Conforming	38	463	173	146	PDT	60
8	69	M	1.5	-3.0	Extrafovea	Nonconforming	38	1080	304	190	0	20
9	73	M	0.7	-0.25	Subfovea	Nonconforming	38	583	255	223	0	29
10†	67	M	0.7	-6.5	Extrafovea	Nonconforming	106	1997	372	219	0	7
					Extrafovea	Nonconforming	49	404				
11	60	F	0.7	0.5	Subfovea	Nonconforming	58	1200	179	271	0	61
12	73	M	0.8	2.0	Extrafovea	Nonconforming	57	1121	204	226	0	53

F, female; M, male; FRT, foveal retinal thickness; FChT, foveal choroidal thickness; PC, photocoagulation; IVR, intravitreal injections of ranibizumab; PDT, photodynamic therapy.

* Patient 4 had three excavations.

† Patient 10 had two excavations.

‡ Landolt visual acuity.

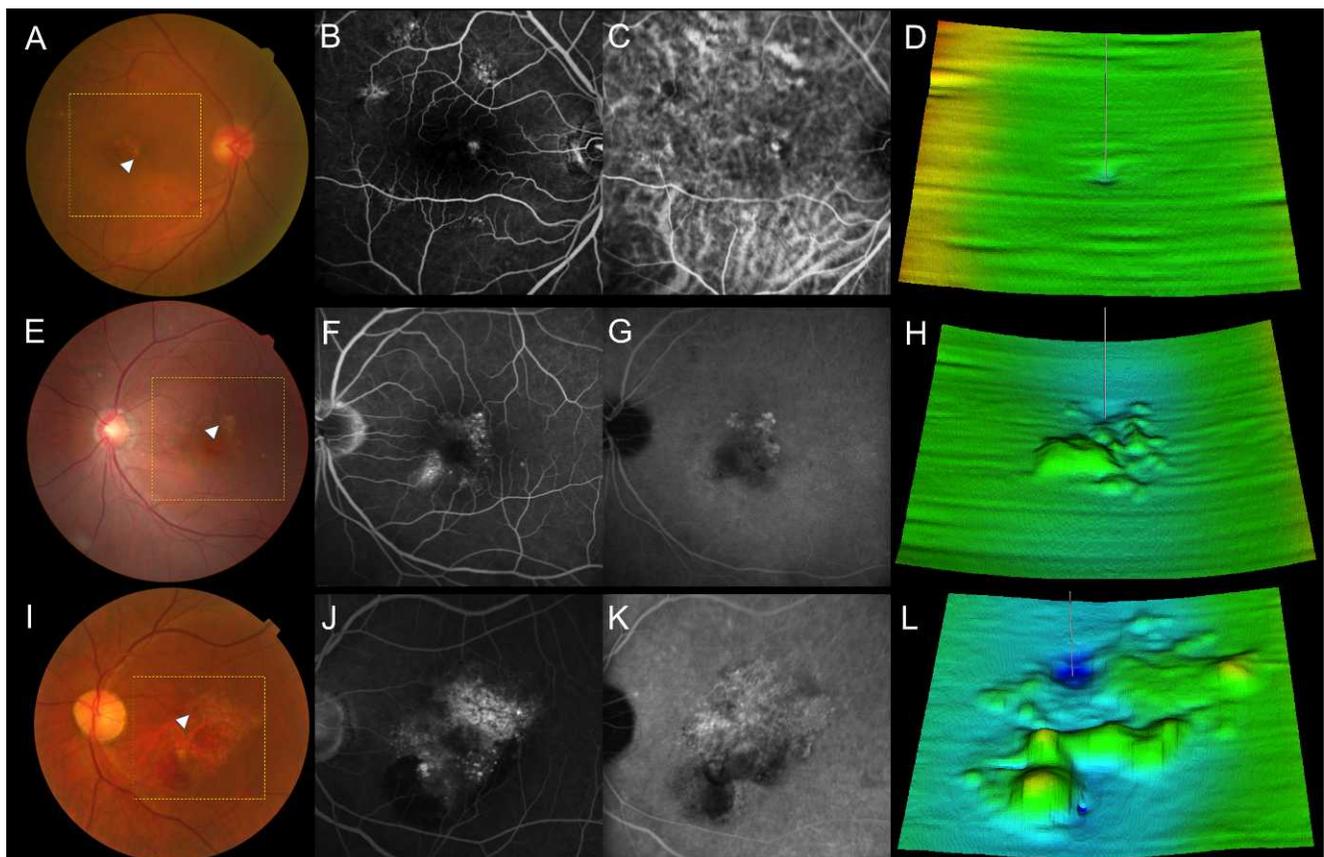


FIGURE 1. Three eyes with exudative age-related macular degeneration with focal choroidal excavation examined with swept-source optical coherence tomography (OCT). (A-D) Patient 7, (E-H) patient 8, and (I-L) patient 12. (A, E, I) Focal excavations were detected in fundus photographs as pigmentary disturbances (arrowheads). (B, F, J) Fluorescein angiogram. (C, G, K) Indocyanine green angiogram showing choroidal neovascularization. (D, H, L) Reconstructed three-dimensional OCT images (dashed yellow squares in fundus photographs) of the retinal pigment epithelium showing the shape of the excavations. White bars indicate the center of the excavations.

TABLE 2. Angiographic and Tomographic Characteristics of Eyes With and Without Focal Choroidal Excavation Associated With Age-Related Macular Degeneration

Patient	Color Photography Findings	Angiographic Findings				Optical Coherence Tomographic Findings				
		Correlation Between Excavation and Choroidal Neovascularization	Polypoidal Lesions	Choroidal Hyperpermeability	Correlation Between FCE and Choroidal Hyperpermeability	Unusual Choroidal Tissue Below Excavation	Suprachoroidal Space Below Excavation	ELM Band	IS/OS Band	RPE
1	Pigmentary disturbance	Within	-	-	-	-	-	-	-	+
2	Pigmentary disturbance	Within	-	-	-	+	-	+	-	+
3	Atrophy	Outside	-	+	Within	-	Within	-	-	+
4	Pigmentary disturbance	Within	-	+	Adjacent	+	Adjacent	+	-	+
	Pigmentary disturbance	Within	-	+	Adjacent	+	Adjacent	+	-	+
5	Hemorrhage	Adjacent	+	+	Within	-	Within	-	-	+
6	Physiological	Within	+	-	-	+	-	+	+	+
7	Pigmentary disturbance	Adjacent	+	+	Adjacent	+	Within	-	+	+
8	Pigmentary disturbance	Adjacent	+	-	-	-	-	+	+	+
9	Pigmentary disturbance	Within	+	+	Within	+	Within	+	-	+
10	Pigmentary disturbance	Within	+	-	-	+	-	+	-	+
	Physiological	Adjacent	+	-	-	-	-	+	-	+
11	Physiological	Within	+	-	-	-	-	+	-	+
12	Physiological	Within	+	-	-	-	-	+	-	+

ELM, external limiting membrane; IS/OS, inner segment/outer segment.

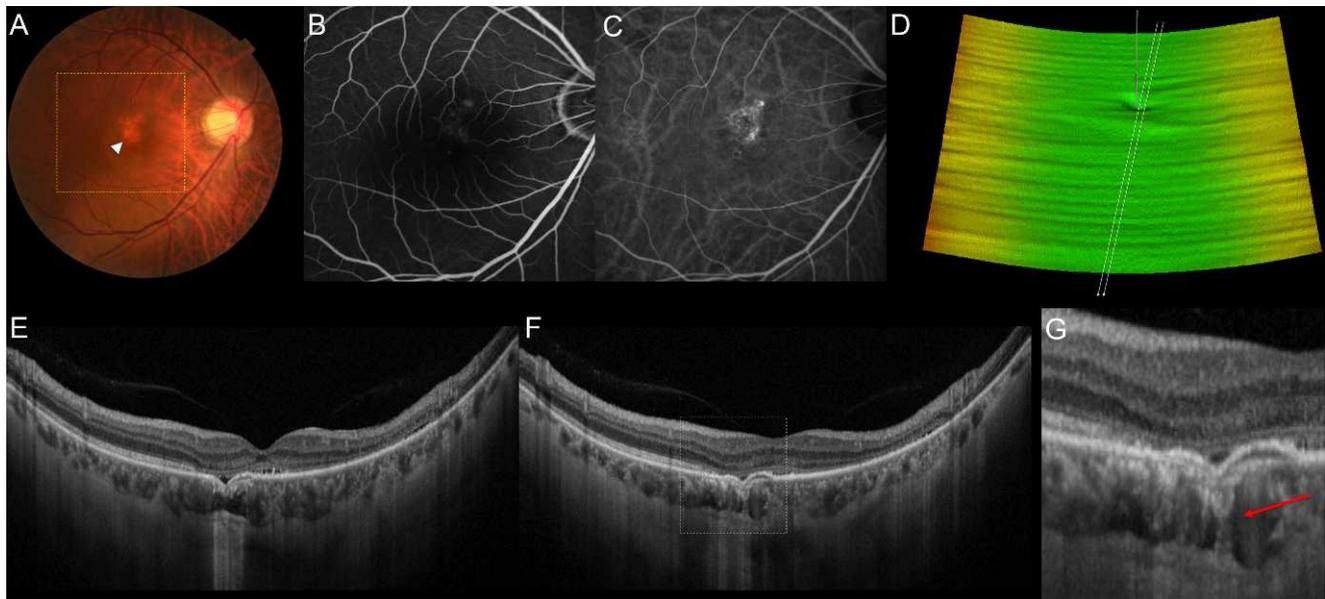


FIGURE 2. Unusual choroidal tissue under the excavation revealed by swept-source optical coherence tomography (OCT). (A) Fundus photograph of the right eye of a 57-year-old man with exudative age-related macular degeneration (patient 2). Fundus photograph showing pigmentary disturbance of the retinal pigment epithelium in the area corresponding to the excavation (*white arrowhead*). The *dashed yellow square* outlines the area ($6 \times 6 \text{ mm}^2$) scanned by the swept-source OCT. (B) Fluorescein angiogram. (C) Indocyanine green angiogram showing choroidal neovascularization. (D) Image reconstructed by segmentation of the retinal pigment epithelium showing the three-dimensional shape of the excavation. (E, F) Multiaveraged OCT sections were made along the *long white arrows*, as seen in the three-dimensional image. Vertical OCT sections through the fovea showing a nonconforming focal choroidal excavation. (G) Magnified image of the area outlined by the *dashed white square*. Unusual choroidal tissue (*red arrow*) is seen bridging the bottom of the excavation and the outer choroidal boundary.

(Fig. 3). The chorioscleral interface was smooth, without scleral outpouching in all the eyes.

Table 2 shows fundusoscopic and angiographic characteristic of eyes with FCE associated with AMD. In 9 excavations (60.0%), color fundus photographs showed pigmentary disturbances. Fluorescein angiography and/or ICGA revealed CNV in all the eyes. Although four patients (4 eyes) did not receive ICGA because of iodine allergy, all of 12 eyes with FCE were examined with ICGA. Of 15 excavations, 14 (93.3%) were located within or adjacent to the area of CNV (Fig. 4). Five eyes (41.7%) showed choroidal hyperpermeability in the mid or late phase of ICGA. In these eyes, all 7 excavations (46.7%) were seen within or adjacent to the areas of choroidal hyperpermeability.

In the current study, the mean follow-up period was 31.6 ± 26.3 months (range, 1–65 months). During the follow-up period, eight eyes received intravitreal injections of ranibizumab and one received photodynamic therapy combined with ranibizumab. One eye was not followed after the initial injection of ranibizumab; the mean number of injections in the remaining seven eyes was 5.1 ± 2.1 (range, 3–9). In five of these seven eyes, no exudative changes were observed at the final follow-up examination. Nonconforming excavations changed to the conforming type when the eyes responded to treatment for CNV. In the five eyes that were followed for more than 4 years, no changes in the size or shape of the excavations were detected (Supplementary Fig. S1).

Comparisons of parametric data of eyes with AMD and FCE with those of eyes with AMD and without FCE are shown in Table 3. There were no significant differences in sex distribution, refractive error, and the foveal retinal or choroidal thicknesses between the two groups. Compared with eyes without FCE, in eyes with FCE, the mean age was significantly higher ($P = 0.040$) and the mean visual acuity was significantly better ($P = 0.014$). In addition, we found that the presence of

polypoidal lesions had a limited effect on either the rate of FCE ($P = 0.44$) or the clinical characteristics of the eyes.

DISCUSSION

It remains unknown whether FCE is a congenital choroidal malformation or an acquired insult. Kumano et al.⁸ speculated that the excavation is caused by outward traction due to choroidal vascular abnormalities resulting from developmental failure in the embryo. In eyes with central serous chorioretinopathy (CSC), Ellabban et al.²⁵ recently showed unusual choroidal tissue beneath the excavation that bridged the bottom of the excavation and the outer choroidal boundary and could possibly produce the excavation. In the current study, we found similar choroidal tissue beneath five excavations. In addition, the suprachoroidal space was observed beneath seven excavations—it appeared as if the outer choroidal boundary was pulled inward by this bridging tissue. In addition, the shape of most excavations was irregular and often pointed outward. This irregular shape could be attributed to the presence of outward traction on the RPE.

Initially, FCE was thought to be a quiescent choroidal abnormality with good visual prognosis. It was later found that FCE is associated with vision-threatening complications, including CNV and polypoidal lesions.^{7,9} In the current study, 14 excavations were located within or adjacent to the area of CNV. In a recent study, Xu et al.¹² reported CNV that was present at the bottom or slope of the excavation in 15 eyes. It is unclear whether CNV developed from the excavation or whether CNV contributed to the formation of the excavation. Because FCE alone rarely causes serious visual symptoms, most of our patients presented at the clinic immediately after noticing CNV-associated visual symptoms. In addition, in a recent study of eyes in which CNV developed from FCE during

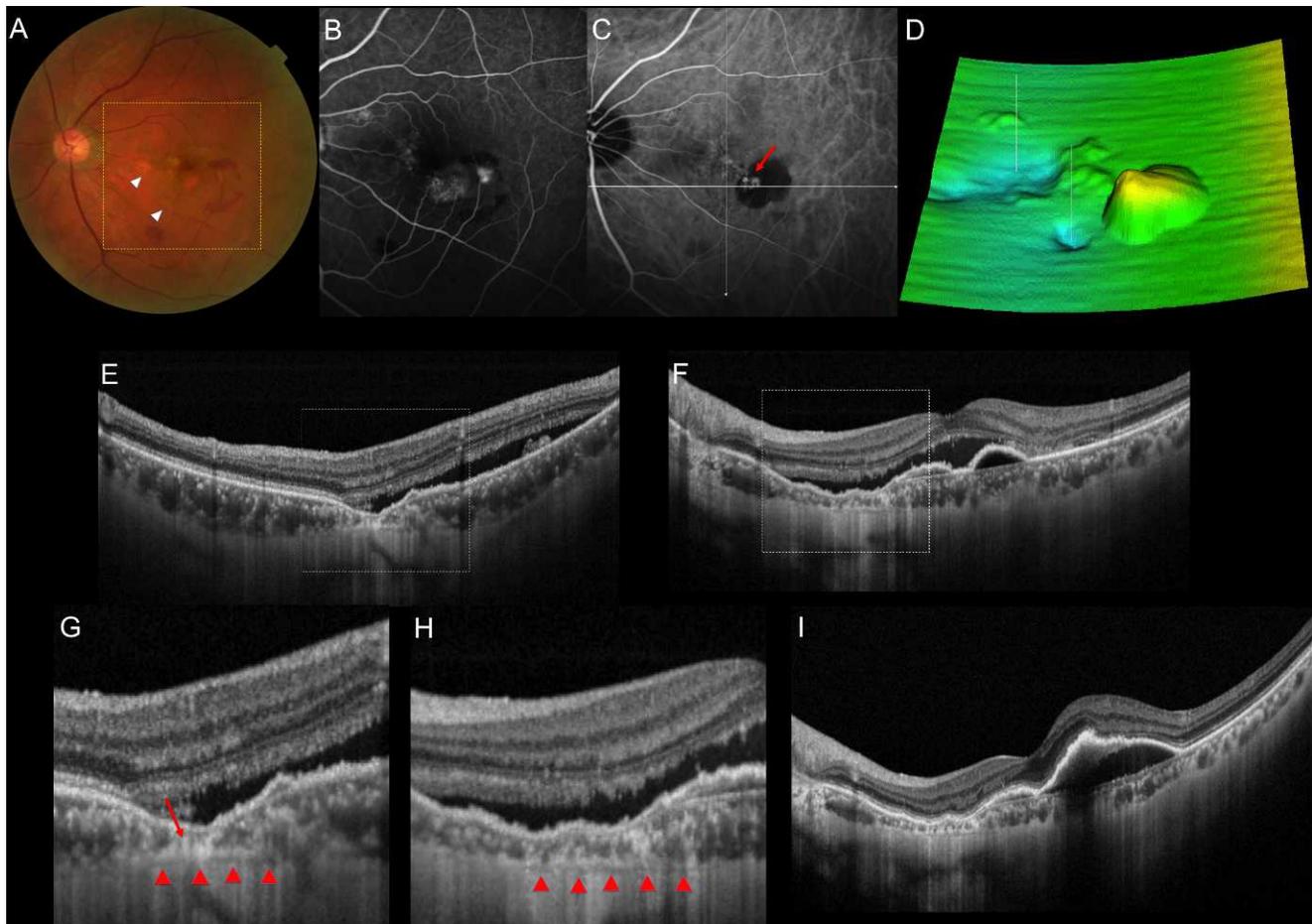


FIGURE 3. Suprachoroidal space beneath the excavation revealed by swept-source optical coherence tomography (OCT). (A) Fundus photograph of the left eye of a 67-year-old man with polypoidal choroidal vasculopathy (patient 10) showing pigmentary disturbances in the areas corresponding to the excavations (*white arrowheads*). The *dashed yellow square* outlines the area ($6 \times 6 \text{ mm}^2$) scanned by the swept-source OCT. (B) Fluorescein angiogram showing occult choroidal neovascularization. (C) Indocyanine green angiogram (ICGA) showing polypoidal lesions (*red arrow*). (D) Image reconstructed by segmentation of the retinal pigment epithelium showing the three-dimensional shape of the excavation. *White bars* indicate the center of the excavations. (E) Vertical and (F) horizontal multiaveraged OCT sections along the *long white arrows* on ICGA showing nonconforming excavations. (G, H) Magnified images of the areas outlined by the *dashed white square*. Beneath the focal choroidal excavation, unusual choroidal tissue (*red arrow*) is seen bridging the bottom of the excavation and the outer choroidal boundary. The suprachoroidal space (*arrowheads*) is seen below the excavation. (I) Horizontal OCT scans obtained after six monthly intravitreal injections of ranibizumab: The excavation changed from the nonconforming to conforming type with the resolution of the serous detachment. There were no remarkable changes in the dimensions or the shape of the excavation during the follow-up period.

the follow-up period, CNV was found to develop from choroidal excavations.

The mechanism underlying the association of these excavations with CNV remains unclear. Obata et al.¹⁰ reported that excavations may lead to aberrant choroidal circulation. In the current study, a few eyes with FCE showed no large choroidal vessels beneath the excavations. Focal choroidal ischemia may be involved in the development of CNV.^{26–29} In the current study, color fundus photographs showed pigmentary disturbances in nine excavations. Focal damage of the RPE and Bruch's membrane due to the excavation may contribute to the development of CNV.³⁰ In a recent report of CNV associated with FCE in younger patients, all CNV showed classic appearance in FA. In addition, two recent case series reported a good response to ranibizumab or bevacizumab in younger patients with CNV associated with FCE. Notably, Xu et al.¹² reported that in 13 of 15 eyes with CNV, CNV regressed with a single injection of ranibizumab. These angiographic characteristics and treatment responses are not found in exudative AMD but are rather typical of secondary CNV.^{31,32}

In younger patients, the pathogenesis of CNV associated with FCE would be different from that of CNV associated with exudative AMD.

In contrast, in another report of CNV associated with FCE, six of eight patients under the age of 50 had type 2 CNV, whereas seven of eight patients over the age of 50 had type 1 CNV.⁹ Similarly, 11 of our patients, all of whom were more than 50 years old, had PCV or type 1 CNV that was located under the RPE. Kobayashi et al.⁷ have reported the limited efficacy of ranibizumab in PCV associated with FCE, and our patients needed repeated injections of ranibizumab. Because exudative AMD is the most common choroidal neovascular disease in people over the age of 50,^{13,14} we speculate that some cases of CNV seen in eyes with exudative AMD might be associated with FCE. However, because FCE was seen in 12 eyes (4.9%) with exudative AMD, its role may be limited. The pathogenesis of CNV that develops around the excavation in older subjects may be different from that in younger subjects.

Margolis et al.⁴ and Katome et al.⁶ reported that FCE is common in eyes with a thicker choroid. Ellabban et al.²⁵

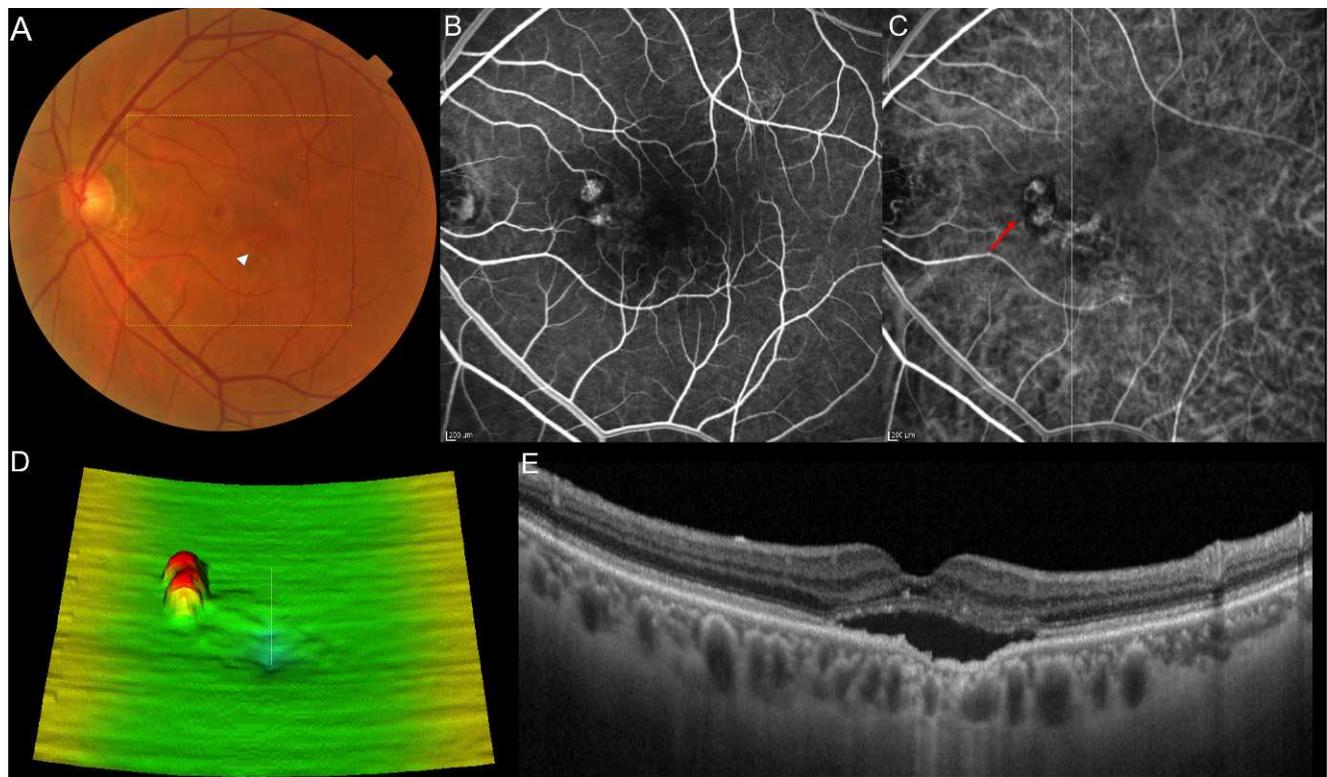


FIGURE 4. A focal excavation consistent with a branching vascular network associated with polypoidal choroidal vasculopathy. (A) Fundus photograph of the left eye of a 73-year-old man with polypoidal choroidal vasculopathy showing pigmentary disturbance in the areas corresponding to the excavations (*white arrowhead*) (patient 9). (B) Fluorescein angiogram showing occult choroidal neovascularization. (C) Indocyanine green angiogram (ICGA) showing a branching vascular network terminating in polypoidal lesions (*red arrow*). (D) Three-dimensional image reconstructed by segmentation of the retinal pigment epithelium showing the shape of the excavation (*white bar*). (E) Vertical section of a swept-source optical coherence tomography image along the *white arrow* in the ICGA showing a nonconforming excavation with serous retinal detachment. The excavation is consistent with a branching vascular network.

reported that the choroidal thickness in CSC eyes with FCE was significantly thicker than that in normal eyes but thinner than that in CSC eyes without FCE. The reason for this difference is unclear. Recent OCT image analysis revealed choroidal thinning in eyes with exudative AMD, compared with PCV.^{33,34} In our patients with FCE, subfoveal choroidal thickness in eyes with PCV was similar to that in eyes with exudative AMD without polypoidal lesions. Jirattanasopa et al.³⁵ reported local choroidal thickening in areas of choroidal vascular hyperpermeability. In our patients, three of four eyes with exudative AMD and three of eight eyes with PCV had

choroidal vascular hyperpermeability. The higher rate of choroidal vascular hyperpermeability in eyes with exudative AMD may account for our finding of similar choroidal thickness.

Previous reports showed that most eyes with FCE are myopic. However, in our study, only five eyes with FCE associated with exudative AMD were myopic. The reason for this observation is unknown. However, in a previous report by Xu et al.,¹² 50% of eyes with FCE that developed CNV were nonmyopic. While FCEs were often seen in myopic eyes, CNV is likely to develop in less myopic eyes with FCE.

TABLE 3. Eyes With and Without Focal Choroidal Excavation Associated With Polypoidal Lesions

	With FCE			Without FCE			P Value*
	Total	Without Polypoidal Lesions	With Polypoidal Lesions	Total	Without Polypoidal Lesions	With Polypoidal Lesions	
N, eyes	12	4	8	231	103	128	
Sex, male/female	10/2	3/1	7/1	147/84	65/38	82/46	0.138†
Age, y	69.7 ± 9.2	70.3 ± 14.7	69.4 ± 6.3	75.3 ± 8.0	76.0 ± 8.1	74.7 ± 7.9	0.040‡
Refractive error, diopters	-0.63 ± 3.25	-0.50 ± 3.01	0.16 ± 3.54	0.84 ± 2.02	1.01 ± 2.20	0.70 ± 1.87	0.371‡
Visual acuity, logMAR	0.15 ± 0.38	0.21 ± 0.60	0.12 ± 0.27	0.41 ± 0.44	0.48 ± 0.46	0.36 ± 0.42	0.014‡
Foveal retinal thickness, μm	255.7 ± 124.8	189.8 ± 62.7	288.6 ± 138.1	261.9 ± 148.8	286.7 ± 182.0	242.0 ± 112.2	0.951‡
Foveal choroidal thickness, μm	257.5 ± 92.3	256.8 ± 91.1	257.9 ± 99.1	232.0 ± 96.5	232.9 ± 97.8	231.3 ± 95.8	0.414‡

* Compared with eyes with and without FCE.

† Fisher's exact test.

‡ Mann-Whitney test.

The current study had several limitations. First, because the number of eyes with FCE was small, the clinical characteristics could not be elucidated fully. Second, all subjects were Asian, and it is possible that the prevalence of FCE is different among other ethnicities. Third, all of our patients had both CNV and FCE upon initial examination because FCE alone rarely causes serious visual symptoms. The current study could not provide information about the condition before the development of CNV. In addition, in the absence of normal control eyes without exudative AMD, a true association between AMD and FCE cannot be established.

In summary, taking into consideration our findings as well as those of previous studies, we hypothesized that the pathogenesis of neovascular complications was induced by FCE involved with outward traction by connective choroidal tissue, possibly resulting from embryonic developmental failure. In general, FCE is a stable condition with minimal symptoms. In some younger patients with FCE, focal damage of the RPE and Bruch's membrane due to the excavation and focal choroidal ischemia may lead to the development of CNV. The clinical characteristics of these CNV are different from those of typical exudative AMD, and they are rather similar to those of secondary CNV. Some older patients with FCE may develop CNV or polypoidal lesions. Although FCE might be partly related to development of CNV associated with exudative AMD, its role appears limited to some eyes.

Acknowledgments

Supported, in part, by the Japan Society for the Promotion of Science (JSPS), Tokyo, Japan (Grant-in-Aid for Scientific Research 21592256) and the Japan National Society for the Prevention of Blindness, Tokyo, Japan.

Disclosure: **Y. Kuroda**, None; **A. Tsujikawa**, Pfizer (F); **S. Ooto**, None; **K. Yamashiro**, None; **A. Oishi**, None; **H. Nakanishi**, None; **K. Kumagai**, None; **M. Hata**, None; **S. Arichika**, None; **A.A. Ellabban**, None; **N. Yoshimura**, Topcon Corp. (F), Nidek (F, C), Canon (F)

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