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Projection Artifact Removal Improves Visualization and Quantitation of Macular Neovascularization Imaged by Optical Coherence Tomography Angiography

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Purpose: To visualize and quantify the size and vessel density of macular neovascularization (MNV) using optical coherence tomography angiography (OCTA) with a projection artifact removal algorithm.

Design: Multicenter, observational study.

Participants: Subjects with MNV in ≥1 eye.

Methods: Patients were imaged using either a swept-source OCTA prototype system or a spectral-domain OCTA prototype system. The optical microangiography (OMAG) algorithm was used to generate the OCTA images. Projection artifacts from the overlying retinal circulation were removed from the OMAG OCTA images using a novel algorithm. After removal of the projection artifacts from the OCTA images, we assessed the size and vascularity of the MNV. Concurrent fluorescein angiography and indocyanine green angiography images were used to validate the artifact-free OMAG images whenever available.

Main Outcome Measures: Size and vascularity of MNV imaged with OCTA before and after the use of a projection-artifact removal algorithm.

Results: A total of 30 subjects (40 eyes) diagnosed with MNV were imaged. Five patients were imaged before and after intravitreal injections of vascular endothelial growth factor inhibitors. After the use of the projection artifact removal algorithm, we found improved visualization of the MNV. Lesion sizes and vascular densities were more easily measured on all the artifact-free OMAG images. In eyes treated with vascular endothelial growth factor inhibitors, vascular density was reduced in all 5 eyes after treatment, and in 4 eyes, the size of the MNV decreased. One of 5 patients showed a slight increase in lesion size but a decrease in vascular density.

Conclusions: Using the OMAG algorithm, OCTA imaging of MNV combined with removal of projection artifacts resulted in improved visualization and measurement of the neovascular lesions. Thus, OMAG with projection artifact removal should be useful for assessing the response of MNV to treatment using OCTA imaging. *Ophthalmology Retina 2016;■:1–13 © 2016 Published by Elsevier Inc. on behalf of the American Academy of Ophthalmology*

Macular neovascularization (MNV) is associated with several major retinal diseases such as age-related macular degeneration (AMD), high myopia, and central serous chorioretinopathy.[1–3] Without prompt treatment, the exudation, hemorrhage, and fibrosis arising from MNV cause irreversible damage to photoreceptors, which ultimately results in the loss of central vision.[4–6] To prevent the progression of disease and permanent vision loss, intravitreal injections of drugs that inhibit vascular endothelial growth factor (VEGF) are recommended.

The current imaging strategies for diagnosing and characterizing MNV include fluorescein angiography (FA) and optical coherence tomography (OCT). Whereas routine OCT provides cross-sectional information about macular anatomy and can document the accumulation of macular fluid and hyperreflective signals associated with MNV, FA has been the preferred imaging strategy to visualize the size, location, and diagnostic features of MNV that have been shown to predict disease severity. However, FA is an invasive procedure that requires the intravenous injection of dye, and while the risk of a life-threatening anaphylactic reaction to the dye is small, FA is also time consuming, expensive, and uncomfortable for the patient.

With the advent of OCT angiography (OCTA),[7–15] retinal and choroidal vascular diseases within the macula can now be diagnosed and monitored noninvasively, safely, rapidly, and more comfortably for the patient. Moreover, OCTA provides invaluable depth-resolved information, which is especially useful for the evaluation of MNV.[16–22] However, it has been reported that OCTA images of structures deep in the retinal vasculature contain projection artifacts from the overlying superficial retinal vessels that

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Table 1. Demographics and Clinical Details of the Patients Who Underwent Treatment with Vascular Endothelial Growth Factor Inhibitors

Patient No.	Age (yr)	Gender	Race	Diagnosis	No. of Injections	Pretreatment Visual Acuity	Posttreatment Visual Acuity	No. of Follow-up Visits	Duration of Follow-up*
1	77	Male	White	Exudative neovascular AMD	1	20/30	20/25	2	7 wk
2†	69	Female	Hispanic	Exudative neovascular AMD	8	20/20	20/20	4	6 mo
3	81	Male	White	Exudative neovascular AMD	3	20/40	20/40	3	2 mo
4	51	Female	White	Exudative neovascular AMD	2	20/70	20/40	2	5 wk
5	74	Female	White	Exudative neovascular AMD	3	20/250	20/125	2	3 mo

AMD = age-related macular degeneration.
The mean ± standard deviation age of the patients was 70.4±11.7 years.
*The duration of follow-up is the time from the first to the last optical coherence tomography angiography (OCTA).
†This patient received 4 injections before this study; OCTA was performed at the last 4 injections.

create the appearance of "false blood vessels" on OCTA images of these deep macular layers.[23,24] These artifacts are particularly troublesome when the region being imaged includes a highly reflective surface such as the retinal pigment epithelium (RPE). Because MNV is always in close proximity to the RPE, these unwanted projection artifacts complicate the interpretation of MNV. Not only is it difficult to visualize the MNV in the presence of the projection

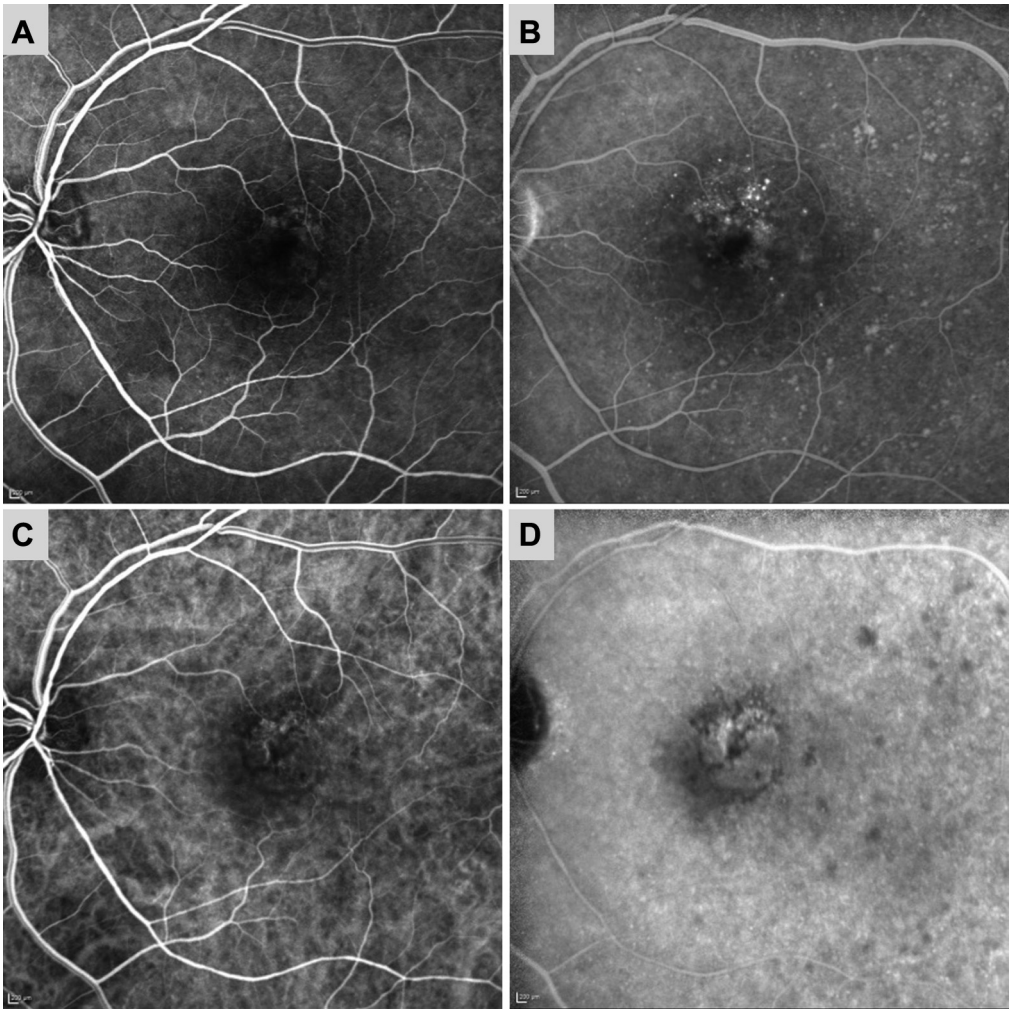

Figure 1. Fluorescein and indocyanine green angiographic images of a 77-year-old man diagnosed with macular neovascularization in the left eye. **A**, An early transit frame from the fluorescein angiography (FA). **B**, Late transit frame from the FA showing stippled hyperfluorescence and leakage. **C**, Early transit frame from the indocyanine green angiography (ICGA). **D**, Late transit frame from the ICGA showing a hyperfluorescent plaque within the central macula.