Three-Dimensional Reconstruction and Analysis of Vitreomacular Traction: Quantification of Cyst Volume and Vitreoretinal Interface Area

Optical coherence tomography (OCT) has made considerable advancements in retinal imaging, especially with the advent of high-resolution, spectral-domain OCT. Nonetheless, viewing and analysis of OCT data are limited to 2-dimensional (2D) slice-based scrolling through consecutive scans (Figure 1). Video available online at www.archophthalmol.com

In a series of eyes with idiopathic vitreomacular traction, we used a method of rendering 2D raster OCT data into 3-dimensional (3D) volumetric objects. By isolating and quantifying distinct retinal structures within these 3D objects, we sought to determine the following: (1) the correlation between cyst volume and area of vitreoretinal adhesion; and (2) the relationship between individual cysts within the retina.

Methods. In this Weill Cornell Medical College Institutional Review Board–approved study, OCT scans (Heidelberg Spectralis HRA + OCT; Heidelberg Engineering, Inc, Carlsbad, California) of idiopathic vitreomacular trac-
tion were imported into Avizo visualization software (VSG, Burlington, Massachusetts) using a custom plug-in written in C++. This plug-in extracts all B-scans, the infrared image, and automated segmentations provided by Heidelberg Eye Explorer software version 1.6.2.0 (Heidelberg Engineering, Inc), all registered to the same coordinate system. Using manually set, threshold-based computational algorithms, boundaries of the cystic spaces, internal limiting membrane, and posterior hyaloid face were segmented in an automated fashion. From these segmentations, 3D objects were created and compared for accuracy with the original 2D OCT scans.

Surface areas of attachment and intraretinal cystic volumes were calculated and converted to millimeter equivalents using the scale embedded within the raw data. The correlation between the surface area of attachment and the volume of cystic spaces was calculated.

To assess the relationships between retinal structures, 3D reconstructions were inspected in the fully immersive Computer Assisted Virtual-Reality Environment (Christie Digital Systems USA, Inc, Cypress, California).

Results. Seven eyes of 7 patients with incomplete perifoveal vitreous detachment and cystoid foveal thickening were included. The 2D OCT data were rendered as 3D volumetric objects with defined cysts, internal limiting membrane, and posterior hyaloid surfaces (Figure 1 and Figure 2).

The total volume of the cysts ranged from 0.00145 mm³ to 0.647 mm³ (mean [SD], 0.115 [0.218] mm³). The surface area of traction between the posterior hyaloid and internal limiting membrane ranged from 0.0114 mm² to 1.0226 mm² (mean [SD], 0.314 [0.316] mm²). There was a strong positive correlation between the tractional surface area and cystic space volume (r = 0.890; P < .01).

Inspection of 3D reconstructions from different viewpoints revealed that several cysts, which appeared separate on conventional OCT, were connected in 3D space (Figure 2 and video, http://www.archophthalmol.com).

Comment. In vitreomacular traction syndrome, volumetric reconstruction of 2D OCT slices permits isolation and analysis of 3D retinal structures. Quantification of cyst volume and vitreoretinal adhesion area revealed a strong positive correlation. As pharmacological vitreolysis emerges, quantification of the adhesion area may influence the decision between observation, intravitreous injection, or surgery.

Previous attempts to evaluate vitreomacular traction with OCT were limited to examining individual OCT slices and measuring overall macular volume and retinal thickness with false-color maps, and they did not isolate or individually quantify retinal structures (Figure 1).4 Attempts to calculate drusen volume had similar limitations.3 In these reports, OCT slices were individually segmented rather than reconstructed as 3D objects.3 The technique described here can be used to quantify drusen volume, geographic atrophy area, and cystic changes in age-related macular degeneration.

Analysis of 3D volumetric reconstructions of OCT images may improve our understanding of pathophysiological features of various retinal diseases. Here, 3D reconstructions revealed that some intraretinal cysts were connected via small tubelike channels not obvious on conventional OCT (Figure 2). Furthermore, quantification of 3D structures may provide meaningful parameters in other disorders such as cystoid macular edema, age-related macular degeneration, diabetic macular edema, and retinal vascular occlusion. However, long-term prospective data from larger patient cohorts are necessary to establish accurate predictive models.

Grant D. Aaker, BA
Luis Gracia, PhD
Jane S. Myung, MD
Vanessa Borchering, BA
Jason R. Banfelder, MChE
Donald J. D’Amico, MD
Szilard Kiss, MD

Author Affiliations: Department of Ophthalmology (Mr Aaker and Drs Myung, D’Amico, and Kiss) and HRH
Commercial Air Travel With a Small Intravitreous Gas Bubble

Although the risks of air travel with an intravitreous gas bubble have been well documented, there have been suggestions in the literature that such a flight may be safe under certain conditions, especially with small bubbles. We report a case of significant visual field loss following commercial air travel in a patient with a 10% intravitreous perfluoropropane gas fill.

Report of a Case. A 64-year-old man with a history of retinal detachment in the left eye visited his ophthalmologist with a 24-hour history of an “explosion” of floaters in the right eye. His history was also remarkable for glaucoma, for which he was receiving 2 medications but had no glaucomatous damage evident in the right eye on optical coherence tomography and visual field testing (Figure 1A and Figure 2A).

On examination immediately following his return to Canada, the cup-disc ratio of his right optic nerve had increased from 0.3 to 0.5. His optical coherence tomographic scan demonstrated a striking loss of the nerve fiber layer from an average thickness of 96.99 µm before vitrectomy to 79.71 µm afterward (Figure 1B). This change was accompanied by a corresponding new superonasal visual field defect demonstrated on Goldmann visual field examination (Figure 2B).

Comment. Vitreoretinal surgery often involves the use of air or medical gases, primarily perfluoropropane or sulfur hexafluoride, injected directly into the vitreous cavity. As resorption of these gases is first order, small gas volumes may be present for weeks or months. Although the risks of air travel with intraocular gas have been well documented, there have been some suggestions in the literature that under certain conditions (eg, low-altitude flight or small gas bubbles) flight with intraocular gas may be safe, if inadvisable.

As an aircraft gains altitude, the atmospheric pressure decreases. Commercial flights routinely reach altitudes up to 40,000 feet above sea level, with cabin pressures typically maintained at less than 9000 feet. As the atmospheric pressure decreases, an intraocular gas bubble will undergo expansion following Boyle’s law: \( P_1V_1 = P_2V_2 \), where \( P \) indicates the pressure of the system and \( V \) indicates the volume of the gas. The eye has several compensatory mechanisms including limited choroidal flattening, scleral expansion, and increased aqueous outflow, but these mechanisms are limited in their ability to accommodate expansion of the intraocular gas bubble. Once the globe’s maximum capacity is reached, the intraocular pressure increases, which may result in acute glaucoma and even central retinal artery occlusion.