Published in final edited form as:

Am J Ophthalmol. 2006 November ; 142(5): 862–864.

Persistence of Cloquet's Canal in Normal Healthy Eyes

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Abstract

PURPOSE—Optic nerve head (ONH) structural imaging with state-of-the-art, high-speed, ultra-high-resolution optical coherence tomography (hsUHR-OCT).

DESIGN—Observational cohort study.

METHODS—ONH centered 3-dimensional (94,371,840 voxel measurements in a 6- × 6- × 1.4-mm tissue volume) hsUHR-OCT data were obtained in one eye from each of six males and nine females normal healthy volunteers (40 ± 9 years of age). The presence of structures projecting anteriorly from the disk into the vitreous was noted.

RESULTS—Structures were noted in 14 of 15 (93%) examined eyes, emanating from the rim of the ONH at the nasal inferior sector, presenting as thin tissue meandering into the vitreous.

CONCLUSIONS—Previous technologies provided limited visualization of ONH structures. The ability to scan the entire disk using 3-dimensional OCT (3D-OCT) in a high-density raster pattern reveals a high frequency of persistence of Cloquet's canal in the normal healthy eye.

Cloquet's Canal (CC) serves as a perivascular sheath surrounding the hyaloid artery in the embryonic eye.¹ At birth, or soon thereafter, the hyaloid artery and associated vascular tree close, and their remnants are thought to be reabsorbed over time²; falling along the inferior surface of the lens and becoming "inconsequential" in the eye. In the mature eye, remnants of CC are evident in some eyes as Mittendorf's dot posterior to the lens and Bergmeister's papilla anterior to the optic nerve head (ONH),³ with persistence of Bergmeister's papilla sufficiently common as to be considered an anatomic variant.¹

Recent advances in high-speed, ultra-high-resolution optical coherence tomography (hsUHR-OCT) imaging using Fourier/spectral domain detection can enable dramatic improvements in resolution and imaging speed.^{4–6} As with the commercially available Stratus OCT (Carl Zeiss Meditec, Dublin, California, USA), hsUHR-OCT allows noninvasive, in vivo, cross-sectional imaging of the retina. Our research prototype instrument has an axial resolution of 3.5 μm and an axial scan speed of ~24,000 scans per second, a factor of two to three times' finer resolution and 50 times' faster scan speed compared with the commercial instrument.⁵ These high speeds enable 3-dimensional OCT (3D-OCT) imaging. We have imaged a number of normal and

diseased ONH using 3D-OCT. We consistently observed a tissue structure extending anteriorly from the inferior nasal rim of the ONH, and extending into the vitreous of both healthy and glaucomatous subjects. Based on its origin and orientation, the authors believe this structure to be the remnants of CC. The purpose of this study was to provide pilot data describing the persistence of CC in the normal healthy adult eye.

The study was approved by the institutional review board of the University of the Pittsburgh School of Medicine, and all subjects provided informed consent before imaging. The study was conducted in accord with Health Insurance Portability and Accountability Act (HIPAA) regulations.

hsUHR-OCT scanning has previously been described in detail.^{5,6} Briefly, broadband (100-nm bandwidth, centered at 840 nm) light from a superluminescent diode light source (Broadlighter, Superlum Ltd, Moscow, Russia) is split and projected onto a stationary mirror and onto the retina. Reflected light is combined to form an interference pattern. Axial scan information is frequency encoded within the interference pattern. Reflections from different depths within the retina contribute to the interference pattern.

The 3D-hsUHROCT ONH centered data sets were obtained in one eye of each of 15 normal healthy subjects (six male, nine female, age 40 ± 9 years). Scans captured a 6×6 mm (512 lateral locations each within 180 vertical scans) slice of retinal tissue, with a slice thickness of approximately 1.4 mm (1024 axial samples/A-scan with a 3.5 μ m resolution). Three-dimensional-OCT data were rendered using image processing software similar to that used in magnetic resonance imaging (Amira, Mercury Computer Systems, Inc, Chelmsford, Massachusetts, USA).

The vitreous immediately anterior to the ONH was examined for reflective structural sources. A reflective structure extending anteriorly from the inferior-nasal ONH was visualized in 14 of 15 eyes (93%, Figures 1 and 2). In each case, the structure emanated from the inferior nasal quadrant rim of the ONH. The same structure was present in a previous publication by Wojtkowski M and associates describing the hsUHR-OCT technique (Figure 3).⁵

The finding of persistence of CC in 93% of healthy eyes demonstrates that the remnant of the hyaloid artery and its associated structures do not disappear completely in the majority of eyes. In fact, remnants of this structure may be detected in nearly every healthy eye we studied. This observation was made possible by advances in imaging technology; future discoveries may be enabled by further improvements in resolution and scan speed.

The ability to assess the entire ONH structure using 3D-OCT with a high-density raster-scan reveals a high frequency of persistence of CC in the normal healthy eye. Supplemental Video available at AJO.com

Acknowledgements

Supported in part by NIH contracts R01-EY13178-06, R01-EY11289-20, P30-EY08098, and P30-EY13078; NSF contract ECS-0119452 and BES-0522845; Air Force Office of Scientific Research contract FA9550-040-1-0011; Medical Free Electron Laser Program contract FA9550-040-1-0046; The Eye and Ear Foundation (Pittsburgh); and an unrestricted grant from Research to Prevent Blindness, Inc, New York, New York.

References

1. Apple, DJ.; Rabb, MF. Developmental anomalies. In: Apple, DJ.; Rabb, editors. Ocular pathology: clinical applications and self-assessment. 3. St Louis, Missouri: The C.V. Mosby Company; 1985. p. 14-60.

2. Mann, IC., editor. The development of the human eye. London, United Kingdom: Cambridge University Press; 1928. The vitreous and suspensory ligament of the lens; p. 151-189.
3. Bron, AJ.; Tripathi, RC.; Tripathi, BJ. Wolfs anatomy of the eye and orbit. 8. 659. London, United Kingdom: Chapman & Hall; 1997. p. 443-444.
4. Wojtkowski M, Bajraszewski T, Gorczynska I, et al. Ophthalmic imaging by spectral optical coherence tomography. *Am J Ophthalmol* 2004;138:412–419. [PubMed: 15364223]
5. Wojtkowski M, Srinivasan V, Fujimoto JG, et al. Three-dimensional retinal imaging with high-speed ultrahigh-resolution optical coherence tomography. *Ophthalmology* 2005;112:1734–1746. [PubMed: 16140383]
6. Fernandez EJ, Povazay B, Hermann B, et al. Three-dimensional adaptive optics ultrahigh-resolution optical coherence tomography using a liquid crystal spatial light modulator. *Vision Res* 2005;45:3432–3444. [PubMed: 16249013]

FIGURE 1.

High-speed, ultra-high-resolution optical coherence tomography (hsUHR-OCT) images of remnants of Cloquet's canal (arrow) in Subject 1 presented as an optical cross-section ($6 \text{ mm} \times 1.4 \text{ mm}$) (Top) and a 3D volumetric rendering ($6 \times 6 \times 1.4 \text{ mm}$) of the nerve fiber layer and the photoreceptor outer segments and retinal pigment epithelial layer (Bottom).

FIGURE 2.

High-speed, ultra-high-resolution optical coherence tomography (hsUHR-OCT) images of remnants of Cloquet's canal (arrow) in subject 2 presented as an optical cross-section (6 mm $\times$ 1.4 mm) (Top) and a 3D volumetric rendering (6 $\times$ 6 $\times$ 1.4 mm) of the nerve fiber layer and the photoreceptor outer segments and retinal pigment epithelial layer (Bottom).

FIGURE 3.

Remnants of Cloquet's canal (arrow) observed in both Stratus optical coherence tomography (OCT) and ultra-high-resolution optical coherence tomography (hsUHR-OCT). (Reprinted from Wojtkowski M, Srinivasan V, Fujimoto JG, et al., Three-dimensional retinal imaging with high-speed ultra-high-resolution optical coherence tomography. *Ophthalmology* 2005;112:1734-1746, with permission from *American Academy of Ophthalmology*).