Comparison of phase-resolved Doppler optical coherence tomography and optical coherence tomography angiography for measuring retinal blood vessels size

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Abstract

The goal of this study was to compare two OCT-based methods for measuring retinal blood vessels size: Phase-resolved Doppler OCT (DOCT) and OCT angiography (OCTA). The study was conducted in rats (n= 6) using a SD-OCT system operating at 1060 nm with 92 kHz image acquisition rate. Arteries and veins were separated by the phase polarity. Results from this study showed that the venal diameters are significantly larger than the arterial diameters, and there is no significant difference in the vessel diameters measured by both methods.

1. Introduction

Retinal blood vessel diameter is an important diagnostic factor in various ocular diseases, such as diabetic retinopathy and retinal vascular occlusion [1]. Recently, OCT and its extensions, including DOCT and OCTA, were widely used to evaluate the retinal blood vessel diameters [2,3]. DOCT utilizes phase difference between adjacent A-scans to measure the blood flow rate [4] and OCTA, especially optical microangiography (OMAG), utilizes decorrelation signal between adjacent B-scans to visualize retinal blood vessels and capillaries [5]. The difference between measurement mechanisms could result in difference of sensitivity to the moving particles and resistance to motion artifact, which could further cause differences in measuring the retinal blood vessel diameter. The goal of this study was to compare two OCT-based methods for measuring retinal blood vessels size: Phase-resolved Doppler OCT (DOCT) and OCT angiography (OCTA).

2. Methods

Eleven-week-old, male Brown Norway rats (~300g) were used in this study (n=6). All experiments described here were approved by the University of Waterloo Animal Research Ethics Committee and adhered to the ARVO statement for use of animals in ophthalmic and vision research. The rats were anesthetized with isoflurane and oxygen mixture maintained at 1.5-2.5% throughout the experimental procedures. Afterwards, the rats were placed in a custom stereotaxic animal holder that allowed for XYZ and angular adjustment of the animal eye with respect to the stationary OCT imaging probe. The base of the animal holder was lined with a thermal pad (Kent Scientific, Torrington, CT, USA) in order to keep the rat body temperature between 36° and 38 °C. One drop of 0.5% proparacaine hydrochloride (Alcaine, Alcon, Mississauga, ON, Canada) was applied to each eye, followed by one drop of pupillary dilator (0.5% tropicamide, Alcon, Mississauga, Canada).

A research-grade spectral domain OCT system was used in this study. Briefly, the OCT system operates in the 1060 nm spectral region and provides ~3.5 µm axial and ~5 µm lateral resolution in retinal tissue with ~100 dB SNR for 1.7 mW optical power of the imaging beam incident on the cornea. An ultra-sensitive optical microangiography (OMAG) protocol was used to generate OCTA images of the retina around the ONH (3.4 mm x 3.4 mm; 512 A-scans × 512 positions × 4 scans/position). Doppler OCT images were acquired with highly overlapped A-scans (~87% overlapping) from a relatively smaller area centered at the ONH (2 mm x 2 mm, 3000 A-scans x 200 B-scans). The camera image acquisition rate was set to 92 kHz, resulting in blood flow velocity detection range of [-17.4, 17.4] mm/s.

In order to evaluate the blood vessel diameter at the same location, a cross-correlation registration method (MATLAB, MathWorks) was used to align the en-face DOCT image and the en-face OCTA image (Fig. 1A-B). For each blood vessel, diameters from two different locations (390 µm and 585 µm from the ONH) were evaluated. Figure 2 shows the measurements of a retinal blood vessel diameter from an *en-face* OCTA image and a DOCT B-scan. The measurements of retinal blood vessel diameters with OCTA were conducted from the fundus view, while in the corresponding DOCT B-scan, the vessel size measurements were done as the axial length of the retinal blood vessel.

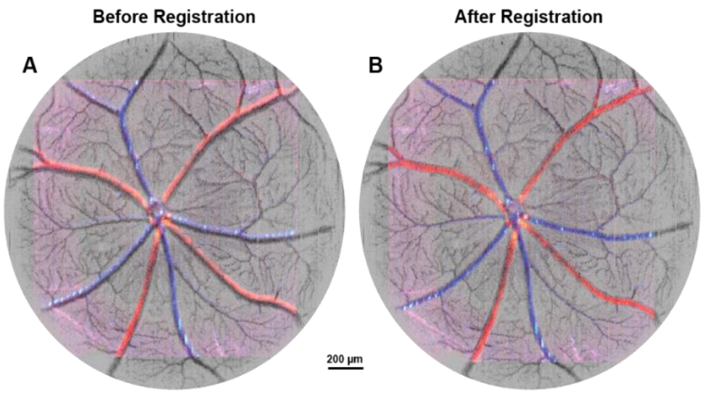

Fig. 1: Overlaid Doppler OCT image and OCTA image before/after cross-correlation registration.

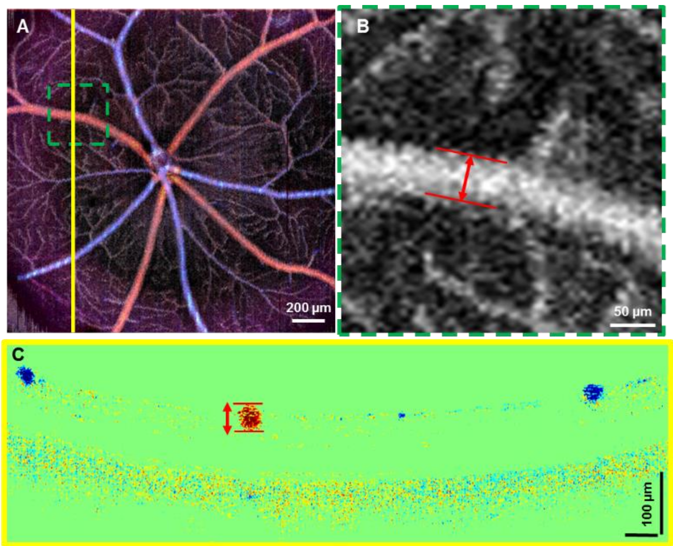

Fig. 2: Measurement of retinal blood vessel from en-face OCTA image and Doppler OCT image.

Paired t-test was used to determine any significant difference in measuring the vessel diameters by two methods, and difference between arterial and venal diameters, measured by DOCT or OCTA. $P<0.05$ is considered as statistically significant.

Both left and right eyes were measured and a total of 12 eyes and 79 retinal blood vessels were evaluated. The arteries and veins are differentiated by the phase polarity in the DOCT images. As shown in Fig. 3, the red sphere represents the veins, and the blue square represents the arteries, respectively. In both methods, the venal diameters are significantly larger than arterial diameters (both $p<0.01$). The retinal arterial diameter measured by OCTA and DOCT are 39.24 ± 6.41 µm and 40.35 ± 5.81 µm ($p = 0.48$), and the absolute difference of retinal arterial diameter measured by these two methods is 0.52± 2.8 µm. Similarly, the retinal venal diameter measured by OCTA and Doppler OCT are 48.13 ± 9.02 µm and 47.17 ± 7.74 µm ($p=0.08$), and the absolute difference of retinal venal diameter measured by these two methods is 0.95 ± 4.9 µm

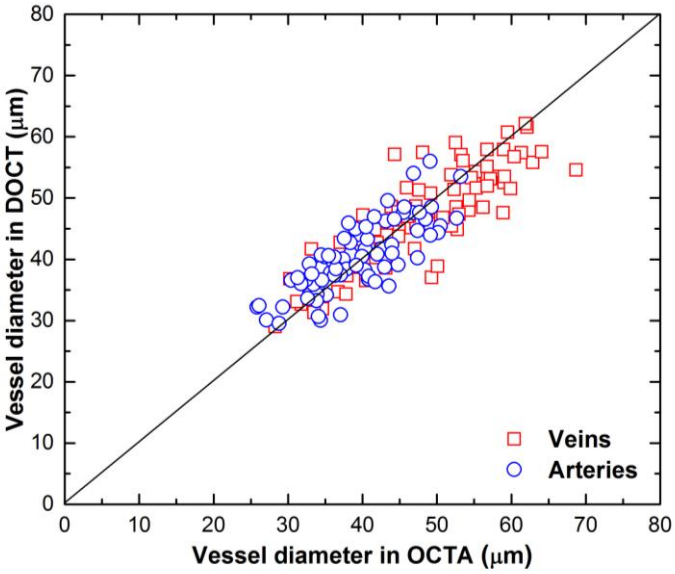

Fig. 2: Comparison between DOCT and OCTA in measuring retinal arterial and venal diameters.

3. Conclusions

Comparison of retinal blood vessel diameters in different OCT extensions (Phase resolved Doppler OCT and OCTA) was conducted. In a total of 79 retinal blood vessels, venal diameters are significantly larger than arterial diameters, and no significant difference was detected in arterial and venal diameter measurements by DOCT and OCTA.

Acknowledgement

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References

[1] Ikram, M. Kamran, et al. "Retinal vascular caliber measurements: clinical significance, current knowledge and future perspectives." Ophthalmologica 229.3 (2013).

[2] Fondi, Klemens, et al. "Measurement of Retinal Vascular Caliber From Optical Coherence Tomography Phase ImagesOCT and Retinal Vascular Caliber." Investigative ophthalmology & visual science 57.9 (2016).

[3] Falavarjani, Khalil Ghasemi, et al. "Retinal vessel calibre measurements by optical coherence tomography angiography." British Journal of Ophthalmology (2016)

[4] Leitgeb, Rainer A., et al. "Doppler optical coherence tomography." Progress in retinal and eye research 41 (2014)

[5] Wang, Ruikang K., et al. "Three dimensional optical angiography." Optics express 15.7 (2007).