Retinal-Choroidal Blood Flow Decreases with Age: an MRI study

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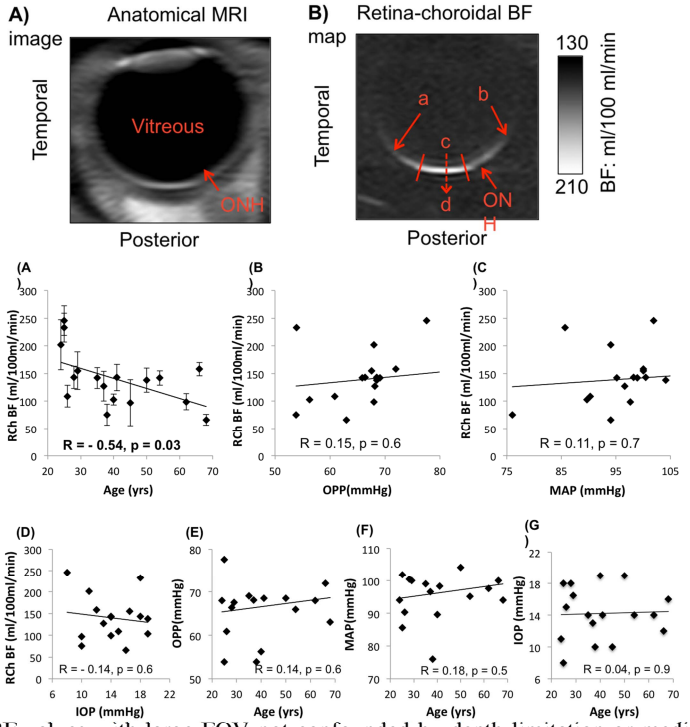
Target Audience Ophthalmologists, neuroscientists, and researchers in aging and blood flow.

Purpose Age is a leading risk factor in age-related macular degeneration, glaucoma, and vascular occlusive diseases. Under normal physiological conditions, blood flow (BF) in the retina is tightly regulated.[1] Optically based imaging techniques have been used to study age-dependent BF changes in the retina. However, most optically based blood flow (BF) imaging techniques are limited to imaging the fovea or the optic nerve head, are confounded by media opacity if present (i.e., cataract and vitreous hemorrhage), and are qualitative or semi-quantitative which makes comparison across different subjects challenging. The goals of the present study were to assess the visual fixation stability achievable with cued eye blinks for blood-flow MRI and to test the hypothesis that retinal-choroidal blood flow changes with age in humans.

Methods Visual fixation stability measurements were made on five healthy subjects (3M, 2F, 24-40yo) using an eye-tracker (ETL-500, ISCAN Inc). The angular resolution was 0.1° and 29.1μm at the posterior retina. MRI was made on healthy subjects (5M, 2F, 25–66yo). Each subject was imaged multiple times (1 to 4) with each trial lasted 3-4 min. Subjects were instructed to maintain stable eye fixation on a target inside the magnet bore and synchronize eye blinking during the sound cue generated by the scanner during the data readout from every dynamic. BF MRI was performed on a 3.0 T Philips Achieva System using a custom receive-only surface coil (~7 cm id). High resolution BF MRI (0.5x0.8x6 mm^3) was acquired on a single central axial slice bisecting the optic nerve head and fovea using the pseudo-continuous ASL technique with background suppression and single-shot turbo-spin echo (TSE) for the image acquisition. Data were acquired and analyzed as described previously.[2] Reproducibility of the blood flow by MRI across multiple repeated scans and across multiple sections on the same subjects has also been described.[2]

Results The eye-tracking results were: i) the temporal standard deviations of displacement during a single fixation period were 29±9□m (±SD) (horizontal direction) and 38±11□m (vertical direction). ii) The temporal standard deviations of displacement across multiple fixation periods were 50±34□m and 48±19□m. iii) The mean absolute displacements of the eye position from the mean reference point were 67±31□m and 81±26□m. The SD displacements were substantially smaller than the MRI spatial resolution employed.

A typical BF MRI of the eye is shown in **Fig 1**. RChBF was negatively correlated with age (BF = 214 - 1.8·age, R= -0.54, p=0.03, **Fig 2A**), declining 1.8ml/100ml/min per year. There was no significant correlation between BF with OPP (R= 0.15, p=0.6, **Fig 2B**), MAP (R=0.11, p=0.7, **Fig 2C**), or IOP (R= -0.14, p=0.6, **Fig 2D**). Age did not have any significant correlations with OPP (R=0.14, p=0.6, **Fig 2E**), MAP (R=0.18, p=0.49, **Fig 2F**), or with IOP (R=0.04, p=0.9, **Fig 4G**). When dividing subjects into two age groups (24-37 yo and 38-68 yo), BF was significantly higher in the younger than the older age group (270±98 vs. 161±54 ml/100ml/min, p<0.001).



Discussion Our results are consistent with findings that choroidal arterioles and the fluorescent intensity decreased with age using indocyanine green angiography,[3] foveolar choroidal circulation decreased with age using laser Doppler flowmetry,[4] retinal leukocyte velocity decreased with age using the blue field entoptic technique.[5] Results using color Doppler imaging are more variable. Some found central retinal artery blood flow velocities decreased 9.9% per per decade,[6] others found no correlation in blood velocity in the central retinal artery and vein with age,[7] and still others reported an increase of peak systolic velocity in the central retinal artery with age.[8]

Conclusions Cued visual fixation on a target achieved adequate stability for blood flow MRI measurement. Retinal-choroidal blood flow negatively correlated with age, declining 1.8ml/100ml/min per year. Such decrease in ocular blood flow could impair delivery of oxygen and nutrients, and removal of metabolic waste, making the retina susceptible to diseases. BF MRI has some unique advantage by offering quantitative BF values with large FOV not confounded by depth limitation or media optical opacity. Future studies will improve spatial resolution and sensitivity to resolve of retinal and choroidal blood flow in humans, as well as to apply blood flow MRI to investigate retinal diseases.

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