Assessment of blood flow velocity and pulsatility in cerebral perforating arteries with 7T phase contrast MRI

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Purpose: Thus far, blood flow velocity measurements with MRI were only feasible in large cerebral blood vessels. High field strength MRI may now permit velocity measurements in much smaller arteries. Our aim was to measure blood flow velocity and pulsatility of cerebral perforating arteries with 7 tesla MRI and to assess the precision by repeated measurements.

Method: A single-slice (2D) phase contrast sequence with two point velocity encoding was used to measure blood flow velocities during the cardiac cycle in perforating arteries in the basal ganglia (BG) and semioval centre (CSO), from which a mean normalized pulsatility index (PI) per region was calculated as V_{max}-V_{min}/V_{mean}. Six human subjects (age 23-29, 2 male) were scanned at 7T MRI (Philips Healthcare) with a 32 channel receive coil (Nova Medical). Scan parameters were: FOV 250x180 mm^2, TR/TE = 26/15 ms, flip angle 60°, readout BW 59 Hz/pixel (to increase the signal to noise ratio of arterial blood, which has a long T_2*), encoding velocity (V_{enc}) 4 cm/s in CSO and 20 cm/s in BG, 2 averages, and 156 ms temporal resolution (reconstructed to 10-13 cardiac phases). The scan was retrospectively triggered using a pulse-oximeter at the fingertip, and took approx. 7 minutes for a heart rate of 60 bpm. Phase contrast measurements were also performed at the M1 segment of the circle of Willis (0.5 mm resolution, Venc 100 cm/s). The precision of the measurements was determined by performing repeated scans, and testing correlations and agreement between the results of the repeated scans. Potentially confounding effects of partial volume and noise on the measurements were simulated using straightforward Bloch simulations, which included the inflow effect and imperfect slice profile of the RF pulse.

Results: The median number of arteries included was 14 in the CSO and 19 in the BG. In the CSO, the average measured velocity per volunteer ranged 0.5 – 1.0 cm/s, and the PI 0.24 – 0.39. In the BG, the average velocity ranged 3.9 – 5.1 cm/s, and the PI 0.51 – 0.62. The average and maximum velocities per artery showed a very strong correlation (ρ 0.76 - 0.86) between repeated scans. The precision of the velocities per vessel decreased with the size of the arteries (mean absolute difference between measurement one and two ± SD of Vmean was 23% ± 23% for the CSO and 14%±16% for the BG). The mean absolute difference ± SD of the PI between repeated scans was 32% ± 9% in the CSO and 18% ± 17% in the BG. The simulations proved velocities can be measured in vessels with a diameter > 80 µm, but are underestimated due to partial volume effects, while pulsatility index is overestimated (Figure 2).

Conclusion: Blood flow velocity and pulsatility in cerebral perforating arteries has been directly measured in-vivo for the first time, with moderate to good precision. This may be an interesting metric to study hemodynamic changes in ageing and cerebral small vessel disease.

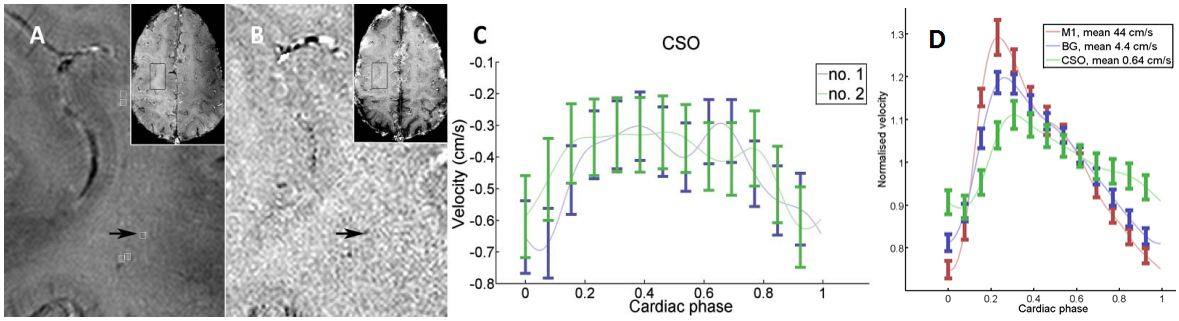

Figure 1: *CSO example data. A: mean (over cardiac cycle) magnitude. B: mean phase. Local maxima in mean velocity are indicated with white squares on the magnitude image. The black arrows point at the vessels for which the individual velocity profiles are shown. C: raw velocity curves for measurement one and two, for the individual vessel indicated with the black arrow. D: mean velocity curves over all vessels and volunteers, per region.*

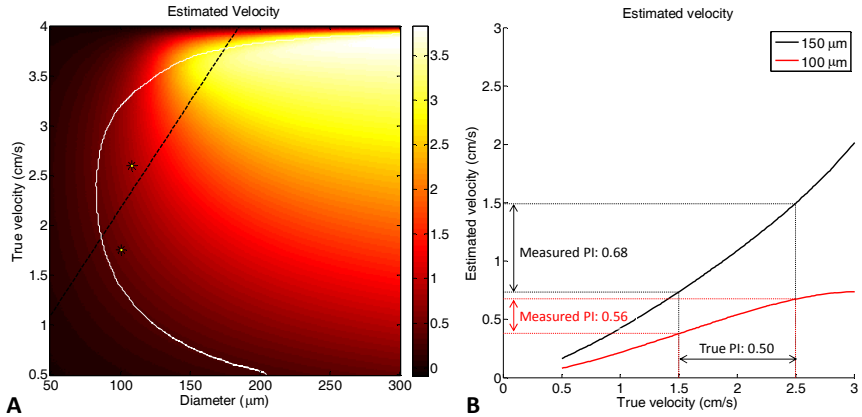

Figure 2: *Simulation data for the scan protocol used in the CSO. A: estimated velocity (color coded) as a function of the true blood velocity (vertical axis) and vessel diameter (horizontal axis). The dashed line and asterisks show literature values. The line originates from feline pial artery measurements[1)], the asterisks from human retinal arteriole measurements[2)]. The velocities in the area to the right of the white line are statistically significant. Most physiological values are within the white line and thus would be detected by our sequence. B: estimated velocity vs. true velocity for two vessel diameters. Velocities are strongly underestimated but the pulsatility is overestimated.*

References: *1.* Kobari M et al, *J Cereb Blood Flow Metab. 1984*, Blood flow velocity in the pial arteries of cats, with particular reference to the vessel diameter. *2.* Nagaoka T, *Invest Ophthalmol Vis Sci. 2006*, Noninvasive evaluation of wall shear stress on retinal microcirculationin humans.
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