Blood flow velocity and pulsatility analysis of cerebral small perforating arteries with 7 Tesla quantitative flow MRI.

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Target audience: Radiologists, neurologists, MRI developers.
Purpose: To measure blood flow velocity profiles and calculate the pulsatility index of the small perforating arteries in the semioval centre of the human brain, using 7 Tesla quantitative flow (Qflow) MRI.
Background: Previously, it has been shown that small perforating arteries inside perivascular spaces in the semioval centre can be depicted in vivo with 7 Tesla MRI. Blood flow velocity and pulsatility measurement of these arteries may be an interesting metric for assessing microvascular changes, for example in the context of ageing and dementia.
Methods: Six volunteers (aged 18-30), without a history of neurological disease, were scanned after written informed consent was obtained in accordance to the Institutional Review Board of our hospital. Imaging was performed on a 7.0 T scanner (Philips Healthcare) using a 32 channel receive head coil with a dual channel volume transmit coil (Nova Medical). The set of protocols was chosen to depict small perforating arteries and perivascular spaces (PVS) in the semioval centre, and to measure flow velocity in head-feet direction. Main scan parameters were as follows: a 2D, 2mm single slice Qflow sequence (FOV 250x180mm^2, acquired resolution 0.3x0.3mm^2, TR/TE 26/13 ms, flip angle 60°, readout BW 59Hz/pixel (to increase SNR of arterial blood, which has a long T2 of approximately 70 ms at 7T[1]), Venc 4 cm/s, retrospectively gated acquisition, 13 reconstructed heart phases, true temporal resolution 156 ms), and a single slice TSE to visualize PVS (250x180mm^2, acquired resolution 0.4x0.4mm^2, 2 mm slice thickness, TR/TE 2000/74 ms).
The slice orientation for both sequences was planned 15 mm (range 10-20 mm) above the corpus callosum, in transverse direction, and angulated parallel to the lowest part of the genu en splenium of the corpus callosum in the mid-sagittal plane. Arteries were defined as small (< 1mm) and round focal hyperintensities on the magnitude images of the 2D Qflow (figure 1), that corresponded with a perivascular space on the T2 TSE. Due to the long TE, veins were hypointense in the magnitude of the 2D Qflow. Two to four perforating arteries per subject were randomly selected, and blood velocity profiles were analysed. Phase correction was performed by drawing a ROI close to the vessel, and subtracting the average velocity of the background from the velocity curve. For each timepoint, the reliability of the velocity measurement was estimated by calculating the standard deviation of the measurement as follows: SD_velocity = Venc / π / SNR_magnitude. To include only arteries with significant flow, arteries in which blood velocity +/- 2SD was equal to zero at any timepoint were excluded from further analysis. All blood velocity profile curves were visually inspected. For each vessel, we recorded the maximum (Vmax) and minimum (Vmin) velocity, and calculated the mean velocity (Vmean) and the pulsatility index (PI). The pulsatility index was defined as (Vmax – Vmin) / Vmean. All analyses were performed in Matlab (v. 2013b, Mathworks).
Results: In all six subjects, perforating arteries in the semioval centre were visualized with the 2D Qflow sequence. Initially, 13 vessels were selected on the 2D Qflow magnitude images. One vessel did not show significant flow and was excluded. For all arteries combined, the mean velocity was 0.9 cm/s, range 0.2 – 2.0 cm/s. All vessels showed pulsatile flow, but velocity profiles during the cardiac cycle differed between vessels. The mean PI was 0.5, range 0.3 – 0.8, SD = 0.2 (Table 1).

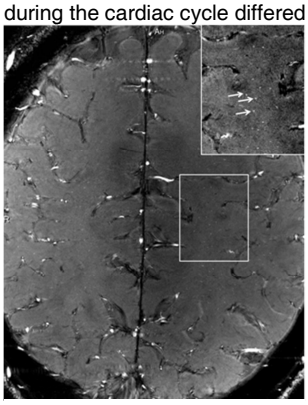

Figure 1. 2D Qflow sequence showing perforating arteries in the semioval centre (arrows).

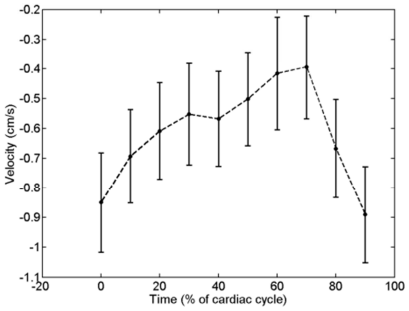

Figure 2. Blood flow velocity profile from vessel 1 in table 2. Error bars indicate the standard deviation of the measurement.

Subject	Vessel n°	Vmean (cm/)	Vmax – Vmin (cm/s)	Pulsatility index
1	1	0.61	0.50	0.81
	2	1.09	0.43	0.39
2	3	0.82	0.37	0.45
	4	1.40	1.01	0.73
3	5	0.40	0.33	0.83
	6	0.74	0.26	0.35
	7	0.91	0.59	0.65
4	8	0.72	0.31	0.43
5	9	1.63	0.59	0.36
	10	0.59	0.43	0.73
6	11	1.02	0.37	0.37
	12	1.05	0.30	0.29

Table 1. Mean velocity, Vmax - Vmin and pulsatility index for all subjects.

Discussion: Blood flow velocity in perforating arteries in the semioval centre was measured with 7 Tesla Qflow MRI, and varied during the cardiac cycle. Flow in these arteries was pulsatile, but across arteries different patterns of blood velocity during the cardiac cycle were observed, and the pulsatility index varied. The main limitations of our results are the influence of partial volume effects, and the fact that blood velocity was only measured perpendicular to the imaging plane. Further validation, including a reproducibility analysis, is needed in the future.
Conclusions: Blood flow velocity pulsations in small perforating arteries in the white matter can be directly measured in humans with 7 Tesla Qflow MRI, and may be an interesting measure to study microvascular changes in the brain.
References: 1. Krishnamurthy LC, Uh J, Dimitrov I, Xu F, Liu P et al. Calibration and Implementation of Quantitative Blood Oxygenation Measurement at 7T, Proc. Intl. Soc. Mag. Reson. Med. 20 (2012), page 203.