Perivascular spaces and their relation to blood vessels: a 7 Tesla MRI study.

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Introduction: Perivascular or Virchow Robin spaces (PVS) are small cavities filled with fluid around arteries and veins in the brain. On MRI PVS have been described as longitudinal structures that are presumably linked to small perforating arteries: around lenticulostriate arteries (LSA) in the deep regions of the brain, and around the perforating medullary arteries in the subcortical white matter that run from the cortex to the centrum ovale (1). PVS enlarge with ageing and are considered to be a marker of cerebral small vessel disease. These enlarged PVS can be detected with conventional MRI and CT. Non enlarged PVS, due to their small size, have mainly been investigated in post-mortem studies. In this study high resolution 7 Tesla MRI was used to study PVS in vivo in four young, healthy individuals. Our aims were: a) to develop a 7 Tesla imaging protocol optimized for visualizing PVS b) to describe the anatomical features of the PVS c) to see if PVS can be linked to corresponding perforating arteries or veins.

Methods: Imaging was performed on a 7.0 T scanner (Philips Healthcare, Cleveland, USA) using a 32 channel receive head coil with a single channel volume transmit coil (Nova Medical, Wilmington, USA). Four volunteers (Age 19 - 26) with no medical history were scanned after written informed consent was obtained in accordance to the Institutional Review Board of our hospital. The set of protocols was chosen to allow distinction between PVS, and related arteries and veins (Table 1), with high resolution in a reasonable total scan duration of less than one hour per subject including planning and image based B0 shimming. Main scan parameters were as follows: A whole brain volumetric (3D) T2w TSE as previously described (2), with TR/TE 3158/301 ms, a tissue specific refocusing sweep (range: 12-90°), optimized for white matter (3), SENSE 2x2.8 (APxRL), 0.7mm acquired isotropic resolution, and scan duration of 10 min.;. a whole brain 3D T1w MPRAGE sequence, with 3500 ms interval between inversion pulses, TI 1200, TR/TE 7.5/3.0 ms, flip angle 8°, SENSE 1.6x1.6 (APxRL), 0.5mm acquired isotropic resolution and scan duration of 16.min.; A 3D time-of-flight (TOF) angiography scan, with TR/TE 15/3.4 ms, SENSE 2.5 (RL), transverse orientation with 60 mm coverage, 0.25x0.3x0.4 mm^3 acquired resolution, and scan duration 10 min.; a transverse whole brain 3D T2*w scan with multi shot EPI readouts (4), TR/TE 94/27 ms, flip angle 24°, SENSE 2.3 (RL) and scan duration 8 min.
For each subject, coronal, sagittal and transverse minimum (minIP) and maximum (maxIP) intensity projections were made with a slice thickness of 4 mm and 2 mm overlap. PVS were defined as longitudinal structures in the brain parenchyma with low intensity on T1 and high intensity on T2 weighted images. For visualization of the perforating arteries the TOF and T1 were used and for the veins the SWI was used.

Table 1. Contrast weighting vs. visibility of PVS and vessels.

	PVS	Arteries	Veins
T_2	+	o/-	o/-
T_1	-	+	o
TOF	o	+	o
T_2*	+	o	-

+ bright, o iso intense, - dark

Results: With the imaging protocol used, PVS were well visualized in all subjects.
Basal ganglia region: PVS had trajectories similar to those of the LSA. PVS were wider in the area proximal to the medial cerebral artery and tapered distally. Connections were observed between the PVS and the basal cisterns.
PVS could in general be linked to a corresponding LSA (Fig. 1), but not all LSA observed could be linked to a corresponding PVS, and vice versa. No correlation between PVS and the track of veins was observed.

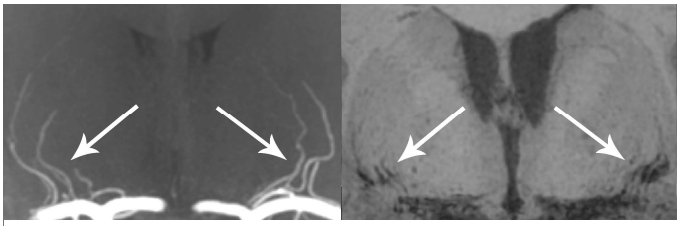

Figure 1. Left: 10 mm maxIP of TOF showing LSA. Right: 4 mm MinIP of T1 showing corresponding PVS. The PVS are widest in the caudal

Lobar region: PVS started below the cortex and converged toward the anterior horn, trigone and posterior horn of the lateral ventricles. No extensions of the PVS into the cortex or ventricular system were observed.
In one subject we could see a perforating artery in the subcortical white matter that corresponded with a PVS (Fig. 2). In the other subjects the perforating medullary arteries could not be visualized. The venous system also converged to the lateral ventricles, and some veins could be linked to a PVS. The vast majority of veins however could not be linked to PVS (Fig. 2).

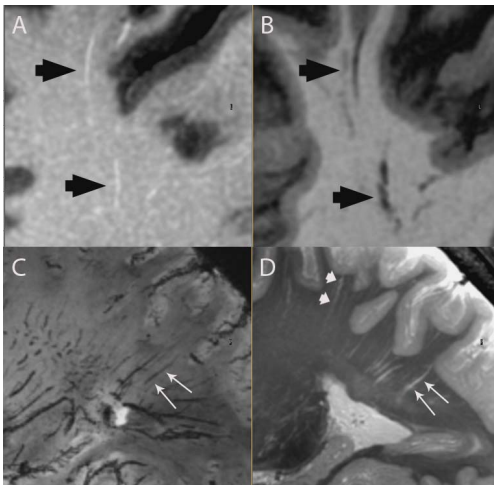

*Figure 2. A: T1 maxIP showing a perforating artery in the subcortical white matter. B: corresponding PVS. C: 4 mm minIP of T_2*w showing veins converging to ventricular wall. D: T_2 TSE maxIP showing PVS in the same area. Some veins could be correlated to PVS (arrows). Arrowheads point out a PVS not correlated to a vein.*

Conclusions: With a dedicated 7 Tesla imaging protocol PVS, perforating arteries and veins can be well visualized in vivo in young and healthy subjects. In the basal ganglia area we were able to correlate most PVS to a LSA.
In the lobar region perforating arteries were generally not visible, most probably due to their small size. However, PVS were frequently observed in this area, of which only some corresponded to veins.
The ability to map PVS and vessels in detail may help to further understand PVS and their relation to cerebrovascular disease.

References:

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