The value of Vessel-Encoded Pseudocontinuous Arterial Spin Labelling (VEPCASL) in Perfusion Assessment of Brain Arteriovenous Malformations: Comparison with Dynamic Susceptibility Contrast (DSC)-MRI

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Introduction. Peri-nidal hypoperfusion around an arteriovenous malformation (AVM), known as vascular steal (1, 2), has been a matter of debate. Different perfusion methods have been applied to the assessment of the vascular steal hypothesis with inconsistent results, which may be attributed to inaccuracies in methodological comparability and insufficient resolution. The aim of this study was to evaluate the efficacy of quantitative multi-inflow time Vessel-Encoded Pseudocontinuous Arterial Spin Labelling (VEPCASL) (3-5) in perfusion assessment of AVMs. VEPCASL perfusion data were compared with those obtained with standard Dynamic Susceptibility Contrast MRI (DSC- MRI).

Methods. Five patients (m:f = 3:2; mean age 51 years) with unruptured AVMs (four glomerular, patients 1-4; one proliferative, patient 5) were investigated with VEPCASL and DSC-MRI on a 3T TIM Verio scanner (Siemens). Two patients underwent a second examination after endovascular therapy (EVT). For VEPCASL absolute cerebral blood flow (CBF) and arrival time, and for DSC-MRI relative CBF (rCBF), cerebral blood volume (rCBV), mean transit time (rMTT) and time-to-peak (TTP) were calculated. Eight regions of interest (ROIs) were selected on a T1-weighted contrast enhanced (CE) sequence (software ITK SNAP): Two peri-nidal (pn), two vicinity (vic) (1-3 cm away from the AVM), two remote (rem) ROIs, two ROIs in the grey matter (GM) (putamen and thalamus), and corresponding reference ROIs in the contralateral hemisphere were selected and superimposed on each perfusion map. The inter-hemispheric ratios (ipsi- vs. contralateral) were used for statistical analysis, using Excel and MATLAB.

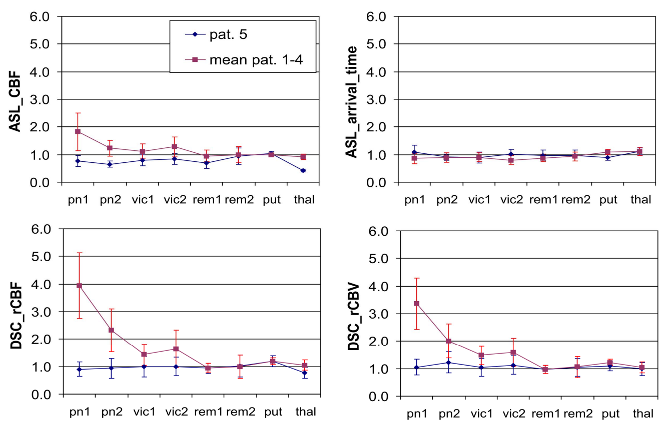

Fig. 1 Mean ratio values (Y-axis) over patients 1- 4 (glomerular AVMs) and of patient 5 (proliferative AVM) from the peri-nidal (pn) via the vicinity (vic) toward the remote (rem) tissue. The vertical red lines represent the standard deviation (SD) across patients 1-4, the vertical blue lines display the SD across the pixels of each ROI of patient 5. The GM structures (putamen (put) and thalamus (thal)) are added as a comparison.

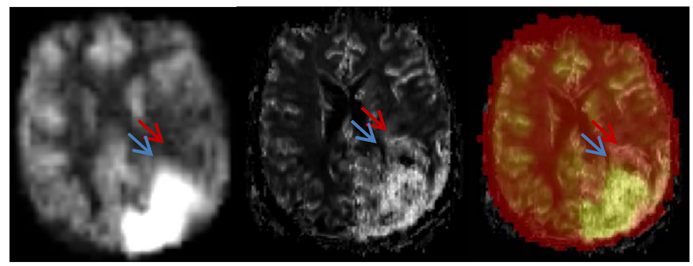

***Fig. 2** Blue arrows marking the margin of the AVM. The peri-nidal area (red arrow) in the DSC-rCBF map (middle) shows an overestimation of signal not seen in ASL-CBF (left), reflecting tissue distortion by fast shunted contrast agent within the AVM. Superimposed DSC-rCBF and ASL-CBF maps (right).*

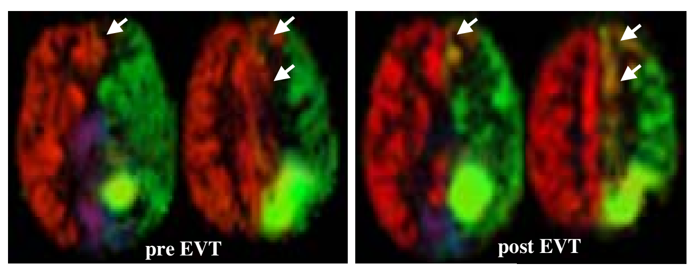

Fig. 3** VEPCASL CBF-maps for patient 1 pre and post 1st stage EVT. In contrast to pre EVT, the post EVT VEPCASL maps show a small amount of blood supply to the ipsilateral anterior cerebral artery territory (arrows) from the ipsilateral internal carotid artery (ICA). The amount of shunt volume within the AVM also appears to be lower post EVT. Encoded vessels: **right ICA (red), left ICA (green), right vertebral artery (VA, blue), left VA (purple).

Results. For the glomerular AVMs, ASL-CBF, DSC-rCBF and DSC-rCBV were highest in the perinidal areas with decreasing values with increasing distance from the AVM (Fig. 1). This tendency was not observed for the proliferative AVM (Pat. 5). Coefficients of variation (cv, without outliers) between patients 1-4 were lower for ASL-CBF (cv = 11.0%) than for DSC-rCBF (cv = 21.3%) and DSC-rCBV (cv = 17.8%). DSC-rCBF correlated strongly with DSC-rCBV. There was a moderate to high correlation between ASL-CBF and DSC-rCBF, and DSC-TTP and DSC-rMTT, respectively. ASL-CBF showed a negative correlation with ASL-arrival time, as expected. A moderate correlation was observed between ASL-CBF and DSC-rCBV (Table 1). Time resolved visualisation of the arrival of contrast agent in DSC-MRI data revealed significant distortion artefacts in the peri-nidal region attributed to artefactual displacement of the tissue in the phase-encode direction caused by the high magnetic susceptibility of the fast inflowing contrast agent within the AVM (Fig. 2). VEPCASL enabled assessment of territorial blood contribution from the different encoded vessels before and after EVT (Fig. 3).

Discussion. The high correlation between ASL-CBF and DSC-rCBF proves the validity of VEPCASL. The lack of need for contrast agent, lower variation of data, and absent sensitivity to magnetic susceptibility shift artefacts makes ASL superior to DSC-MRI for perfusion assessment of AVMs. The ability to label different vascular territories separately with VEPCASL enables the estimation of perfusion contribution from the respective supplying vessel, and may thus be of significant use in the determination of perfusion normalisation between treatment stages. The peri-nidal hyperperfusion in the high-shunting glomerular AVMs suggests a functioning autoregulation masking an underlying vascular steal, whereas the different perfusion pattern in the proliferative AVM indicates a similar haemodynamic process to that known from cerebral proliferative angiopathy.

	ASL-CBF	ASL-arrival time	DSC-TTP	DSC-rCBF	DSC-rCBV	DSC-rMTT
ASL-CBF	1.00	-0.57	-0.21	0.68	0.56	-0.31
ASL-arrival time		1.00	-0.06	-0.31	-0.23	-0.14
DSC-TTP			1.00	-0.27	-0.12	0.69
DSC-rCBF				1.00	0.91	-0.22
DSC-rCBV					1.00	-0.05
DSC-rMTT						1.00

***Table 1** Spearman's rank correlation between parameters, r = correlation coefficient (p < 0.05 green).*

Conclusion. Assessment of regional perfusion could be a useful adjunct for the risk assessment of impending or worsening neurological deficits as well as for treatment considerations in AVMs. As ASL is superior to DSC, ASL should be the preferred method for perfusion analysis in differrent subtypes of AVMs.

References. *(1) Symon, L. Int Anesthesiol Clin 7 (1969). (2) Taylor CL et al, Neurosurgery 50 (2002). (3) Wong EC et al. Mang Reson Med 58 (2007). (4) Chappell et al., Magn Reson Med 64 (2010). (5) Okell TW et al. ISMRM 2012: #3518.*