Pulsed arterial spin labeling perfusion MRI correlates with clinical severity in patients with vertebrobasilar artery stenoses

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Introduction: The prevalence of vertebral or basilar artery (VBA) stenosis is high in patients with stroke and/or transient ischaemic attack (TIA) in that territory. Symptomatic VBA stenosis is associated with a high risk of recurrent ischaemic cerebrovascular events [1] [2]. Vertebral angioplasty or stenting is therefore a potential treatment option, although the procedure is not without risk. Non-invasive characterisation of brain perfusion may help to guide medical decision-making, while avoiding the need for invasive arterial angiography, but research has been limited thus far [3]. Currently, clinical perfusion imaging is assessed by contrast-enhanced CT or MRI. Quantification of cerebral blood flow (CBF) is possible using non-invasive arterial spin labeling (ASL) [4]. Perfusion-weighted ASL images are, however, dependent on the arterial arrival time (AAT) [4], which is the time it takes labeled blood water to move from the labeling to the imaging region of interest [5]. Unfortunately, clinical scenarios, such as ischaemia [5] or atherosclerosis [6], are known to produce prolonged AAT that impacts CBF quantification. The purpose of our study was to determine the feasibility of a pulsed ASL implementation that included multiple inflow measurements and a 3D GRASE readout (3D-GRASE-PASL) in patients with recently symptomatic VBA stenosis. Since the occipital cortex is often supplied almost entirely by the VBA [7], we hypothesized that occipital lobe perfusion would be affected by VBA stenosis.

Methods: Twenty-eight subjects participated in this study, which was approved by the local ethics committee (patients: N=21, 7 women, mean age 66 ± 11 years; healthy controls: N=7, 3 women, mean age 54 ± 7 years). Patients were recruited from our outpatient TIA clinic. Three neurologists scored patients as being likely to have a severe, moderate or no VBA-related perfusion deficit on the basis of clinical history and contrast-enhanced MRA, which was performed separate to this study. Healthy controls had no known neurological history. 3D-GRASE-PASL, FLAIR, time-of-flight and DWI data were acquired on a 3 T Siemens MRI scanner. 3D-GRASE-PASL imaging volume was 220 mm x 220 mm x 110 mm (5/8 k-space; 64 x 64 x 24 matrix size; voxel dimensions: 3.4 x 3.4 x 5.0 mm^3), TR/TE = 3150 / 23 ms, 10 inflow times, TI=[400:200:2200ms], static background suppression, 2 k_z-interleaves, acquisition time: 9:00. A two-parameter (CBF and AAT), single compartment ASL model was used to fit the multi-TI data for every voxel using least squares fitting in Matlab. Absolute CBF quantification relied on 1) estimating M_0 of cerebrospinal fluid (CSF), 2) T_2-correction and 3) correcting for the RF coil receive sensitivity profile, the latter of which was characterised based on the control cohort. AAT values by contrast are in absolute of time (sec) directly from the fitting procedure. Mean CBF and AAT were calculated for two regions of interest (ROIs): 1) occipital and 2) parietal lobes, the latter of which served as a control ROI. Sensitivity was defined as the % of total voxels whose fit estimates were significant (P < 0.05) on the basis of the ASL kinetic fitting routine confidence intervals.

Results: One patient with severe VBA stenosis underwent a vertebral angioplasty and ASL data were collected pre and post-procedure. Fig. 1 shows that both CBF and AAT had improved 33 days post-angioplasty. Figs. 2 and 3 show AAT and CBF data, respectively, in the main patient groups. Across the patient groups, there were no regional differences in either CBF or AAT (i.e. occipital vs. parietal, P>0.2). However, patients who from clinical data were expected to have impaired perfusion in the VBA-supplied territory (N=4) had a significantly prolonged AAT in the occipital lobe, when compared with the patients expected to have normal perfusion (N=10) (unpaired t-test P < 0.01). CBF showed a trend towards hypoperfusion in the severe group (unpaired t-test P = 0.08). Measurement sensitivity in the occipital lobe was 70 ± 18% and 59 ± 22% in the patient group, compared with 85 ± 13 % and 76 ± 13% in the control cohort, for % of significant voxels detected in AAT and CBF estimates, respectively.

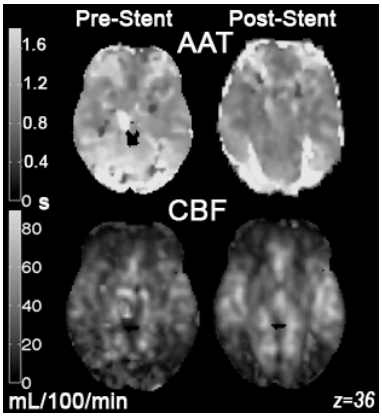

Fig. 1. Case study from one patient with severe VBA disease who underwent angioplasty (left: 11 days pre-stent, right: 33 days post-angioplasty)

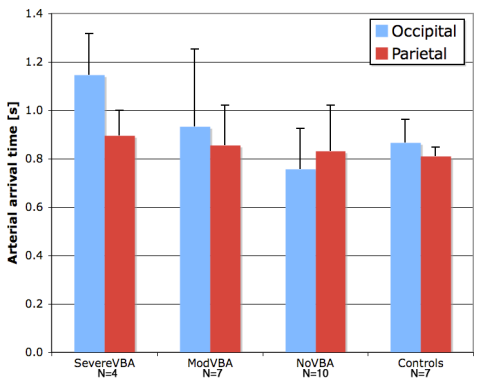

Fig. 2. AAT in occipital and parietal lobes graphed for each group. Occipital AAT was prolonged in patients with presumed severe VBA.

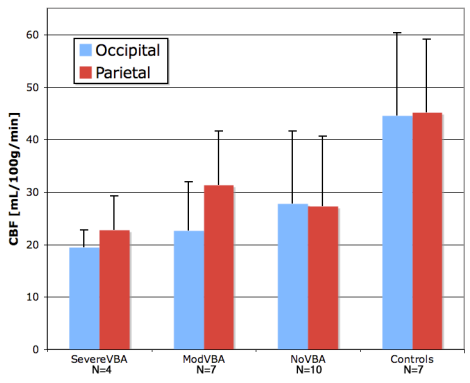

Fig. 3. CBF in occipital and parietal lobes graphed for each group. Patients with presumed severe VBA had the lowest perfusion.

Discussion: Atherosclerotic disease contributes to chronic hypoperfusion in the brain [8] and/or compensatory redistribution of the vascular territories [9]. The results of this study support our hypothesis that perfusion of the occipital lobe is impaired in patients with VBA-disease: AAT increased and CBF decreased in the occipital lobe in keeping with the severity of VBA disease. Using our 3D-GRASE-PASL method, our preliminary results suggest that AAT is more sensitive than CBF at detecting VBA subgroup differences. AAT and CBF sensitivity estimates in the occipital lobe did not depend on patient group, but not surprisingly produced fewer % of voxels when compared with the healthy control cohort (P<0.04). CBF values tended to be low compared to literature values and may be due to partial volume issues associated with the 3D GRASE readout. Perfusion is also age-dependent and the current control cohort was younger than patient cohorts (P<0.01), precluding our ability to separate ageing from VBA disease related perfusion effects.

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