MEASUREMENT OF HEMODYNAMIC PARAMETERS IN CAROTID OCCLUSIVE DISEASE USING PARTIAL VOLUME CORRECTED PCASL fMRI

Iris Asllani[1], Shazia Dharssi[1], Marykay Pavol[1], Ronald L Lazar[1], and Randolph S Marshall[1]
[1]*Columbia University, New York, NY, United States*

INTRODUCTION: One of the main advantages of arterial spin labeling (ASL) fMRI *vs.* BOLD is that ASL yields an absolute measurement of CBF – a key physiological parameter of brain function and metabolism. Therefore, ASL can be used to simultaneously measure both baseline and activation changes in CBF under various conditions. This is especially important in clinical applications where separating the changes in baseline from changes in activation patterns could prove crucial in understanding how the disease affects the brain. In this study, we used pseudo-continuous ASL (PCASL)[1] to measure changes in baseline CBF (ΔCBF_B) and changes in CBF due to motor activation (ΔCBF_A) in patients with carotid occlusive disease. These changes in CBF are being regressed against cognitive measures acquired on the same patients. The overall goal of the study is to determine the hemodynamic factors that correlate with the severity of the symptoms in this patient population.

METHODS: This is an ongoing study with a recruitment target of 63 patients with ≥80% stenosis. To-date, we have imaged 6 patients (age = 76 ± 5 y, 4 females). For each patient, ΔCBF_A is defined as the change in CBF per hemisphere using a bilateral finger-tapping paradigm[2]. The reported CBF values correspond to the BA4 motor-ROI obtained from pickatlas and conjoined with each patient's gray matter (GM) mask[2]. The motor activation paradigm consists of 4 ON-OFF blocks, 4 minutes each as previously described[2]. Briefly, each ON-OFF block consists of 30 ASL time-points (15 per condition) and is repeated 8 times (i.e., 120 ASL time-points per condition). Average baseline CBF is computed from the ASL images obtained during the OFF blocks.

Image Acquisition*:* The following images are acquired on a Philips 3T scanner: (1) Structural MPRAGE, used to obtain tissue information[2]; (2) PCASL as per Osch et al.[3], using labeling duration of 1.9s and post-labeling delay (PLD) = 1s; (3) FLAIR used to measure white matter hyper-intensities (4) T2*-weighted image for measuring the presence of microbleeds. Furthermore, we obtained arterial transit time (ATT maps) on 7 subjects prior to the start of the study. This map is used for computation of CBF on all patients as detailed in Borogovac et al.[2].

Image Analysis: ASL images were analyzed using a method described in detail in Asllani et al.[4]. We use partial volume correction (PVEc) analysis of ASL data[4] to account for hemispheric changes in brain atrophy. Each patient's MPRAGE is used to obtain voxelwise tissue information as posterior probability maps[4].

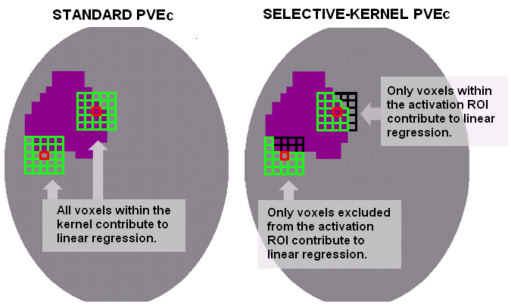

Fig.1: PVEc kernel modification for activation

Data Analysis: For each patient, the unaffected hemisphere is used as the control. A paired t-test is run on both (ΔCBF_A) and (ΔCBF_B) to investigate the effect of occlusion on the BA4 motor-ROI. To account for the smoothing effect of the PVEc method[4,5], we have modified the activation kernel based to the shape of the BA4 motor ROI as schematically shown in Fig.1.

RESULTS: Baseline CBF images from a randomly selected patient are shown in Fig.1. NOTE that the PVEc ASL method yields flow density images (panels 1-3, left to right), which represent the amount of flow per unit GM tissue, and therefore do not contain structure information[2,4] (i.e., GM/WM contrast). We use these images to account for brain atrophy, which can be substantial in this population. All patients showed hemispheric asymmetry in baseline CBF.

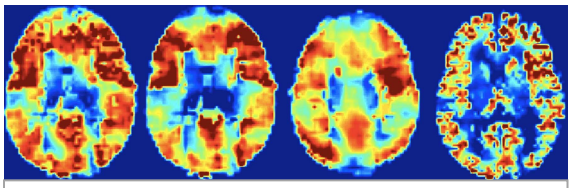

Fig.2: Panels 1-3, left to right, show baseline GM flow density images from a patient with 100% right carotid occlusion. NOTE that these images do not contain structure information as they represent the amount of flow a voxel would have if it contained 100% GM (c.f. Asllani et al.[3]). These images are used to account for atrophy in this patient population. The right most panel shows the net CBF image which shows good WM vs GM contrast. In all cases, note Right/Left asymmetry in

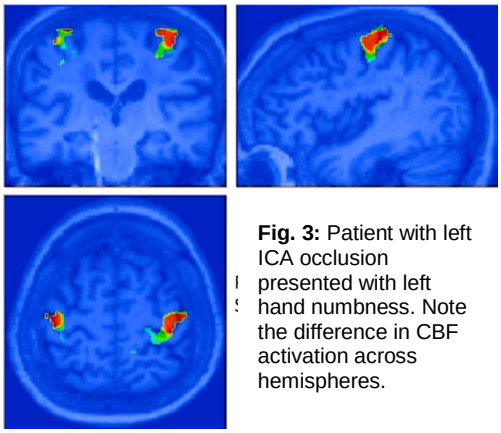

Fig. 3: Patient with left ICA occlusion presented with left hand numbness. Note the difference in CBF activation across hemispheres.

The hemispheric asymmetry defined as the difference in avg. CBF between the two hemispheres was 16 ± 4 (t=2.6, p<0.005). We report % change data rather than absolute values to account for variability in baseline CBF across patients. Interestingly, the ΔCBF_B did not correlate with ΔCBF_A, i.e., not all patients showed asymmetry in ΔCBF_A. For example, for one of the patients, while the difference in ΔCBF_B between the two hemispheres was significantly different (avg ΔCBF_B 18 mL/100g*min, p>0.005), the change in CBF due to activation was statistically the same [$(\Delta CBF_A)_{Right} - (\Delta CBF_A)_{Left} \sim 7$ mL/100g*min, p>0.005].

DISCUSSION: Use of an fMRI platform to investigate cerebral hemodynamics is justified by the wide availability of MRI at stroke centers throughout the country. Should our methods prove to be useful as a clinically relevant diagnostic tool, there would be much wider application than what currently available. Importantly, the results shown here provide further evidence for the inadequacy of BOLD fMRI for studying activation in neurovascular disease[6].

REFERENCES: [1] Dai W. et al., MRM 60(6), (2008); [2] Borogovac A. et al., JCBFM 30 (2010); [3] Gevers S. et al., JCBFM 31(8), (2011); [4]Asllani I. et al., MRM 60(6), (2008), [5]Chappel M.A. et al., MRM 65 (2011); Blicher J.U. et al., JCBFM 32(11), (2011).