Independent Determinants of Cerebral Blood Flow from Multiple Post Label Delay Arterial Spin-Labeling and Phase Contrast Angiography Help Differentiate the Influence of Small and Large Arteries

Andrew D. Robertson[1] and Bradley J. MacIntosh[1,2]

[1]Heart & Stroke Foundation Canadian Partnership for Stroke Recovery, Sunnybrook Research Institute, University of Toronto, Toronto, ON, Canada, [2]Department of Medical Biophysics, University of Toronto, Toronto, ON, Canada

Target Audience: Those interested in cerebral hemodynamics.

Purpose: Cerebral blood flow (CBF) is dependent on the heart and large arteries to direct blood towards the brain (i.e., proximal characteristics) and the efficiency of arterioles and microcirculation to distribute blood within tissue (i.e., distal characteristics). Differentiation between proximal and distal characteristics may help elucidate mechanisms associated with CBF changes over time or in the context of vascular disease. This exploratory analysis sought to examine the relationship between CBF and hemodynamic characteristics related to both large artery [arterial cross-sectional area (CSA) and mean blood flow velocity (MFV)] and large-to-small artery phenomena [arterial transit time (ATT)]. A clinical cohort of chronic stroke survivors was considered for this study.

Methods: MRI was performed on 13 individuals with prior stroke (age: 66 ± 12 years, 3 women, time post stroke: 19 ± 16 months). Images were acquired on a 3-Tesla MRI system (Philips Achieva). Structural imaging included a T1-weighted acquisition (voxels=0.9x0.7x1.2 mm^3, flip angle=8°, and TR/TE=9.5/2.3 ms). Vascular imaging included phase contrast angiography (PCA) to measure large artery CSA and MFV, pseudo-continuous arterial spin labeling (PCASL) with a 1600 ms post-label delay (PLD) to estimate CBF, and a lower space resolution multiple-PLD PCASL sequence to estimate ATT[1] (Fig.1). PCA captured a single slice 5 cm distal to the carotid bifurcation with cardiac synchronization (voxel dimensions=0.5x0.5x5.0 mm^3, TR/TE= 20/9.1 ms, flip angle=15°, maximum velocity=100 cm/s). PCASL acquired 30 control and 30 tag images (voxel dimensions=3x3x5 mm^3, flip angle=90°, TR/TE=4000/9.6 ms). Multi-PLD PCASL made acquisitions at PLDs of 400, 800, 1200 and 2000 ms (voxel dimensions=4x6x6 mm^3, flip angle=90°, TR/TE=4000/5.8 ms). CSA of the bilateral internal carotid and vertebral arteries were obtained by semi-automated segmentation of the PCA magnitude image. MFV were calculated by averaging the phase-velocity image within each arterial mask. Post-processing of PCASL data included motion correction, control-tag differencing, and 5-mm spatial smoothing. CBF quantification incorporated a proton density estimate and consensus parameter constants.[2] ATT estimates were generated using a curve fitting protocol in MatLab.[3] Internal carotid and vertebral artery territories were based on previously reported topography.[4] Regions of interest for analysis were restricted to a 16-mm slab near the coronal midpoint of the PCASL acquisition (Fig. 2). All images were co-registered to the participant's CBF image for analysis. One-way repeated measures ANOVA were used to compare vascular characteristics between the four arterial territories. Relationships between characteristics were examined using Pearson product-moment correlations, and subsequent stepwise multiple linear regression.

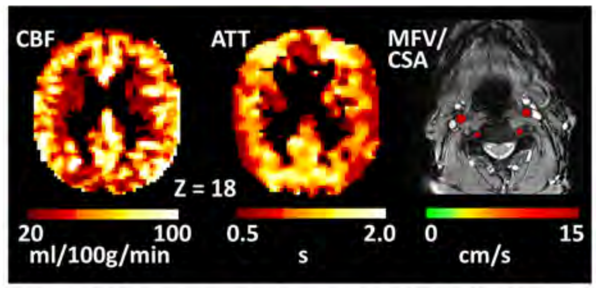

Figure 1. Representative images of CBF (left), ATT (middle) and MFV/CSA (right)

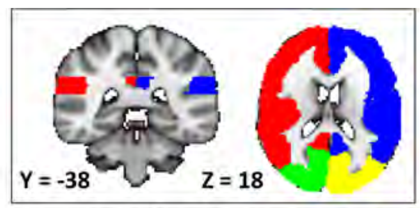

Figure 2. Region of arterial territories used for hemodynamic comparison

Results: CSA and MFV were greater in the internal carotid than the vertebral arteries ($p<0.001$). A similar trend was noted in CBF ($p=0.009$), though pairwise comparisons were not significant after adjustment. In contrast, ATT was greater in vertebral than carotid territories ($p<0.001$). When all territories were considered in a single analysis, CBF correlated inversely with ATT (r_{52}=-0.50, $p<0.001$), but not with either CSA or MFV. Post hoc, anterior and posterior territories were examined separately. Similar relationships between the vascular characteristics and CBF were observed in both the internal carotid (Fig. 3) and vertebral vascular beds, though associations were weaker in the posterior circulation. In multivariate modeling, nearly half of the variance within anterior CBF (adj r^2=0.43) was described by two independent predictors: ATT (t=-4.6, $p<0.001$) and CSA (t=2.2, p=0.041). Posterior CBF was only predicted by ATT (t=-2.2, p = 0.036, adj r^2=0.14).

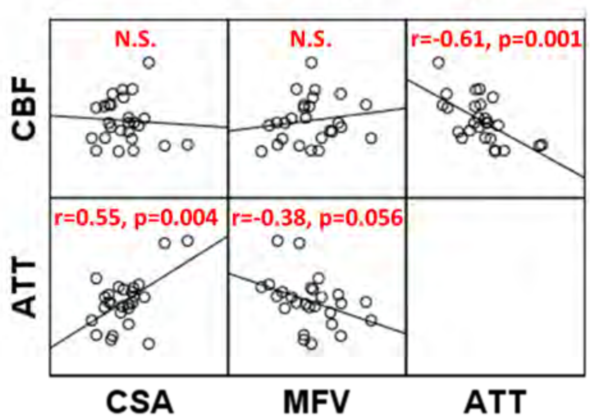

Figure 3. Scatterplots for CBF and ATT in the anterior circulation, as well as CSA and MFV from the bilateral internal carotid arteries (n=26)

Discussion and Conclusion: This work helps to characterize the differential impact of macrovascular and microvascular hemodynamic alterations that are associated with CBF. CSA and ATT were independent predictors of anterior CBF in this cohort that consisted of 10 strokes in the anterior circulation and 3 in the posterior circulation. A large CSA reflects greater arterial conductance,[5] whereas and a shorter ATT is thought to reflect less reliance on collateral flow.[3] The operational differences between these two variables make them suitable for characterizing mechanisms related to changes in CBF during prospective monitoring. Future work will examine this relationship within other cohorts, including those specific to large and small vessel disease processes.

References:

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