Quantification of Cerebellar Blood Flow using Arterial Spin Labeling

A. J. Huang1,2, J. Hua1, J. Farrell1, Q. Qin1, J. J. Pekar1, M. van Osch3, J. E. Desmond2, and P. van Zijl1

1FM Kirby Research Center, Johns Hopkins University, Baltimore, MD, United States, 2Department of Biomedical Engineering, Johns Hopkins University, Baltimore, MD, United States, 3Department of Radiology, Leiden University Medical Center, Leiden, Netherlands, 4Department of Neurology, Johns Hopkins University, Baltimore, MD, United States, 5FM Kirby Research Center, Johns Hopkins University, Baltimore

Introduction: The cerebellum is responsible for a variety of functions, most notably the coordination of motor function and sensory perception (1), and influencing cognition (2). Perfusion is an important pathophysiological parameter that can be measured noninvasively using arterial spin labeling (ASL) (3). The cerebellum is perfused by three main arteries that branch off of the vertebral artery: the posterior inferior cerebellar artery (PICA), the anterior inferior cerebellar artery (AICA), and the superior cerebellar artery (SCA) (4). Lower blood flow in the medial SCA and mediod PICA has been implicated in ataxia of gait and stance, a condition where patients lose motor control (5). ASL has been widely used to quantify perfusion in the cerebrum (3, 6). Here we demonstrate the feasibility of using pseudocontinuous ASL to quantify perfusion in the cerebellar gray matter. Based on perfusion weighted images measured over multiple post-labeling delays, an optimal range of inversion times is suggested for quantification of cerebellar blood flow in human brain.

Subjects and Methods: Three healthy individuals were scanned on a Philips 3T Achieva Scanner with body-coil excitation and a 32-channel SENSE receive coil. The balanced pseudocontinuous labeling scheme was used (7). ASL images were acquired using a single-shot gradient-echo EPI (SENSE = 2.5, TR/TE = 2500/14 ms). Seven slices were acquired to cover the entire cerebellum. The slices were centered axially in the middle of the cerebellum, and labeling occurred 84 mm below the center of the cerebellum. A labeling duration of 600 ms was chosen because of the unique position of the cerebellum close to the labeling location. Other scan parameters include FOV = 240x240 mm², voxel size = 3x3x7 mm³, 35 pairs of controls/labels, RF interval 1 ms, RF duration 0.5 ms, and flip angle 18°. Labeling efficiency was estimated to be 0.85 based on simulations by Wu et al (8). In order to assess the effects of remaining arterial label, perfusion images were acquired over multiple TIs (in 100 ms intervals from 200-1500 ms after labeling; the order was pseudorandomized). For blood flow quantification, an Mn scan was acquired across the ventricles at the same resolution (3x3x7 mm³). Mn was quantified according to the procedure outlined by van Osch et al (9). Blood flow was calculated using the one-compartment model in Donahue et al modified for the PCASL (10). Values of 1,165 ms and 1,627 ms (11) were used for tissue and blood T1, respectively, and a value of 0.9 mL blood/g tissue was used for the blood-brain partition coefficient for water (λ). A 1 mm isotropic MPRAGE scan was acquired for comparison purposes. In all images, extra-cerebellar matter was manually removed for image clarity. Images were motion-corrected and co-registered using standard FSL routines.

Results and Discussion: Figure 1a shows a perfusion model overlaid on the acquired ΔM/M data. This model can fit CBF, as well as bolus transit time parameters, by acquiring over multiple inversion times (TI). The results show that an inversion time of 1000 ms after labeling is sufficient for labeled spins to exchange with the tissue. Average blood flow in the cerebellar gray matter was fitted 63.6±5.0 mL/100g parenchyma/min over the post-labeling delays of 200-1500 ms, which is in agreement with published PET flow values of 62.0±12.4 mL/100 g/min (12). Figures 1b and 1c show a representative blood flow image compared slice-by-slice to an MPRAGE image, averaged to a 7 mm slice for comparison with the ASL image. The top row contains arterial spin labeling images from the inferior cerebellum to the superior cerebellum in the same location as the averaged MPRAGE scan shown in the bottom row. One of the issues with quantification of blood flow using arterial spin labeling models is the quantification of the equilibrium magnetization of blood, M₀blood. Traditionally in the cortex, M₀CSF can be quantified using a voxel of pure CSF in the lateral ventricles and related to M₀blood via water densities (a factor of 0.87). However because of coil homogeneity issues, the ventricles are too far away from the cerebellum to obtain an accurate M₀CSF. Therefore, we propose to use the superior cerebellar cistern (just above the cerebellum) or the cisterna magna (just below the cerebellum) to obtain a pure CSF voxel in the future.

Conclusion: We show the feasibility of using pseudocontinuous ASL to study perfusion in the cerebellum. We report post-labeling delay of 1000 ms to obtain flow values for the cerebellum. The average CBF over three subjects was fitted to be 63.6±5.0 mL/100 g parenchyma/min using a multiple inversion time method. The transit time of the labeling edge of the bolus was fitted to 275.7±23.2 ms, and the transit time of the trailing edge of the bolus was fitted to be 1,786.7±160.7 ms. This could potentially be useful to study cerebellar pathologies.


Funding: NIH-NCRR P41-RR15241, R01MH060234, R01AA018694