Quantification of Cerebellar Blood Flow using Arterial Spin Labeling

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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 medial 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.

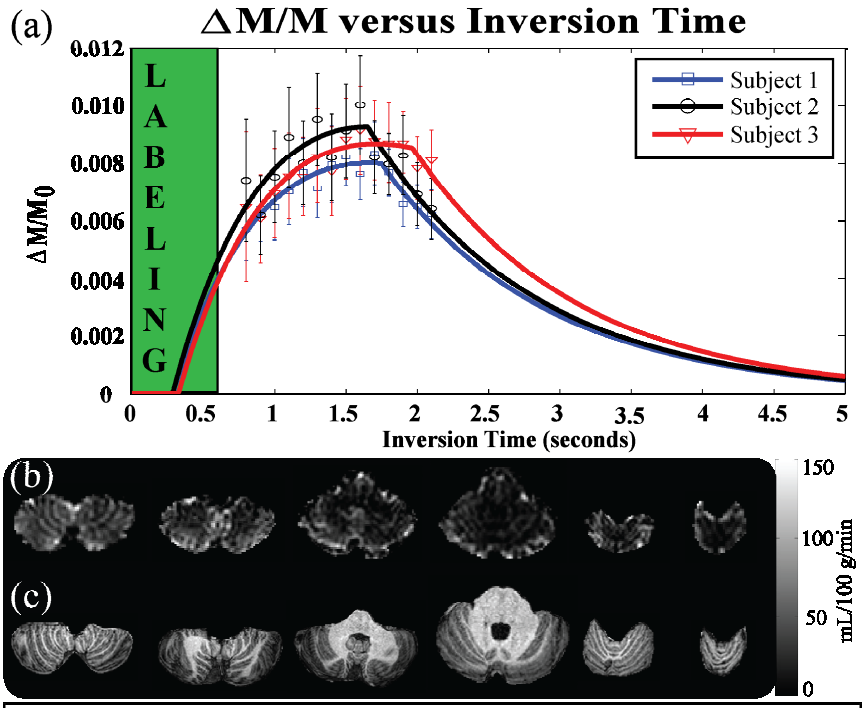

Figure 1. (a) A perfusion model was overlaid on acquired ΔM/M0 data. Mean CBF was fitted out to be 63.6±5.0 mL/100 g parenchyma/min. Leading and trailing edges of bolus were fitted to be 275.7±23.2 ms and 1786.7±160.7 ms, respectively. Error bars represent the standard deviation over each subject.
(b) Arterial spin labeling (left => right: inferior cerebellum to superior cerebellum)
(c) MPRAGE images acquired at the same slice location as ASL images

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 = 240x240mm^2, voxel size =3x3x7 mm^3, 35 pairs of controls/labels, RF interval 1ms, RF duration 0.5 ms, and flip angle 18º. 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 pseudo-randomized). For blood flow quantification, an M_0 scan was acquired across the ventricles at the same resolution (3x3x7 mm^3). M_0 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 $\Delta M/M_0$ data. This model can fit out 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, $M_{0,blood}$. Traditionally in the cortex, $M_{0,CSF}$ can be quantified using a voxel of pure CSF in the lateral ventricles and related to $M_{0,blood}$ 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 $M_{0,CSF}$. 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 leading edge of the bolus was fitted to be 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.

References: (1) Bellebaum et al. Cerebellum. 2007;6(3):184-92. (2) Marvel CL et al. Neuropsychol Rev. 2010;20(3):271-9. (3) Williams et al. PNAS. 1992;89(1):212-6. (4) Tatu et al. Neurology. 1996;47(5):1125-35. (5) Timmann et al. Neuroscience. 2009;162(3):836-51. (6) Oguz et al. Radiology. 2003;227(2):567-74. (7) Wong EC. MRM. 2007;58(6):1086-91. (8) Wu et al. MRM. 2007;58(5):1020-7. (8) van Osch et al. MRM. 2009;62(1):165-73. (10) Donahue et al. NMR Biomed. 2006;19(8):1043-54. (11) Lu et al. MRM. 2004;52(3):679-82. (12) Ito et al. JCBFM. 2003;23(6):665-70.

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