Turbo-flash based Arterial Spin Labeling at 7T

Z. Zuo[1,2], R. Wang[1,2], D. Liu[1,2], R. Xue[1], Y. Zhuo[1], and D. J. Wang[3]
[1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China, People's Republic of, [2]Graduate University, Chinese Academy of Sciences, Beijing, China, People's Republic of, [3]Neurology, UCLA, Los Angeles, CA, United States

Introduction: Arterial spin labeling (ASL) at 7T is attractive due to prolonged blood T1 as well as increased SNR at ultrahigh field (1). However, shortened T2/T2* and B1/B0 field inhomogeneities are the main obstacles to realizing the potential advantages of 7T ASL. Turbo-flash is a promising approach for 7T imaging due to its relatively low specific absorption ratio (SAR) and short TE that minimizes susceptibility artifacts. The goal of this work is to implement and optimize turbo-flash based pulsed and pseudo-continuous ASL at 7T to explore and maximize the SNR gain of 7T ASL.

Methods: Five healthy subjects were scanned on a 7.0 T Siemens Magnetom system with a Nova medical volume transmit and 24-ch receiver coil. A turbo-flash based pulsed ASL (PASL-TFL), using QUIPSS II FAIR, and a turbo-flash based balanced pseudo-continuous ASL (PCASL-TFL) sequence were developed (2). Three experiments were carried out at both 7T and 3T: **Exp 1)** PCASL-TFL was applied to acquire resting perfusion images with 3 spatial resolutions (1.7 X 3.4, 1.7 X 1.7 and 0.85 X 1.7mm^2), respectively. **Exp 2)** PASL-TFL was scanned at post-labeling delays of 1 to 3s with a step of 0.5s (resolution = 3.4 X 1.7mm^2, 30 tag/control pairs for each delay) to measure the dynamic curve of labeled signal. **Exp 3)** PASL-TFL was applied for functional MRI using an alternating finger tapping paradigm (4 cycles of 36s left hand and 36s right hand), with 3 spatial resolutions (1.7 X 3.4, 1.7 X 1.7 and 0.85 X 1.7mm^2) respectively. The fMRI data were analyzed using SPM and FSL, with Z-score images threshold at P < 0.05. The above 3 experiments were repeated on 4 of the 5 subjects on a 3T Siemens Tim Trio system with the product 12-ch receiver coil. At 3T, the 3 spatial resolutions tested were 3.4 X 3.4, 1.7 X 3.4 and 1.7 X 1.7mm^2. The common imaging parameters were: flip angle = 7^0, TR = 3/5s for PASL/pCASL, TE = 1.96ms, post-labeling delay = 1s, label duration = 700ms for pCASL, a single axial slice of 5mm through the motor cortex. The selective inversion band was 4cm in PASL and the label offset was 4.5cm in pCASL.

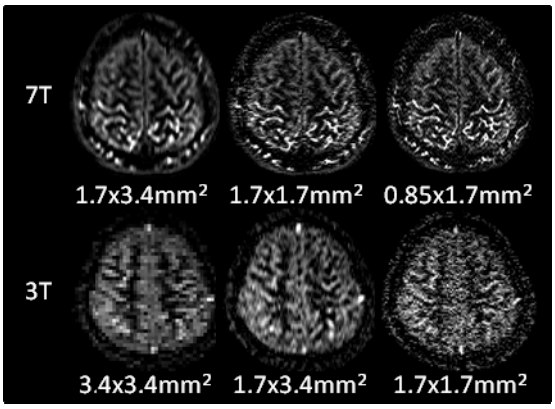

Fig. 1 PCASL perfusion images at 7T(top) and 3T(bottom) with 3 different resolutions

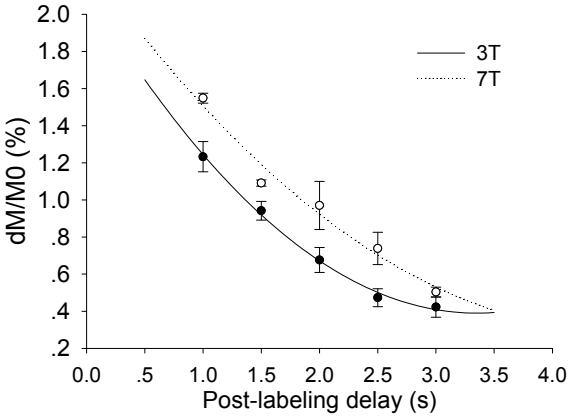

Fig. 2 Dynamic time courses of fractional PASL signal (dM/M0) as a function of post-labeling delay time

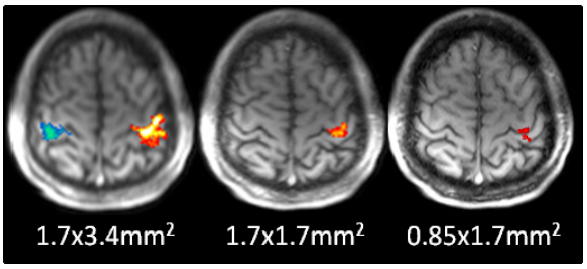

Fig. 3 PASL fMRI map overlaid on raw TFL images with 3 different resolutions at 7T

Results: Fig. 1 shows a direct comparison of PCASL-TFL perfusion images with 3 spatial resolutions acquired at 7 and 3T. At 7T, the perfusion image quality does not degrade with higher resolution while 3T images appear noisy at the high resolution of 1.7 X 1.7mm^2. The measured mean SNR were 8.40 at 7T compared to 4.02 at 3T for the identical resolution of 1.7 X 3.4mm^2 (i.e. 2.1 fold SNR gain). The mean CBF values were 54.9±2.3 ml/100g/min at 7T. Fig. 2 shows the mean dynamic curve of fractional PASL signals (dM/M0) at 7T and 3T. The experimental data match extremely well with theoretical model, assuming blood T1 of 2.10 and 1.65s at 7 and 3T respectively. Fig. 3 shows the fMRI results of motor cortex activation with 3 spatial resolutions at 7T. The mean perfusion signal changes were 54.5±4.6, 48.4±5.8 and 45.8±6.2% with the resolution of 1.7 X 3.4, 1.7 X 1.7 and 0.85 X1.7 mm^2 respectively. The high resolution fMRI map precisely located primary motor cortex in the precentral gyrus.

Discussion: Turbo-flash based ASL is a promising approach to maximize the SNR gain of 7T ASL, while minimizing field inhomogeneity effects and improving the spatial and temporal resolution of ultrahigh field ASL. More than 2 fold SNR gain is readily achievable at 7T compared to 3T, which opens the door to ultrahigh field fMRI with high spatiotemporal resolution as well as novel approaches to investigate the biophysical mechanism of hemodynamic responses.

References: [1] Wang J et al., MRM, 48, 242-254, 2002. [2] Wu WC et al., MRM, 58, 1020-1027, 2007.

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