Pseudo-continuous Arterial Spin Labeling at 7T

W-M. Luh[1], T-Q. Li[2], E. C. Wong[3], and P. A. Bandettini[1]

[1]Functional MRI Facility, NIMH, National Institutes of Health, Bethesda, MD, United States, [2]Laboratory of Functional and Molecular Imaging, NINDS, National Institutes of Health, Bethesda, MD, United States, [3]Departments of Radiology and Psychiatry, University of California, San Diego, La Jolla, CA, United States

Introduction

Arterial spin labeling (ASL) techniques benefit from the increase in T1 values at high field strength (1). However, the SNR improvement at high field strength can only be realized with an optimal tag duration which also increases with field strength. At 7T, based on ASL signal models, the optimal tag duration for whole brain coverage can reach 3 and 1.3 sec for continuous and pulsed ASL, respectively. The optimal tag duration will further increase for higher spatial resolution because of an increase in transit time. Due to SAR limitations, only head-size volume excitation RF coils are currently used on the 7T system at our center. It is difficult to perform pulsed ASL to obtain a large tag width or to perform continuous ASL without special hardware. Pseudo-continuous ASL (PCASL) (2, 3) can potentially resolve both problems at 7T by allowing a long tag duration without special hardware. However, both B1 and B0 inhomogeneity with the volume excitation coil toward the tagging location presents challenges for PCASL since the tagging location is often at the edge of the excitation coil exhibiting B1 drop off and B0 inhomogeneity is typically larger away from the isocenter. PCASL relies on proper B1 amplitude to match flowing spins with a certain velocity range and requires precise phase shift created by the mean gradient within RF intervals. In the present study, we implemented PCASL at 7T and demonstrated these effects and a simple way to mitigate them.

Methods

Due to sensitivity to off-resonance of PCASL pulses, the midpoint between the slices and tagging location was positioned at the isocenter and a high-order shimming routine was performed with shimming volume enclosing both the imaging slices and tagging location. Imaging slices were acquired off isocenter by shifting the frequencies of the slice excitation RF pulses. A total of 13 contiguous axial slices of 5 mm were acquired using gradient-echo EPI with TE=20 ms and 64x48 matrix size. The labeling tag duration of 2500 ms was used with 1400 ms post-labeling delay. PCASL labeling train consists of repetitive Hanning-shaped RF pulses of 800 μs long and 0.05 G amplitude with intervals of 1708 ms during a maximum/mean gradient strength of 0.8/0.06 G/cm. Labeling B1 amplitudes of {0.05, 0.55, 0.6, 0.65, 0.7} G were used for each 4 min scan. B0 and B1 maps were generated from dual echoes and triple flip angles gradient-echo images of coronal slices. Experiments were conducted on a whole-body 7T GE MRI scanner with a birdcage transmit coil and a multi-channel receiver coil on 6 healthy subjects under approved protocols. The average SAR reported by the integrated RF power monitors in the scanner was 1.2-1.8 W/kg.

Results

From the calculated B0 and B1 maps, at 60 mm off isocenter toward the neck, off resonance was about 100 Hz relative to the isocenter and B1 was about 85% relative to the center of the images. **Fig. 1** shows the PCASL ΔM_0 ((control-tag)/control) perfusion images with tagging location at 38 mm (top row) and 60 mm (middle row) off isocenter, and the corresponding T1 maps (bottom row). The center of imaging slices was 26 mm off isocenter opposite to the tagging location. **Fig. 2** shows the changes in ΔM_0 with various B1 amplitudes. With 10% increase in B1 (=0.06G), perfusion signal increases about 25% but decreases for higher B1 amplitudes.

Discussion and Conclusion

PCASL tagging pulses are sensitive to off resonance effects as shown in Fig. 1 which is consistent with Bloch equation simulations. However, if the amount of off resonance is known at the tagging location, the deviation in phase accumulation can be compensated through adjusting the phase shift applied to the tagging pulses. However, if multiple feeding arteries are present at different in-plane locations, this approach may be problematic when off resonance varies significantly among these locations. Higher tagging B1 amplitude can be used to compensate for B1 drop off, providing the resulting SAR is within guidelines and not higher than required values. However, if off resonance dominates, increase in B1 does not result in improved tagging efficiency (data not shown). In summary, PCASL is sensitive to both B0 and B1 inhomogeneity at 7T but can be compensated for if the amount of inhomogeneity is known and can be minimized with careful placement of slice and tagging locations. Using this approach, the full benefits of increased blood T1 and higher SNR of 7T may be obtained.

References

1. Wang et al., *MRM* 48: 242 (2002).
2. Garcia et al., *ISMRM*: 37 (2005).
3. Wong, *ISMRM*: 668 (2006).

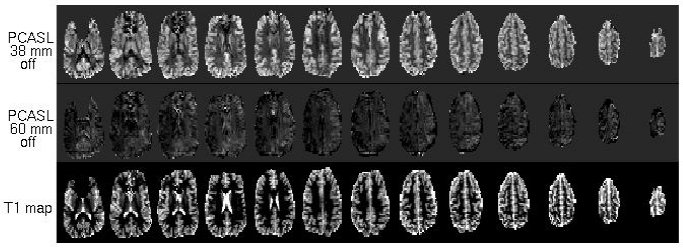

Fig. 1. Normalized PCASL ΔM_0 images with 38 (top) and 60 mm (middle) off isocenter at tagging location and T1 maps (bottom).

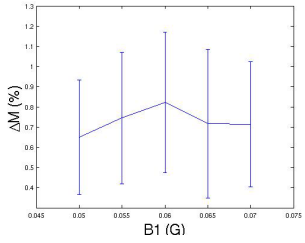

Fig. 2. Averaged PCASL ΔM_0 signal within gray matter ROIs vs. PCASL RF B1 amplitudes.