Effect of background suppression and physiological noise removal on the sensitivity of arterial spin labeling fMRI

Y. Behzadi[1], K. Restom[2], J. Perthen[2], T. T. Liu[2]

[1]Bioengineering, UCSD, San Diego, CA, United States, [2]cFMRI, UCSD, San Diego, CA, United States

Introduction

Quantitative perfusion-based functional magnetic resonance imaging (fMRI) with arterial spin labeling (ASL) has the potential to provide a more accurate reflection of neural activity than the more commonly used blood oxygenation level dependent (BOLD) signal [1,2]. However, ASL techniques tend to be less sensitive due to inherently low signal-to-noise (SNR) and have been of limited use in cognitive fMRI studies, in which activations tend to be less robust and more variable than primary sensory studies. Recently, application of a modified retrospective image based (mRETROICOR) technique for the reduction of physiological noise has been shown to increase sensitivity in primary sensory areas [3]. Also of potential utility is the application of background suppression (BGS) methods that have been shown to reduce the variance of baseline ASL measures [4,5]. This study examines the effect of BGS and mRETROICOR in increasing the sensitivity of perfusion fMRI both in the visual cortex and the hippocampus.

Methods

Experimental Protocol: A visual stimulation study was performed with the use of a black and white radial checkerboard flashing at 8 Hz presented in a block design paradigm consisting of 4 cycles of 20s stimulation with 40s rest. Three subjects underwent 4 repeats of the block design with two runs acquired with and without the application of BGS. A hippocampal study was also performed in three subjects and consisted of subjects viewing alternating 25 second blocks of familiar and novel landscape scenes [6]. The paradigm was repeated 5 times (two runs with BGS pulses and three runs without BGS).

Image acquisition: Scanning was performed on a 3T GE Signa whole body system, with a body transmit coil and an 8 channel receive only head coil. A PICORE QUIPSS II (PQ2) [7] sequence was used with a dual gradient echo spiral readout. Imaging parameters for the visual experiment were: TR=2s, TI1=600ms, TI2=1500ms, $\theta = 90°$, FOV = 24×24 cm2, matrix size 64×64, TE1=9.1ms, TE2=30ms, with three 7mm slices positioned through the primary visual cortex at an oblique angle parallel to the calcarine sulcus. The tagging band was 100 mm thick, positioned 10mm from the proximal edge of the first slice. A small diffusion pulse (b-factor=2) was also used. Hippocampal imaging parameters were TR=3s, TI1=700ms, TI2=1400ms, TE1=2.8ms, TE2=24ms, and a 200 mm tag. Three 6 mm slices were positioned parallel to the hippocampus. Spatially selective BGS inversion pulses were optimized to null gray and white matter for the given TI2 and were applied at 233/833ms and 300/1000ms, for the hippocampal and the visual stimulation studies, respectively. Cardiac pulse and respiratory effort data were sampled at 40 Hz.

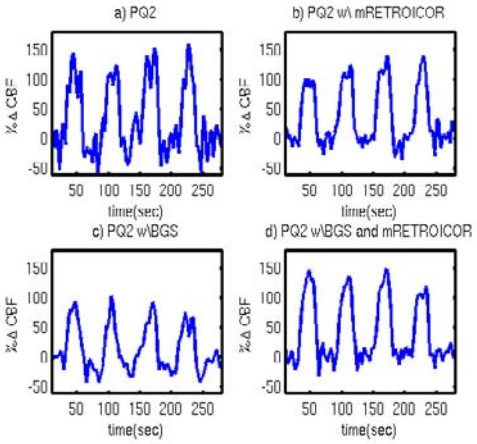
Image processing: Images from each subject were co-registered for motion correction. Perfusion (CBF) time series were formed from the running subtraction of the ASL data derived from the first echo. Cardiac and respiratory confounds were removed from the data using the methods (mRETROICOR) described in [3]. Correlation coefficients were calculated using a reference function consisting of the stimulus pattern convolved with a gamma density function with the inclusion of proper nuisance terms. For the hippocampal study, the number of voxels per run per subject over a correlation threshold of 0.20 was determined within a defined hippocampal region of interest (ROI). Similarly, the number of voxels within a visual cortex ROI exceeding a correlation threshold of 0.40 was tabulated for the visual stimulation study . The number of voxels above a threshold is used as a measure of relative sensitivity.

Results

The average number of activated voxels across runs and subjects was computed for each experimental condition and normalized to the number of activated voxels for PQ2 without BGS or mRETROICOR. Results are presented in Table 1 with accompanying standard deviations reported in parentheses. For both brain regions, mRETROICOR increases the number of activated voxels with respect to no correction. The application of BGS increases the number of activated voxels in the visual study but not in the hippocampal study. Figure 1 shows the effect of mRETROICOR (panel b), BGS (panel c), and the combination of BGS and mRETROICOR (panel d) on the average PQ2 time-series of a single subject in the visual stimulation study (panel a).

Table 1. Normalized Number of Activated Voxels

	Hippocampal Study	
	-	mRETROICOR
PQ2	1.0	1.39 (.23)
BGS	.94 (.21)	1.31 (.17)
	Visual Study	
	-	mRETROICOR
PQ2	1.0	1.30 (.19)
BGS	1.27 (.12)	1.51 (.10)



Discussion

The number of activated voxels is increased with the application of mRETROICOR in both the visual and hippocampal areas. However, BGS only leads to sensitivity increases in the visual study. This may result from errors in the BGS saturation and inversion pulses due to field inhomogeneities in the medial-temporal lobe. Although BGS significantly increases sensitivity in the visual study it also eliminates the BOLD signal. Therefore, its application in ASL fMRI should be limited to applications where the functional perfusion signal is of primary interest. Additionally, improvements provided by BGS application are limited by interslice acquisition delays which allow for static tissue recovery in later slices. This can be addressed with pulse sequence modifications such as the use of refocusing pulses as described in [4] or the use of fast single-shot 3D acquisition sequences. [8]. In contrast, mRETROICOR provides robust increases in sensitivity without the need for specialized pulse sequences and should be routinely utilized.

References

[1] Luh, W.M. et al., Magn. Res. Med., 44:137-143, 2000. [2] Golay, X. et al., Top Magn. Reson., 15(1):10-27,2004. [3] Restom, K. et al., 12th ISMRM Proc., 2525, 2004. [4] St. Lawerence, KS et al., Magn. Res. Med., 53(3):735-8, 2005.[5] Ye FQ, et al., Magn Reson Med, 44:92-100, 2000. [6] Stern CE. et al., Proc. Natl. Acad. Sci., 93:8600-8665, 1996. [7]Wong E.C. et al., Magn. Res. Med., 39:702-81,1998. [8] Fernandez-Seara et al, Magn. Reson Med. 54:1241-7, 2005.