The effect of cardiac pulsation on fMRI data analysis

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Introduction

Current functional MR studies in human brain are largely based on data acquired by a constant TR and hence over different cardiac phases. Studies that manipulate physiological condition by hypercapnia or hypocapnia have demonstrated variation in baseline CBF and the magnitude of BOLD response (1,2). In addition, cardiac pulsation also affects local perfusion measurement (3), whose effect on functional MR experiment has not been addressed yet. In this study, a pulsometer was used to synchronize image acquisition with different cardiac phases. Data collected at two different flow velocities were compared with the conventional method without gating. Physiological implication and technical considerations are summarized.

Materials and Methods

Four healthy volunteers were scanned after giving written consent forms. A full-field flickering black-white radial checkerboard was used for visual stimulation, which alternates with periods of darkness with a small white fixation at the center. The paradigm consisted of four blocks (24s on, 36s off), preceded by a 48s baseline scanning. Images were acquired from three slices parallel to the calcarine sulcus with a voxel size of 3.4x3.4x5 mm^3. A pulsometer was hooked to the subject's index finger to gate image acquisition. ASL and BOLD experiments included three scans: constant TR, variant TR acquiring data at the end of systole and diastole. PICORE QUIPSSII was used to alternately produce tag and control images with single shot gradient echo spiral readout (TR=2400ms, dual echo with TE1/TE2 = 3ms/30ms TI1/TI2 =700ms/1400ms). An in-plane saturation was applied immediately after the tagging, ensuring that tissue signal is not affected by variant TR. ASL and BOLD signal were then generated from the running difference of the first echo and the running average of the second echo, respectively. Activated area was detected by baseline correction and pixel-by-pixel correlation analysis (c.c. = 0.3, $p<0.05$, cluster size = 3). The pixels detected through all three scans were averaged for signal time curves.

Results and Discussion

A typical set of ASL and BOLD activation maps and signal time curves are shown in Fig 1 and 2, respectively. Compatible spatial specificity is found in both contrasts as images are acquired at single or mixed cardiac phases. The baseline perfusion averaged over the activated region is 68 and 35 ml/100ml/min with end systolic and diastolic acquisition, respectively, and 50 ml/100ml/min without gating. Higher ASL signal change is observed at low flow whereas the absolute flow increase is approximately equal to high flow condition. When data are collected over multiple cardiac phases, both ASL and BOLD exhibit larger change. BOLD signal change is slightly smaller along with a larger post stimulus undershoot at high baseline perfusion. We attribute this finding to the relatively less vessel compliance when baseline flow is elevated. The presented data demonstrate the interaction between fMRI signal and cardiac pulsation. Gated fMRI has higher effective temporal resolution and can be used for detecting finer hemodynamics. Meanwhile, this method is more sensitive to subject's motion and has a higher demand for system stability.

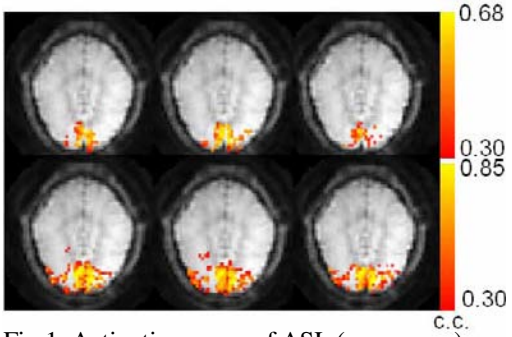

Fig 1. Activation maps of ASL (upper row) and BOLD (lower row). From left to right: end systolic, diastolic and non-gated image acquisition.

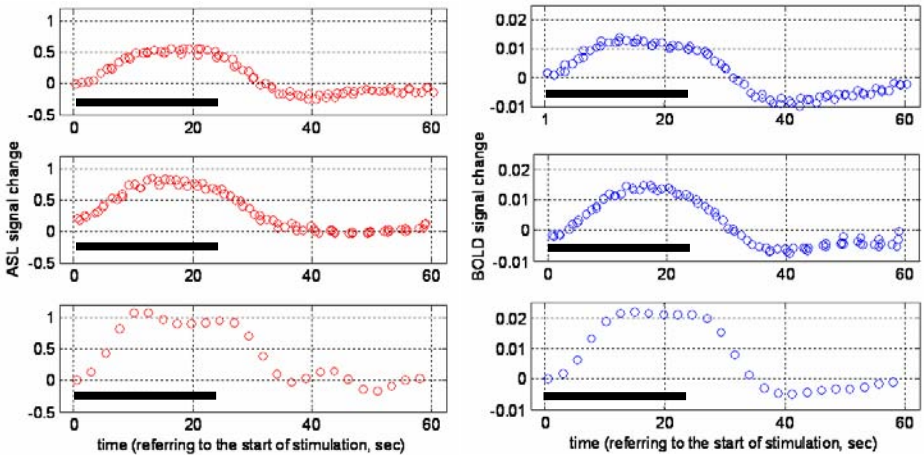

Fig 2. Signal time curves obtained by averaging over voxels detected by three scans (left column: ASL, right column: BOLD). From top to bottom: end systolic, diastolic and non-gated image acquisition.

References

1. Corfield et al., NeuroImage 2000;13: 1207-1211.
2. Hoge et al., Proc Natl Acad Sci USA 1999;96:9403-9408.
3. Wu et al., ISMRM Proc 2005. p 1149.