Simultaneous Measurement of Cerebral Blood Volume, Cerebral Blood Flow, and Cerebral Blood Oxygenation after Hypercapnia Challenge: A Preliminary Result

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Introduction:

In human experiments, a 40% to 59% increase of cerebral blood flow (CBF) and a 3% increase of BOLD signals has been documented under 5% CO2 inhalation [1,2]. Simultaneous acquisition of CBF, cerebral blood oxygenation (CBO), and cerebral blood volume (CBV) under hypercapnia challenge has not been documented before. We aim to investigate the change of CBF, CBO and CBV under hypercapnia challenge test using a hybrid pulse sequence modified from Yang's original design [3].

Materials and Methods:

This study was performed on a 3T MR scanner (Achiva). The optimal inversion delay time (TI) for blood attenuation was measured using a multi-TI dynamic inversion recovery scan (Fi.g 1). The CBF, CVO and CBV images were acquired using a hybrid pulse sequence (Fig. 2) modified from the Yang's sequence design [3]. With applying alternative selective and nonselective inversion gradients, dual echo EPI acquisitions provide images for generating CBF, CBO and CBV images [3]. The fMRI study and hypercapnic challenge were done using methods as described by Juan CJ, et al. in 2006 [4]. For hypercapnia challenge, 5% of CO2 was inhaled by the healthy subject. Segmentation of gray matter using Fuzzy C-means method was done for analysis of signal change of gray matter after hypercapnic perturbation.

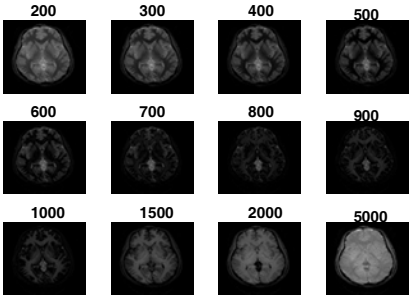

Figure 1. Multi-TI dynamic scans (TR/TE = 8000/5.5 ms) with invariant receiver gain.

Results:

Figure 3 showed the CBF, CBO and CBV maps on one visual stimulating fMRI study. BOLD image was most sensitive, followed by FAIR and VASO images in a decreasing order. On challenge test, a 20% (FAIR), .4% (BOLD) and 0.6% (VASO) change of signal intensity was noted between steady state hypercapnic and resting statuses.

Figure 3. Geographic demonstration of the change of CBV (VASO), CBF (FAIR) and oxygenation (BOLD) during a single box-car fMRI study. (matrix size: 128 x 128, FOV = 220 mm, SL = 5 mm, analyzed by SPM2)

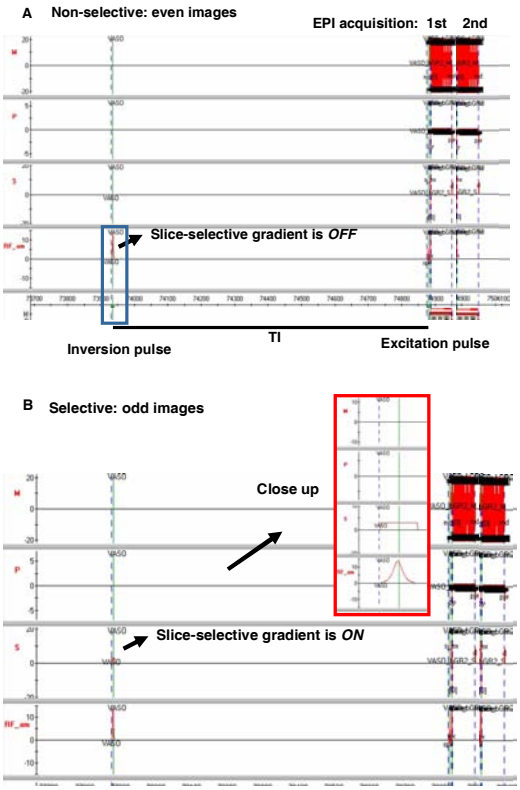

Figure 2. Geographic demonstration of the change of CBV (VASO), CBF (FAIR) and oxygenation (BOLD) during a single box-car fMRI study. (matrix size: 128 x 128, FOV = 220 mm, SL = 5 mm)

Discussion:

Our study provides a simultaneous measurement of three physiologic parameters under hypercapnic challenge, which is free from inter-experiment variation. Our results are consistent with prior researcher regarding the CBF and BOLD signal changes [1,2]. Unlike the apparent increase of CBF and BOLD signals, the CBV remains relatively unchanged after CO2 perturbation. Due to the limitation of case number, further investigations with adequate subjects are necessary to clarify the behavior of CBV under hypercapnic challenge.

References:

1. Kety S S, CF. *J Clin Invest* 1948;27:484-492.
2. Novack P, etj al. *J Clin Invest* 1953;32:696-702
3. Yang y, et al. Magn Reson Med. 2004;52:1407-17
4. Juan CJ, *et al. ISMRM* 2006:541.

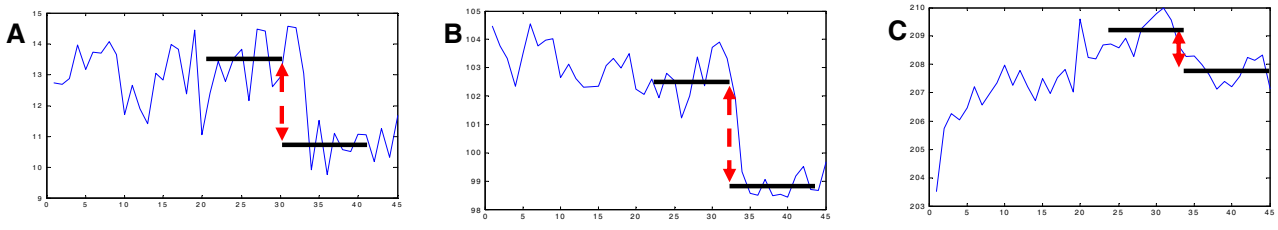

Figure 4. Signal intensity-time curves on CBF (A), CBO (B) and CBV (C) after hypercapnia challenge (5% CO2 inhaltion).