The application of functional challenge tasks in Moyamoya patients

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Background

Moyamoya disease is characterized by the puff of smoke (Moyamoya) collateral vessels near the stenosis regions induced by progressive stenosis of the internal carotid artery, anterior (ACA), middle (MCA) and posterior cerebral artery (PCA). Stealing phenomena is induced with decreased cerebral vascular reactivity (CVR) [1] and maximal vasodilatory of surrounding vessels is approached. However normal brain function is preserved with normal oxygen extraction function (OEF) [2]. CVR and OEF are critical indicators for evaluating the severity of Moyamoya disease. In this research, blood oxygenation level dependence (BOLD) functional Magnetic Resonance Imaging (fMRI) of carbogen inhalation and hand grasping are adapted as challenge tasks to probe CVR and OEF in Moyamoya disease.

Materials and Methods

The functional challenge tasks of BOLD fMRI were conducted using a 3T MR system (GE Discovery MR750 with an 8-channel head coil) and data from nine patients (three male and age range from 3 to 33) were included. Gradient echo echo planar images (EPI) of carbogen inhalation task were acquired with following imaging parameters: TR = 2000 msec, TE = 30 msec, acquisition matrix = 64×64×40, field of view (FOV) = 230*230 mm^2, slice thickness = 4 mm, and repetition number (NR) =360. The imaging parameters of hand grasping task were almost the same as carbogen inhalation tasks except TR=2012 msec and NR=120. The T_1-weighted images with 3D magnetization-prepared rapid gradient-echo (MPRAGE) were acquired as anatomical images.

In carbogen inhalation task, medical grade carbogens (1-5% CO_2) and air was delivered alternatively with five blocks of 2 minutes (**Figure 1**) after 2 minutes baseline of air inhalation. Gas inhalation was obtained by a medical grade non-rebreathing mask with high flow rate (15 liters /minute) and a home-made automatic switching system. The end-tidal CO_2 (etCO2) was recorded with Powerlab (ADInstruments). In hand grasping task, hand grasping and resting were performed alternatively with six blocks of 40 seconds (**Figure 1**). Visual cue was delivered to instruct patients with a projector in scanning room.

The data analysis was performed using Group ICA of fMRI Toolbox (GIFT) (Calhoun, 2004) and SPM8 (Wellcome Department of Cognitive Neurology, London, UK). The standard preprocess of fMRI data was performed with SPM8. For carbogen task, ICA components were extracted with GIFT and correlated with etCO2 curve. The optimal ICA components were selected with correlation coefficient (cc) >0.3 and combined with weighing of cc value. The reference functions were the combined ICA component and functional paradigm of hand grasping task convolved with hemodynamic function to calculate t-value of carbogen inhalation and hand grasping, respectively. The manual ROI (region of interest) (**Figure 3**) was selected to cover motor activation area of most patients, and the same ROIs of bilateral hand motor area were applied in both carbogen inhalation and hand grasping tasks of nine Moyamoya patients.

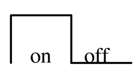

Figure 1: In functional tasks, carbogens (1-5% CO_2) and air was delivered during 1-minute on and 1-minute off state, respectively; hand grasping and rest were performed during 20-second on and 20-second off state, respectively.

Results

The mean and standard deviation of t-value in bilateral motor areas for both functional challenge tasks of nine patients were listed (**Table 1**). The mean values of t-value for both tasks were scatter plotted to probe the relationship between two tasks(**Figure 2**). It showed a trend that higher t-value of hand grasping task was obtained with higher t-value of carbogen inhalation task. The mean values of bilateral motor areas were close for most patients but they were quite different in 9th patient. In this patient, negative t-value at right ROI for carbogen inhalation (**Figure 3b**) and hand grasping tasks (**Figure 3a**) indicated impaired CVR and increased OEF.

Discussions

BOLD-based ROI selection of motor area was difficult because t-value of hand grasping task was low in Moyamoya patients with impaired neurovascular coupling. Because their motor function was preserved, direct detection of neuronal activation should be considered to select optimal ROI for quantitative analysis. By mapping relationship between CVR and OEF by carbogen inhalation and hand grasping tasks, respectively, the increase OEF during functional challenge might imply the critical state of hemodynamics.

References

[1] Mikulis et al., Stroke, 2011;42:1261-1269; [2] Mikulis, Stroke, 2013;44:S55-S57

	CI_R	CI_L	HG_R	HG_L
1	-3.1±1.0	-4.2±1.3	5.1±3.3	5.0±2.1
2	3.1±2.6	0.1±1.9	-0.4±1.5	1.2±0.9
3	6.2±2.0	11.7±3.6	6.3±2.0	1.7±2.5
4	7.1±2.4	5.0±3.2	6.2±2.8	7.6±3.0
5	10.4±2.0	6.5±1.8	7.2±2.2	4.9±3.0
6	-1.4±6.8	3.5±7.1	0.8±0.7	1.4±0.9
7	-3.9±1.9	-1.6±2.7	2.9±0.7	2.5±1.0
8	2.8±1.7	3.1±1.5	1.1±0.8	2.0±1.5
9	-0.2±1.5	10.3±3.2	-2.6±0.9	3.5±2.1

Table 1 Functional challenge tasks of nine patients (1-9) were summarized by mean and standard deviation of t-score within the manual ROI. *CI: carbogen inhalation; HG:*

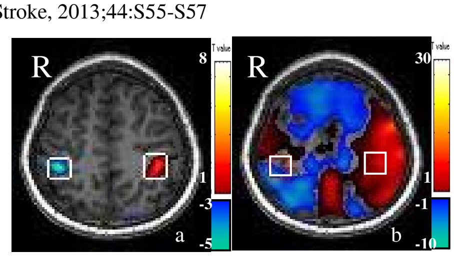

Figure 3 The functional maps of hand grasping task (a) and carbogen inhalation (b). White rectangles indicated selected ROIs in this slice and color represented t-value as colorbar next to figure.

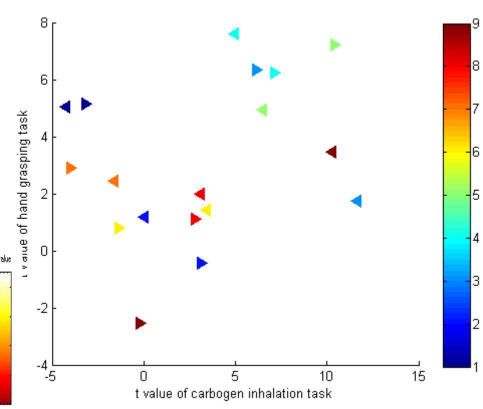

Figure 2 The scatter plot of mean t-scores of CI (x axis) and HG (y axis) was derived from ROIs of bilateral cerebral hemispheres in nine patients (1-9). *Different color represented different patients as colorbar ;* ▶ *and* ◀ *indicated right and left side, respectively.*