MRI of cerebral vasoreactivity: stimuli and analyses comparisons

A. Krainik[1,2], O. David[2], E. Chipon[2], I. Tropres[2], M. Baciu[3], J. Warnking[2], C. Segebarth[2], and J-F. Le Bas[1,2]
[1]MRI unit, CHU Grenoble, Grenoble, France, [2]Mixt unit UJF / INSERM U594, CHU Grenoble, Grenoble, France, [3]UMR 5105 CNRS, UPMF, Grenoble, France

Purpose: Assessing cerebral vasoreactivity (CVR) to capnic modulation may be important for interpreting the BOLD fMRI signals (Cohen 2002; Stefanovic 2006). It has also diagnostic potential, beyond fMRI. In order to further develop this imaging method using MRI, we therefore compared the BOLD responses to the stimuli (STIM) that led to hyper- and to hypocapnia, and assessed the impact of the haemodynamic response functions (HRF) used for fitting the data.

Subjects and methods: Ten right-handed non-smoker healthy subjects (5 women, 5 men; age: 22-37yo) were examined using a 1.5T MR scanner (Philips Intera). BOLD acquisitions were performed using T2*-weighted Gradient Echo Planar Imaging (TR/TE = 3000/50ms; voxel size = 4x4x4 mm) with 32 axial slices covering the entire brain. CVR to capnic modulation was assessed using a block-designed paradigm alternating normocapnic state (N) and capnic stress (C): [N(60sec) – C(120sec) – N(60sec)]x3 for a total duration of 12min (Fig. 1). The "STIM" factor had 2 conditions: 1°) hypocapnia during hyperventilation (Krainik 2005), 2°) hypercapnia during carbogen (7% CO2) inhalation (6l/min).
SPM5 was used for image processing. Preprocessing consisted in coregistration, realignment, reslicing, spatial normalization using MNI template and spatial smoothing (FWHM=6mm). First-level statistical analyses were performed using two types of HRF convolved with the stimuli: 1°) canonical HRF provided by SPM5 and 2°) adjusted HRF after gamma fitting of averaged signal time course across healthy subjects (Fig. 1). A second-level factorial ANOVA with repeated measures was applied to evaluate the main effects of the capnic stimuli (STIM) and of the model function (HRF) factors, and their interaction. For convenience, statistical results were expressed as positive values. Threshold for statistical significance was set at p=0.05, after false-discovery-rate correction for multiple comparisons.

Results: Throughout the grey matter, hypercapnia induced BOLD signal increase whereas hypocapnia induced BOLD signal decrease (Fig. 1). Interaction between STIM and HRF and significant main effects of STIM and HRF factors were detected in the grey matter. Post-hoc comparisons using t-tests showed stronger activations with hypercapnia and adjusted HRF. Asymmetrical statistical values were noted in eloquent areas with a left hemisphere predominance, especially along the central sulcus in the primary sensorimotor cortex and language related areas (Broca's and Wernicke's areas) (Fig. 2).

Conclusion: The hypercapnic stimulus and adjusted HRF provide optimal sensitivity to map CVR. In the right-handed volunteers of this study, CVR maps using BOLD fMRI exhibited a hemispheric asymmetry in eloquent areas with a left hemispheric predominance in primary sensorimotor cortex and language related areas. Further studies are carried out to evaluate the possible positive interaction between regional neuronal activity and cerebral vasoreactivity.

Fig. 1

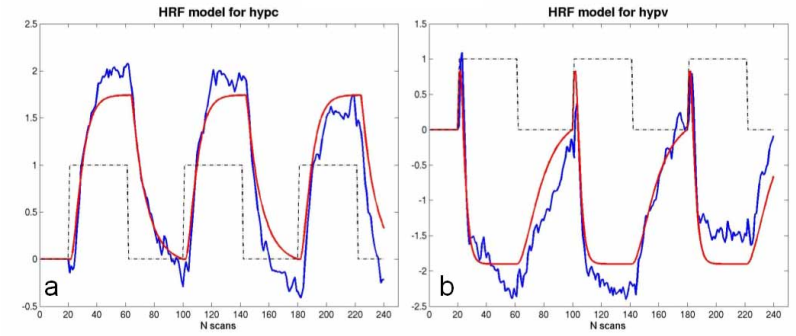

Figure 1: Adjusted HRF (red lines) for hypercapnia (a) and hypocapnia (b) obtained after gamma fitting from averaged BOLD signal time courses (blue lines) during capnic modulation (dotted line) (normocapnia =0)

Fig. 2

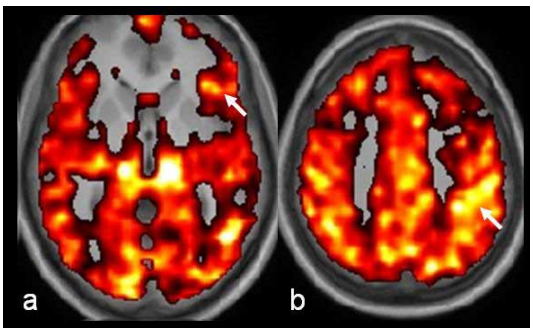

Figure 2: CVR map obtained using hypercapnia and adjusted HRF showed hemispheric asymmetry with a left predominance in eloquent regions such as Broca area (a) and primary sensorimotor cortex (b)

References:

Cohen ER *et al. J Cereb Blood Flow Metab* 2002;22:1042-53
Krainik A *et al. Stroke* 2005;36:1146-52
Stefanovic B *et al. Neuroimage* 2006;30:726-34