Monitoring of the Consistency of Brain Activation by Using a Dynamic Analysis of t-Statistics - An Application to Conventional Mapping of the Motor Areas

T. Nakai[1], E. Bagarinao[2], K. Ohishi[3], C. Kato[4], and K. Matsuo[1]

[1]Functional Brain Imaging Lab, Dept Gerontechnology, National Center for Geriatrics and Gerontology, Ohbu, Aichi, Japan, [2]Grid Technology Research Center, National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaragi, Japan, [3]Center of Magnetic Resonance Microimaging, Department of Radiology, Johns Hopkins School of Medicine, Baltimore, MD, United States, [4]Department of Management and Information Science, Toyohashi Sozo College, Toyohashi, Aichi

Introduction

Dynamic mapping of t-statistics (dynamic fMRI) enables to visualize the temporal characteristics of brain activation in response to the switching of task conditions [1,2]. The correlation of the dynamic response of t-statistics (TRF) covering a series of task conditions reflected the functional organization among the visual areas [2]. Although this technique will be useful to verify the neuronal basis of cognitive process, the scan time to cover several task conditions in one session (> 10 min) may be too long for clinical purposes. In this study, the application of dynamic fMRI for clinical studies, which mostly employs a single task condition for each session, was investigated. The stability of activation in the motor areas during simple motor execution was evaluated by using 'consistency mapping' based on the dynamic fMRI technique [3]. The TRF was compared across the motor areas and among the task conditions.

Material and Methods

Five normal subjects (2 males) and two patients (1 male) who gave written informed consent participated in this study. The volunteers performed four sessions of motor execution task paced by prompting of a cross hair mark at 1Hz displayed on an LCD panel. The conditions were gripping-opening movements of the right or left hand, and flexing-extending movements of the right or left ankle joint. The sessions were designed in a block manner (4 task and 5 rest block, 30 sec for each block, fixation in the rest blocks).

Functional data were obtained using a T2* weighted gradient recalled echo EPI sequence (TR = 3000 ms, TE = 30 ms, 30 axial slices, 4 mm thick, FOV = 22 cm) on a 3T MRI scanner (GE Signa VH/i3.0T). The 90 volumes of functional images were realigned, normalized and the center coordinates of the ROI (5x5x3 pixels) for each motor area were determined by using SPM2. The TRF was extracted using a Matlab module (Baxgui) employing the algorithm of incremental (IA) and sliding window analysis (SWA, window width = 30 pts) based on a general linear model [1, 2]. The TRFs in the primary motor area (M1), supplementary motor area (SMA) and cerebellum were compared. A consistency mapping analysis was applied to the functional data sets as reported previously [3].

Results

In normal volunteers, the t-value in these areas reached significant level ($p<0.001$) at the end of the first task block (Fig.1). Regression analysis indicated that there was no significant difference of variance among the four sessions in each area (ANOVA, $p < 0.05$). No ipsilateral M1 activation was detected and the consistency ratio (CR) within the selected ROIs was over 0.95 at the consistency length (CL) of 40. There results suggested that the TRF is not brain region specific in short fMRI sessions. In the metastatic brain tumor case, the regression analysis of the TRF did not report significant difference between the compensative ipsilateral M1 activation (CR > 0.9) and that on the contralateral side. The TRF in the right SMA was not significantly different from that of normal volunteers, while the right M1 was not activated at all. This observation suggested that the effort to move the paralyzed extremity. In another brain tumor case (s/o glioblastoma), the patient had left hemiparalysis and no activation was detected in the right M1 (Fig.2). The CR of the SMA activation was 0.40 by LF movement and 0.76 by RF (CL = 40). This low consistency of activation was compatible with reduced task performance.

Discussion

In clinical fMRI focused on identifying the location of the functional centers of interest, imperfect task performance diminishes the detection power. Although the examined number of subjects is small, it was suggested that the consistency mapping of activation might reflect the potential effect of the patho-physiological changes on the brain activation. The inconsistency may depend on two factors, i.e. patho-physiological changes of the HRF related to the local circulation induced by the lesions, and the secondary change of the neuronal activation due to the functional disorder of other units organizing the neuronal circuit. Mismatching of the TRF within the neuronal network may account for this difference. In conclusion, it was suggested that consistency analysis of the activation can be applied to individual analysis of clinical fMRI not only to monitor the task performance but also to further evaluate the patho-physiologic correlation.

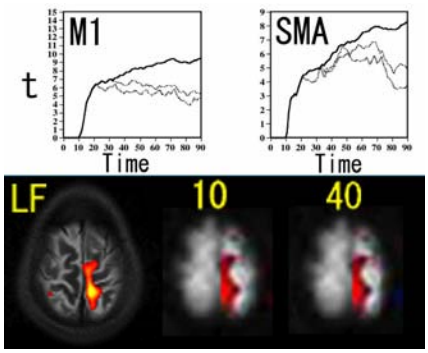

Fig.1 The averaged TRFs obtained from the normal volunteers and an example consistency map of the right M1 during LF movement. 10/40 : consistency length (CL).

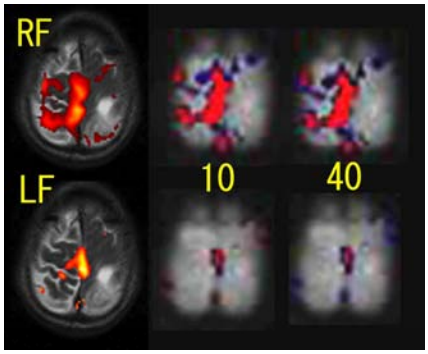

Fig.2 The consistency maps obtained from a brain tumor case. Activation in the M1 was not observed by LF movement. The blue areas indicate the region of inconsistent activation during the CL.

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