

back on to structure images. Further quantitation was performed on signal intensity and relative index of regional of interest (ROI). The analysis showed in the acute stage, the response on the lesion side was weaker than the sound side. However, in the chronic stage the response being more complicated and worth further study.

Keywords: Functional Magnetic Resonance Imaging, Visual Cortex, Motor Cortex, Hemoglobin, Ischemic Stroke

Introduction

Functional MRI is the technology utilizing intrinsic contrast agent (Oxy- vs. Deoxyhemoglobin) for the study of the perfusion changes during activation of specific brain regions, e.g., motor, sensory or visual cortex. The theoretic basis of this intrinsic contrast agent bases on a phenomenon called Blood Oxygen Level-Dependent (BOLD) first proposed by Ogawa et al. The BOLD effect originates from that at tissue or capillary level, the diamagnetic oxyhemoglobin gives up its oxygen and results in paramagnetic deoxyhemoglobin. The presence of paramagnetic molecules in blood produces alternation in magnetic susceptibility, which in turn changes the effective decay rate of transverse magnetization. Susceptibility variations induce local field difference, which cause dephasing of spins leading to attenuation of signal intensity in gradient echo images. The variations are most pertinent for functional MRI in tissue corresponding to changes in concentration of paramagnetic deoxyhemoglobin in blood within the capillaries, which in turn are indicators of changes in tissue perfusion.

On the other hand, with the conventional MR technique, the acute findings of ischemic infarct can only be demonstrated by some indirect "signs",

such as loss of gray matter ° White matter interface, perifocal edema represented by increased intensity on T2WI, breakdown of BBB by Gd-DTPA enhancement ... etc.. In the later stage, the change in tissue characterization such as loss of neurons, encephalomalacia indicated by decreased intensity on T1WI, are already "signs" for irreversible brain tissue damage. Hence, no information about those tissue of hypoperfusion ° – penumbra regions could be obtained. Since the viable tissue is the corner stone for neurological improvement after stroke. It is our greatest concern, whether or not the area of reversible ischemic change could be defined quantitatively. Through this clinical endeavors to protect and save those penumbra could then be developed.

Material and Methods

Subject

In the first year of the project data from normal control was collected with motor and visual stimulation. In the second, patients with ischemic infarcts were studied. In the last year of the project, we studied patient with ischemic stroke with different time interval from the onset.

Part A Motor Study

Subjects participated in the motor study, were asked to move their fingers of one hand in a way that each finger opposes the thumb tip alternatively and continuously in order to activate the motor cortex of the contralateral side during the imaging acquisition process.

Part B Visual Study

During the visual study, red flash light from LED-goggled were given simultaneously to both eyes of the subjects to activated their visual cortex. The stimulation frequency is set at 8 Hz to obtain optimal response of the visual activation.

Image Acquisition

Images were acquired on a 1.5 T GE Signa and 1.5 T Siemens Magnetom (with EPI) clinical imager located at the department of radiology in national Taiwan university hospital. For experiment with Signa surface coils were applied in the experiment. A 5-inche surface coils were placed against the occipital pole for the visual study; and one pair of T-M-J surface coils were placed symmetrically in the frontoparietal regions just above the motor cortex. Birdcage volume coil was used in the Magnetom machine.

Conventional MR Imaging

Conventional pulse sequence imaging were also obtained in each subjects including the T1WI, T2WI and the PD images.

f-MRI Study

In Signa study, single slice was used in either experiment, the slice went through the calcarine gyrus was chosen for the visual study and the slice went through the motor cortex was chosen for the motor study. "FLASH" pulse sequence in gradient echo was adopted in generating the functional images. The parameters were as following : TR 110 / TE 50 / $\alpha = 45^\circ$ / FOV 24X24 / 256X128 / NEX = 1 / slide thickness = 4 mm / FC. In Magnetom, six to eight slices were used in either experiment, slices went through the calcarine gyrus was chosen for the visual study, and slice went through sensory-motor cortex for motor study. T2WI in EPI pulse sequence was adopted in generating the functional images. The parameters were as following : TR 2000 / TE 54 / FOV

40X40 / 256X128 / NEX = 1 / slide thickness = 4 mm.

Image Processing

After the images were acquired, the post-processing algorithm i.e., correlation coefficient was applied to those functional images. The computation was on the degree of correlation to an assumed input function that was a square wave function in our experiment. The activated pixels (those over the statistic threshold) were then displayed and mapped back on to the T1WI image of the same level or on to the original image. Further analyses focused on those activated pixels. On one hand the averaged signal intensity in the region of interest (ROI) were computed and expressed in percentage. On the other hand the pixel number in ROI as well as the control area was calculated and the relative index between the ROI / control was then obtained. The former analysis was performed in either modality, visual and motor while the latter method was done only on motor stimulation.

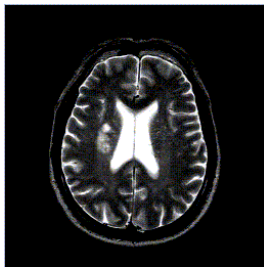
Results

Part A Motor Study

Motor stimulation increased signal intensity over the motor cortex. In control group, the averaged signal changes in ROI during activation was $5.06 \pm 0.9\%$. The relative activating index of ROI / Control area was 4.85 ± 2.75 . In patient group, motor activation evoked signal intensity changes over motor cortex of either hemisphere. The averaged signal intensity change (SIC) in ROI of motor cortex during activation was $1.67 \pm 1.03\%$ on the normal side and $1.48 \pm 0.4\%$ on the lesion side. The relative APN in ROI of normal side is 0.51 and 0.49 for lesion

side. Therefore, the RAI of motor response in this study is 1.97. However, none reached statistic significance.

Fig. 1A



1B

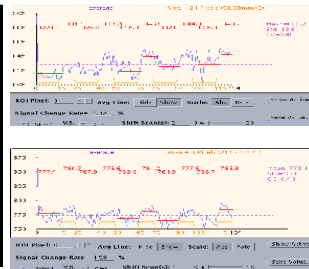


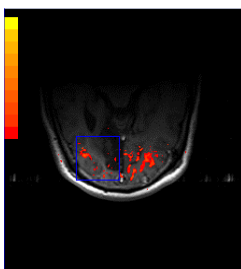
Fig.1 A) T2WI showed increased signal intensity at the corona radiata of the right hemisphere. B) Upper chart showed response from left motor cortex with an activated pixel number (APN) of 24 and SIC of 1.82 %. Lower chart showed response from the right side with an APN of 9 and SIC of 1.58%.

Part B Visual study

Visual cortex stimulation increased signal intensity in the occipital cortex mainly over bilateral banks of the calcarine sulci. The signal changes during the activation was $6.1 \pm 2.8\%$.

In patient group, visual activation task resulted an averaged SIC of $3.32 \pm 2.06\%$ on the normal side and $3.56 \pm 1.23\%$ on the lesion side. The relative APN of the normal side is 0.58 and 0.42 for the lesion side. Consequently, the RAI of normal versus lesion is 1.31. Again, non-of these reach statistic significance.

Fig.2A



2B

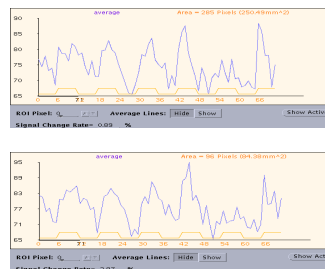


Fig 2A Functional images with activated pixels displayed against on a TIWI structure image. Ischemic lesion can be seen in the right occipital cortex. 2B Upper chart showed functional response from the left occipital

lobe with an APN of 285 and SIC 0.98% while lower chart showed response from the right side with an APN of 96 and SIC 2.97%.

Discussion

Correlation coefficient is a popular post-processing algorithm. It is indeed robust and is capable of demonstrating the activated regions. However, high correlation simply means that the response is better conformed to the input function, which we have assumed as a “square wave”. Nevertheless the brain does not necessarily behave as a “square wave”. Therefore we need more information about the temporal sequence of the brain response. Methods emphasizing “data driven” should be explored among which algorithm applying artificial neural net especially those of unsupervised, self-organized net worth our further attention. In our research projects new technique has been developed from other subprogram. Preliminary implement of the automatic algorithm of identifying functional response in the normal human brain as well as in the ischemic brain has been.

In order to have better measurement of the response in certain cortical area, we measured the signal changes in voxel other than pixel. To achieve this goal multi-slice acquisition is preferred. Therefore, EPI is a superior technique in terms of speed of acquisition.

In conclusion, the promising technology of functional MR imaging was applied in a preliminary clinical study for ischemic stroke patients. It is our long-term goal that a non-invasive and convenient model for investigating therapeutic approaches in clinical as well as experimental settings will be established on the foundation we have constructed in this integrated three-year project.