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Functional Magnetic Resonance Mapping of Motor Cortex In Patients With Mass Lesions Near Primary Motor and Sensory Cortices

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Abstract—**Purpose: To study motor cortex mapping in patients with mass lesions near primary motor and sensory cortices with BOLD-fMRI. Material and Methods: 18 patients with mass lesions near primary motor and sensory cortices, and 8 healthy volunteers were investigated with fMRI using a 1.5T GE Signa scanner. The specific task was repetitive selfpaced index finger to thumb opposition with a frequency of approximately 2 Hz. Each task paradigm consisted of twelve 20-second blocks alternating between rest and activation. All functional data was sent to SUN GE Advanced Workstation 4.0 for post processing. Results: 14 patients showed functional activaton near mass lesion, 4 patients failed to show, and one patient with meningeoma was excluded because of heavy head movement. Of 14 patients, the functional activation of eloquent cortex was different between the group with declination of muscle force and the group with normal muscle force, generally the activated areas of the former were more scattered, dislocated, relative smaller than that of the latter. Conclusion: fMRI is a valuable method for pre-operative evaluation of neurosurgical patients and probably can evaluate the muscle force pre- and post-operation approximately.**

***Keyword*—fMRI; primary motor and sensory cortices; SMA; Functool; pre-operative planning**.

I. INTRODUCTION

FUNCTIONAL magnetic resonance imaging (fMRI) is a non-invasive and widely available technique for mapping brain functions. It is based upon the blood oxygenation level-dependent (BOLD) effect [1]. The current understanding of this effect is that functional increases of oxygen consumption by neuronal cells induce concomitant relative increases of the local perfusion that exceed the relative oxygen consumption changes. The decreased concentration of deoxygenated hemoglobin induces a higher signal on T2*-weighted images. [2]

One limitation of radical surgical excision of intracerebral tumors is the risk of producing neurological deficits in functionally important or “eloquent” brain regions. To save the patient from deficits following neurosurgery, the location of functionally important areas in relationship to the lesion must be identified. This can be difficult for a number of reasons. First, it has been shown that even in the normal brain there is a considerable variability between function and anatomy. Secondly, in case of undistorted anatomy, eloquent areas may be identified using specific sulcal landmarks. For instance, the hand-function can be located at the O-shaped structure of the pre-central gyrus. Mass effects associated with brain tumors can distort these common relations, making anatomy-based localization of functional areas impossible. In the third place, in response to pathology, functional areas may be relocated to other areas in the brain, thereby altering the normal relationships between function and anatomy [3-5].

The primary motor and sensory cortices(PMSC)are well-known functional areas. And the supplementary motor area (SMA) is also considered eloquent in motor processing. Although damage to the SMA can lead to severe motor deficits and language deficits, these deficits resolve completely in the majority of patients [6, 7]. Our aim was to mapping motor cortex in patients with mass lesions near primary motor and sensory cortices with fMRI.

II. METHODOLOGY

Subjects: 18 patients with mass lesions near primary motor and sensory cortices, and 8 healthy volunteers were investigated with fMRI. Subject age varied from 24 to 77 years. All patients had space occupying lesions near or encroaching upon primary motor and sensory cortices as revealed by high resolution MRI. All subjects gave informed consent to participate in the study. None of the subjects experienced any procedure related side affects.

Experimental design and Imaging methods: MRI was performed using a 1.5T GE Signa scanner which was equipped for echo-planar imaging (EPI). Head movements were minimised in all patients using foam pads and Velcro straps. Images were acquired using a standard head coil.

Anatomical images: After localizing images in three planes, 4 axial T1-weighted inversion recovery anatomical slices were obtained which were oriented parallel to the line running through the anterior and the posterior commissure, and almost contain Rolando's fissure. Imaging parameters were TR: 2300 ms, TE: 11.2 ms, Inv 750 ms, Matrix 320× 224, FOV: 240 × 240 mm, slice thickness:7 mm, space between slices:1.5mm.

Functional images: Blood oxygenation level dependent (BOLD) imaging was performed using a singleshot T2* weighted gradient echo EPI sequence (imaging parameters: TR: 2000 ms, TE: 500 ms, FA: 90°, Matrix 64×64, FOV: 240×240 mm). Four 7mm thick slices were obtained which had the same localization and orientation as the anatomical slices, 4:16 minutes 512 images were generated (0.5 sec/image).

Each task paradigm consisted of twelve 20-second blocks alternating between rest and activation. The specific task was repetitive selfpaced index finger to thumb opposition with a

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frequency of approximately 2 Hz. Tasks were performed independently on both sides. Subjects were trained how to perform the motor tasks outside the scanner and were watched during task performance.

Image postprocessing and Date-analysis: All images was sent to SUN GE Advanced Workstation 4.0 for post processing. Use "correlation coefficient" in Functool software, the Confidence Level was set at a p value of $p < 0.001$. The correlation coefficient of ROI must >0.500. Functional activation maps were colour-coded according to the statistical significance of difference between the rest and activation states and overlaid over the anatomical T1 weighted images for anatomical reference. All postprocessing images were at the same Window Width (0.150) and Level(0.400).

III. RESULTS

1 Volunteers: of 16 functional runs, 14 runs showed functional activation in ipsilateral PSMC, and all runs showed functional activation in contralateral PMSC and in hibateral SMA. The functional activation in ipsilateral PMSC was much smaller than contralateral PMSC (see fig. 1).

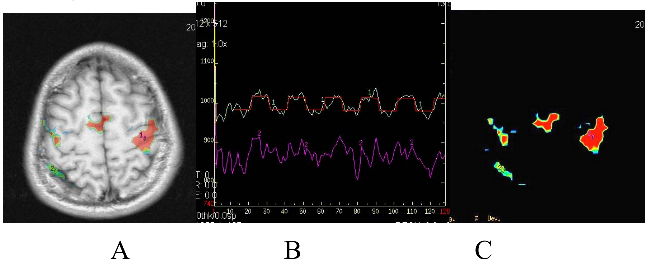

Fig.1 A: the functional activation imaging of one volunteer with the task of right index finger to thumb opposition, showed activation in left PMSC and in hibateral SMA, also showed much smaller activated areas in right PMSC. B: shown the time-intensity curve of ROI, the curve marked '1' was almost coherent with the block design curve. The curve marked '2' was irregular, and considered it as a artifact. C: the functional map of the same slice, showed the Correlation Coefficient of ROI '1' was 0.803, and ROI '2' was 0.495.

2 Patients: 18 cases include 7 metastatic tumor, 6 meningeoma, 2 neurogliocytoma and 3 arteriovenous malformation , one patient with glioblastoma multiforme had twice fMRI exam(Pre-operation and post-operation). 14 patients showed functional activaton near mass lesion, 4 patients failed to show, and one patient with meningeoma was excluded because of heavy head movement. 8 of 14 patients, the muscle force of lesion contralateral extremity declined, and fMRI showed the activated areas of PMSC or SMA scattered、shifted, relative smaller compared with the activated areass of uninjured side or with the volunteers', parts of them showed the activation of premotor cortex (PMC), parietal cortex (PC). Six of 14 patients, the muscle force of lesion contralateral extremity was normal, and the functional activation imagings showed: a. the PMSC or SMA was not involved, b. the PMSC or SMA was shifted, but the activated areas were almost the same as uninjured side's. c. The PMSC or SMA was shifted, and the activated areas were relative smaller, but there were other activated areas such as PMC.(see fig. 2-4).

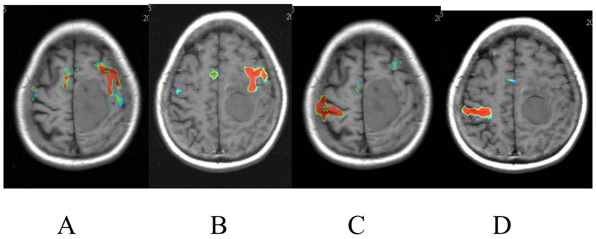

Fig.2 The functional activation images of a patient with meningeoma of left cupular part near cerebral falx. A and B showed the left side PMSC was pushed forward, and only right SMA was activated. C and D showed the functional activation areas of right side. Declination of the muscle force of right extremity of the patient was slight.

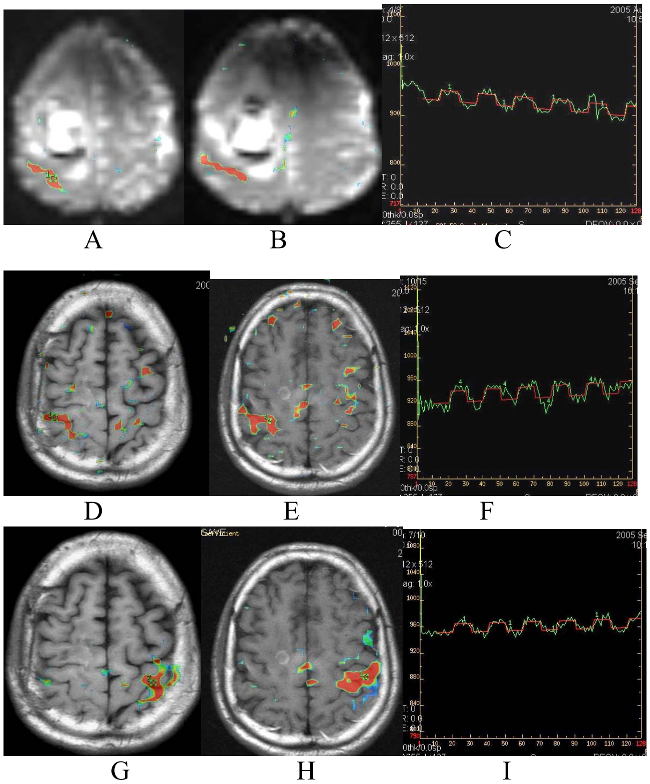

Fig.3 A patient with glioblastoma in right frontal lobe. A, B, and C showed the functional activation areas pre-operation, less than 3/5 muscle grade of left hand. The right PMSC was pushed backword and the activated areas of it were relative small. C showed the time-intensity curve of ROI in right PMSC. the Correlation Coefficient was 0.760. D-I showed the functional activation areas post-operation, 5/5 muscle grade of left hand. D and E showed the activated areas of right

PMSC were relavive smaller than left PMSC's(G, H), and was more scattered. The activated areas of SMA and left PMSC in D and E were relative larger than that in G and H. Besides, there were activated areas in bilateral PMC. The Correlation Coefficients of F was 0.679, and I was 0.753.

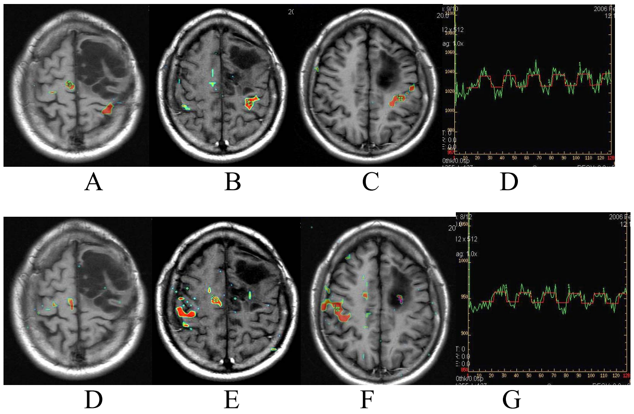

Fig.4 A lesion in left frontal lobe nine months after the resection of meningeoma in left frontal region near cerebral falx, 5/5 muscle grade of right hand. The functional activation areas of left PMSC(A,B,C) were almost the same as the areas of right PMSC(D,E,F). Only right SMA was activated. The Correlation Coefficients of D was 0.613, and I was 0.630.

IV. DISCUSSION

Different studies have correlated electrophysiological cortical mapping techniques with the haemodynamically based fMRI method [8, 9]. They found corresponding sites of the brain activated during fMRI which were subsequently detected with direct electrical cortical stimulation or transcranial magnetic stimulation. They concluded that fMRI was able to detect haemodynamic changes in parenchymal areas which had a good spatial concordance with those cortical regions exhibiting the highest motoneuron density during electromagnetic stimulation.

Functool is a post-processing productivity tool for further enhancing the application of Dynamic MR imaging by facilitating image analysis of time/intensity changes. Xie Sheng et al. evaluated the role of Functool in the postprocessing of the fMRI data and compare with AFNI , concluded that Functool was reliable in the postprocessing of the block-designed fMRI data.[10]

Functional magnetic resonance imaging (fMRI) of the brain is increasingly being considered as a valuable method for pre-operative evaluation of neurosurgical patients[11-13]. There were 14 patients successfully showed functional activation. The spacial relationship between eloquent brain areas and mass lesion can be clear showed. fMRI is capable of identifying sensorimotor areas even in the presence of space occupying and distorting brain lesions, it can help the surgeon to assess the feasibility of resection and in surgical planning. Furthermore, fMRI probably can evaluate the muscle force pre- and post-operation approximately, according to the functional activation of eloquent areas. As Fig.3 showed, after operation the muscle force of the patient rehabiled(5/5 muscle grade), and the fMRI imagings showed more activations in secondary motor cortex. This can be explained by functional reorganization[14-15].

Still, there are 4 patients failed to show functional activaton, the reasons may include: 1 head movement. Motion can reduce the accuracy of fMRI, and, more important, it can render it completely useless. Indeed, motion is the most important reason for unsuccessful fMRI runs. Unfortunately, patients tend to move their heads more than healthy subjects [16]. 2 the amplitude or frequency of finger tapping is not steady, or the pace of finger movement is not concordant with the task paradigm. Some patients maybe can not do it correctly because of his illness. In that case, we can not process the imaging data with Functool correctly. 3 mass lesion influence the hemodynamics of brain parenchyma. Schreiber et al. found that fMRI activation is reduced near glial tumors, but usually is not affected by non-glial tumors [17]. They suggested that this phenomenon might be explained by the fact that glial tumors grow more infiltratively, altering the cellular architecture, and that non-glial tumors show more delineation from normal tissue, leaving the cellular architecture intact. Holodny et al. found that the amount of activated voxels was 35% less at the tumor site compared to the contralateral site. Two possible reasons given by the authors are a loss of autoregulation and a changed venous response because of compression of the tumor on neighboring vasculature[18]. For the success of fMRI exam, a precise and rigorous design is necessary, and head movement control is especially important.

V. SUMMARY AND FUTURE DEVELOPMENTS

In summary, successful fMRI mapping can be obtained routinely in most patients with cerebral tumors. fMRI is a valuable method for pre-operative evaluation of neurosurgical patients and probably can evaluate the muscle force pre- and post-operation approximately. fMRI is sensitive to cortical changes, but provides limited information concerning the integrity of the white matter structures [19]. the combination of fMRI and tractography based on diffusion tensor imaging and Integration of functional MRI results in neuronavigation systems will be beneficial for reducing postoperative deficits [19-23].

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