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ANALYSIS OF RESECTION OF BRAIN TUMOR IN ELOQUENT AREA USING fMRI

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Abstract- Resection of tumor in eloquent areas of brain represents a challenge in neuro surgery. In this study, we have attempted to come up with a methodology in which we process the fMRI image of a patient with brain tumor. We have made a detailed observation of the activation in eloquent areas of the brain during an ongoing motor task through SPM software.

In this paper, activation in brain areas of a tumor patient while performing motor task has been compared with that of a normal subject. The difference in activated areas has been used to analyze the effect of tumor in areas used to perform motor task. Subsequently, a detailed statistical analysis has been done to locate the exact position of activation so as to determine the amount of risk involved in tumor resection.

Keywords- functional Magnetic Resonance Imaging (fMRI), Statistical Parametric Mapping (SPM), Brain tumor detection, Statistical Analysis, Activity regions, eloquent areas, Motor task

Introduction

New imaging technologies have revolutionized both brain tumor surgery and radiation therapy. The neurosurgical oncology group is skilled in such techniques as positron emission tomography (PET), frameless-based stereo taxis and functional magnetic resonance imaging to ensure the most accurate diagnostic biopsies and maximal resection of benign and malignant primary and metastatic brain tumors.

Functional magnetic resonance imaging (fMRI) allows physicians to map areas of the brain associated with vital functions such as speech, vision, hearing, taste, touch and voluntary movement. Sensory and motor activities alter the flow of blood and the use of oxygen in the areas of the brain involved in these functions, producing signals that can be detected by the MRI scanner. A functional MRI assessment before surgery clearly shows the differences in brain organization from one person to an-other and can be critical in determining the best surgical approach.

Surgery is the treatment modality of choice for most of the lesions of the brain. The location of the tumoural lesion generally can be well defined using conventional magnetic resonance (MR) imaging. The surgical approach and resection of the tumour should be performed with no or minimal damage to the eloquent brain areas such as language, sensorimotor and visual motor cortices. Therefore, it is important to locate eloquent brain areas relative to the tumoural lesion.

This paper prospectively evaluates the effect of preoperative functional magnetic resonance (MR) imaging localization of language and motor areas on therapeutic decision making in patients with potentially resectable brain tumors. Thirty-nine consecutive patients (19 male, 20 female; mean age, 42.2 years) referred for functional MR imaging for possible tumor resection were prospectively evaluated. Sentence completion and bilateral hand squeeze tasks were used to map language and sensory motor areas [1-3].

This paper evaluates the value of preoperative magneto encephalography (MEG) imaging of functional connectivity to predict the results of intraoperative electrical stimulation (IES) mapping, the clinical gold standard for neurosurgical localization of functional areas. Resting-state whole-cortex MEG recordings were obtained from 57 consecutive subjects with focal brain tumors near or within motor, sensory, or language areas. Neural activity was estimated using adaptive spatial filtering algorithms and the mean imaginary coherence between the rest of the brain and voxels in and around brain tumors were compared to the mean imaginary coherence between the rest of the brain and contralesional voxels as an index of functional connectivity. IES mapping was performed in all subjects. The cortical connectivity pattern near the tumor was compared to the IES results [4-7].

This paper is about evaluation of the implementation of functional magnetic resonance imaging (fMRI) for clinical use in patients with a brain tumor in the setting of a regional hospital.

The preprocessing mainly was achieved with the usage of Statistical Parametric Mapping (SPM) tool [Fig-1]. Twenty-three patients underwent a fMRI examination as preoperative evaluation for a tumor adjacent to a eloquent brain area. The location and distance of the tumor relative to the fMRI activation area for this eloquent brain area was determined. Presence of postoperative neurological deficits was compared to the result of the fMRI examination. The fMRI examination was not interpretable in four of the twenty-three patients. In nine patients the eloquent brain area was located more than two centimeters from the tumor: seven showed no neurological deficit postoperatively, one patient experienced a temporary deficit, and one patient had not been operated yet. In the remaining ten patients the eloquent brain area was located less than two centimeters from the tumor: after (partial) resection of the tumor often using intra-operative cortical stimulation, six patients showed no neurological deficits, and three patients had temporary or permanent deficits. One patient was not operated. The clinical implementation of fMRI was successful in the preoperative evaluation of patients with a brain tumor and useful to plan the surgical intervention and to minimize postoperative neurological deficits [8,9].

In this paper it is reported that motor networks in subjects with brain tumours are comparable to those observable in control patients, and that left frontal connections between the PMA and SMAs are critical for motor performance. It is shown that patients who presented with motor weakness have significantly decreased mean motor network connectivity. A computationally simple, straightforward method of demonstrating the anatomic location of nodes corresponding to SMA, PMA and SPL, when the location of the motor cortex is known is developed. A drawback of this approach is that it requires registration to a standard brain. But this technique is suitable for rapid translation to clinical use [10-12].

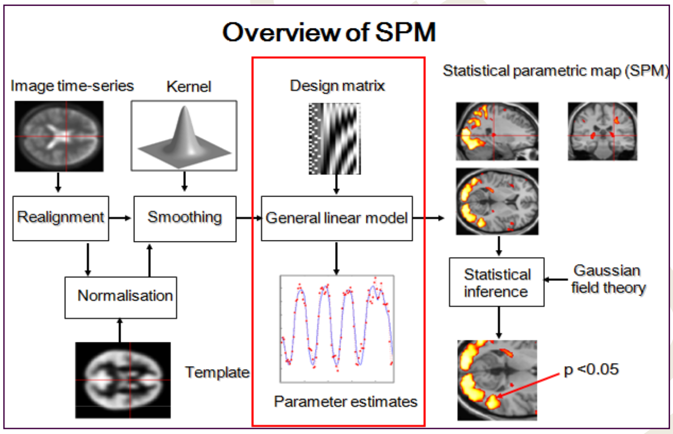

Fig. 1- Overview of SPM Process

Methodology

Re-Orientation

ACPC Alignment and Co-Registration of structural images with standard structural T1 image: ACPC line is two fiducial points, one at the anterior commissure and one at the posterior commissure. The resulting transform will bring the line connecting them to horizontal to the AP axis. The midline is a series of points defining the division between the hemispheres of the brain (the mid sagittal plane). The resulting transform will put the output volume with the mid sagittal plane.

Pre-Processing

Preprocessing can be done in a few different ways

a) Direct Normalization

i) Realign -> Slice Time* -> Normalization -> Smoothing

b) Indirect Normalization

i) Realign -> Slice Time* -> Coregistration -> Segmentation -> Normalization ->Smoothing

Realignment

The realignment step corrects for motion across and within sessions of an individual subject [Fig-2],[Fig-3]. Acceptable movement is up to 6mm, however, with the realignment step and inclusion of the text output even the most extreme movement can be controlled for. This routine realigns a time-series of images acquired from the same subject using a least squares approach and a 6 parameter (rigid body) spatial transformation.

A 3D rigid body transform is defined by:

3 translations - in X, Y & Z directions

3 rotations - about X, Y & Z axes

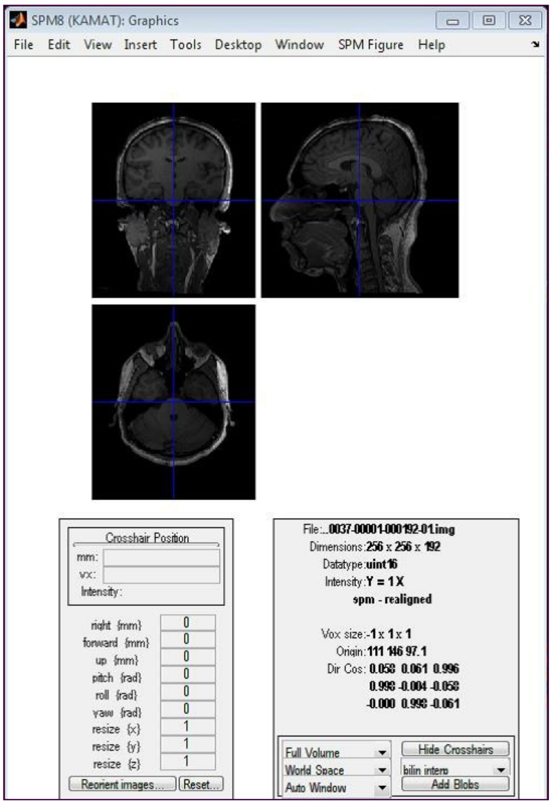

Fig. 2- Realignment output for normal subject

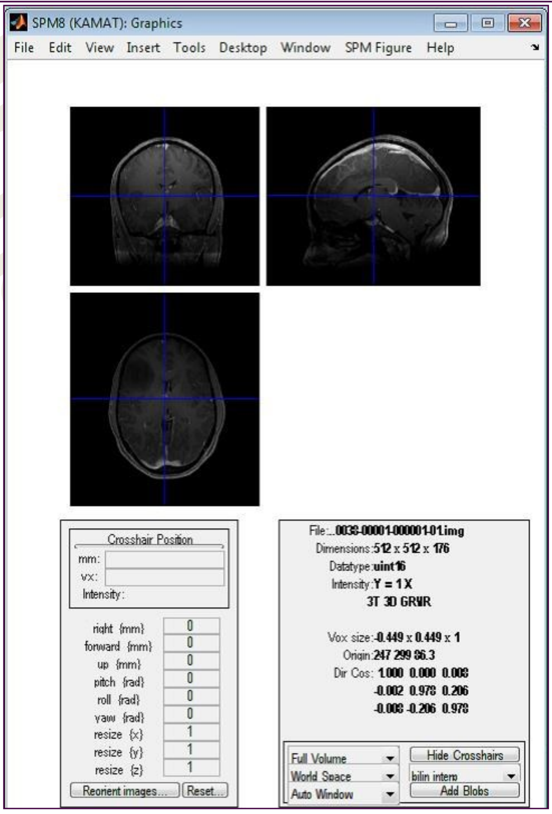

Fig. 3- Realignment output for tumor patient

Coregistration

This step is included for indirect normalization. Since EPI data is not as detailed as the structural T1 images this option allows for a better normalization to the MNI template. In this step you will coregister the individuals T1 to their EPI.

Segmentation

This is the second step in indirect normalization. This will segment the T1 image into CSF, white matter, & grey matter. Segmentation is based on the MNI template; therefore this step must calculate the transformation before segmenting. These calculations will be used to in the next step of normalization of the EPI images.

SPM uses a method of segmenting MR images into different tissue classes, using a modified Gaussian Mixture Model. By knowing the prior spatial probability of each voxel being grey matter, white matter or cerebrospinal fluid, it is possible to obtain a more robust classification. In addition, a step for correcting intensity non-uniformity is also included, which makes the method more applicable to images corrupted by smooth intensity variations.

Healthy brain tissue can generally be classified into three broad tissue types on the basis of an MR image. These are grey matter (GM), white matter (WM) and cerebrospinal fluid (CSF). This classification can be performed manually on a good quality T1 image, by simply selecting suitable image intensity ranges which encompass most of the voxel intensities of a particular tissue type.

The segmentation based on tissue probability template map (TPM) compute probability of different tissue in terms of intensity.

Output: The grey matter images [Fig-4], [Fig-5] are named the same as the originals, except that they are prefixed by c1rsREFD.

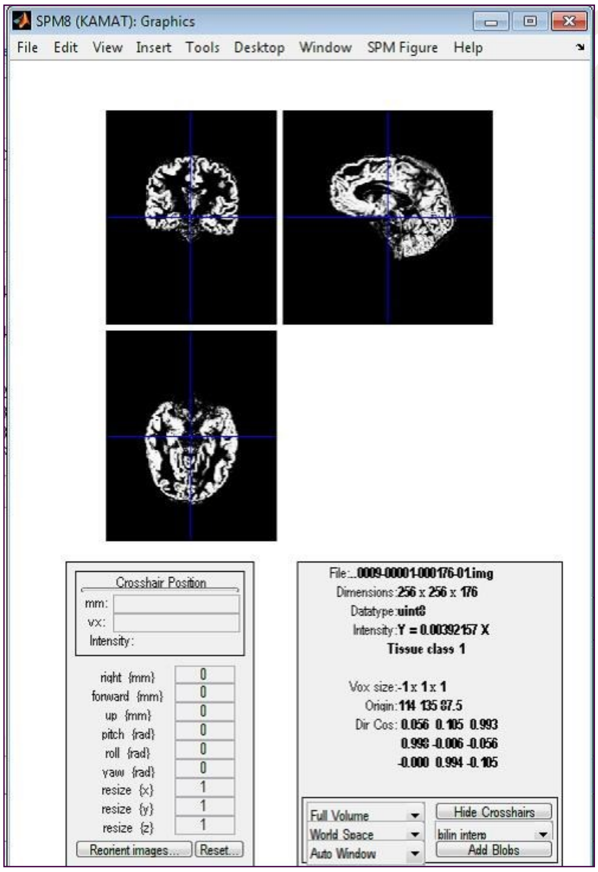

Fig. 4- Segmented Gray Matter output for normal subject

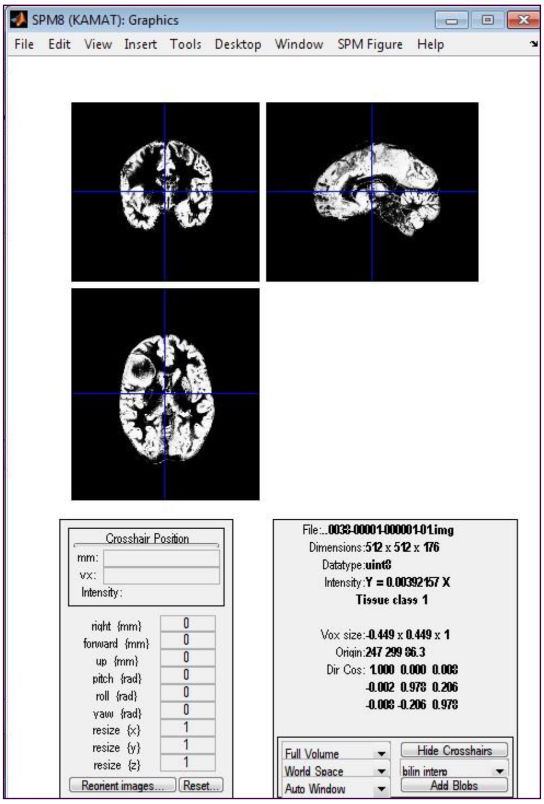

Fig. 5- Segmented gray matter output for tumor patient

Output: The white matter images [Fig-6], [Fig-7] are named the same as the originals, except that they are prefixed by c2rsREFD.

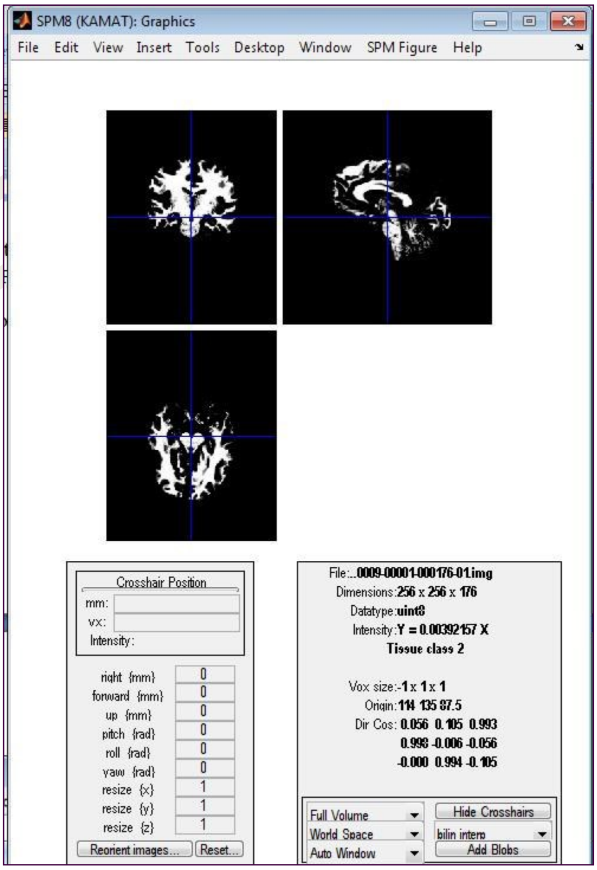

Fig. 6- Segmented white matter output for normal patient

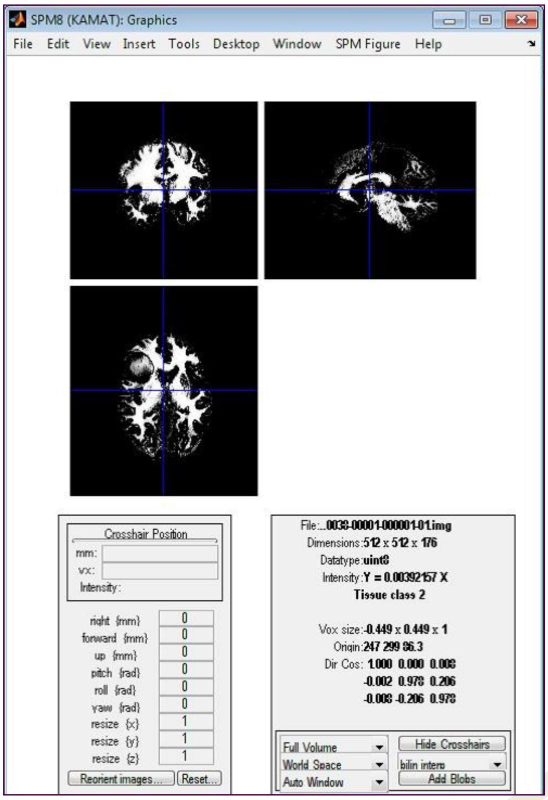

Fig. 7- Segmented white matter output for tumor patient

Output: The cerebrospinal fluid images [Fig-8], [Fig-9] are named the same as the originals, except that they are prefixed by c3rs-REFD.

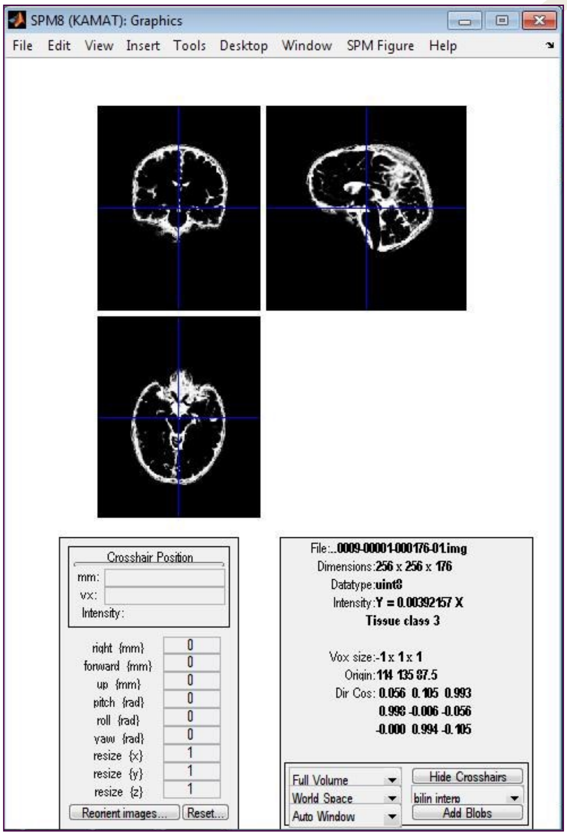

Fig. 8- Segmented CSF output for normal subject

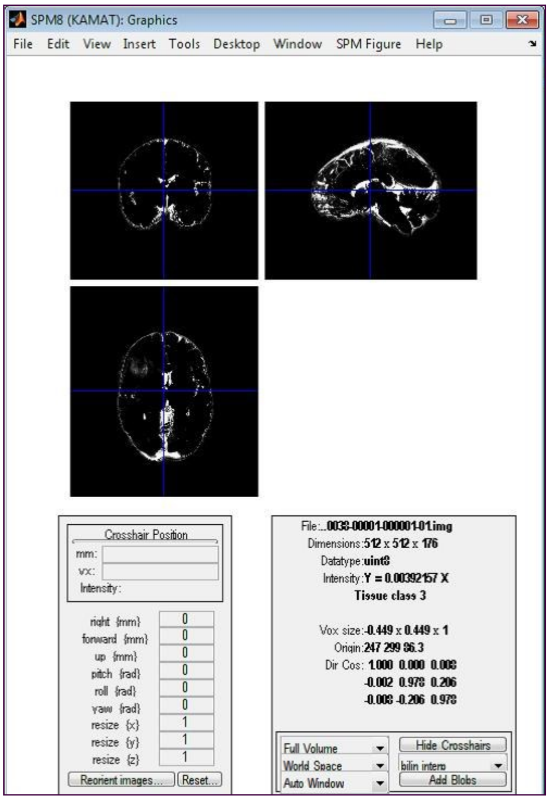

Fig. 9- Segmented CSF output for tumor patient

Normalization

In neuroimaging, spatial normalization is an image processing step, more specifically an image registration method. Human brains differ in size and shape, and one goal of spatial normalization is to deform human brain scans so one location in one subject's brain scan corresponds to the same location in another subject's brain scan.

Output: The normalized images [Fig-10], [Fig-11] are named the same as the originals, except that they are prefixed by wmrs.

Results

The images represent The Brain Activation for Motor Task [Fig-12], Sectional Overlay [Fig-13], [Fig-14]. The corresponding data represented by these images are also shown in the table as Statistical Result in SPM [Table-1], the Converted Co Ordinates from SPM To GingerALE [Table-2] and the Output in Talairach [Table-3].

The same steps of pre processing and post processing are followed and applied for right hand motor task. The entire procedure is repeated for processing the data of a normal person for the same motor task. The results so obtained are then compared.

Conclusion

The MRI and FMRI images of both normal subject and tumor patient are processed. A simple motor task consisting of finger tapping is used and a paradigm is designed based on general linear model in SPM. The results so obtained are exported to GingerALE and Talairach softwares for further analysis. It has been observed that there is a significant difference in the number of activated clusters for the motor task. The number of clusters has been found to be more in number than that of normal subject. This could be accounted for by the fact that in case of tumor patients there will be recruitment of compensatory mechanisms and hence multiple areas of brain to perform the motor task. Further, the exact lobe, component and Brodmann areas associated with activation have been determined so as to precisely locate the activation areas in and around the tumor. Based on these results a surgeon can decide the best possible approach in resecting the tumor with minimal damage to eloquent areas.

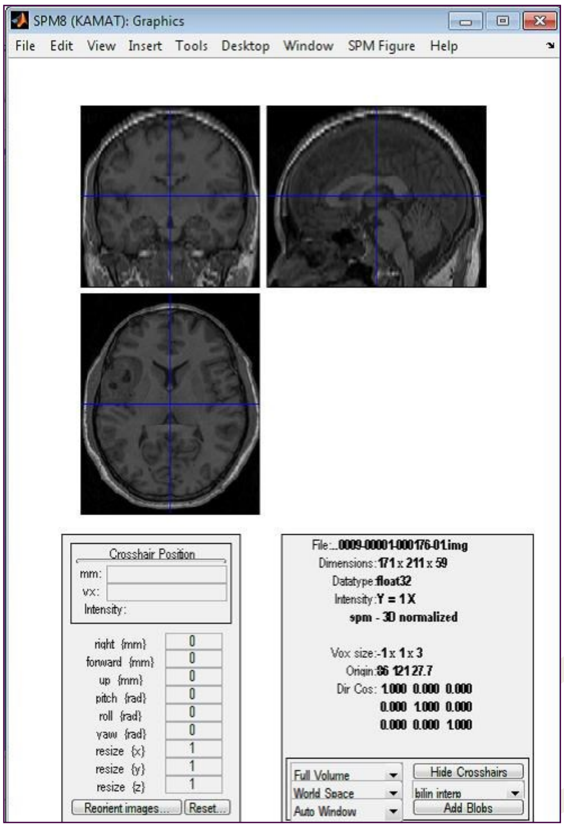

Fig. 10- Normalization Output for Normal Subject.

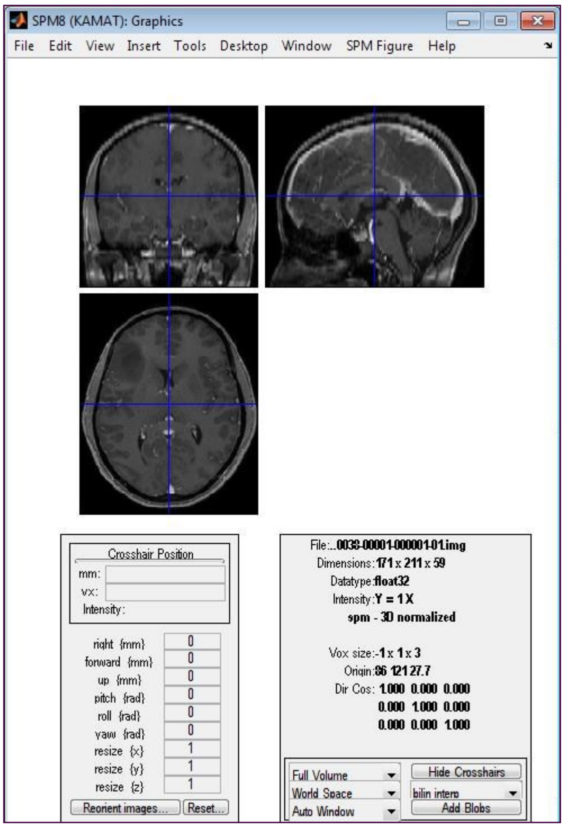

Fig. 11- Normalization Output for Tumor Patient

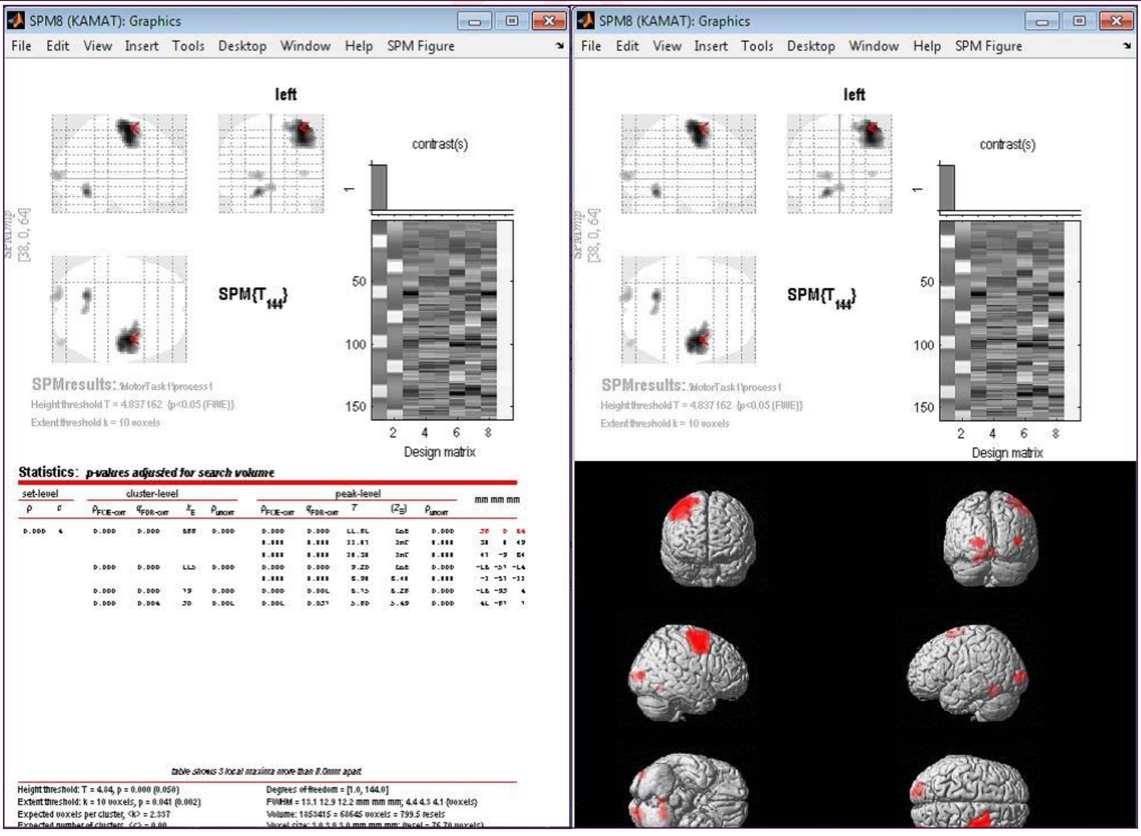

Fig. 12- Tumor Patient-Left Hand Motor Task

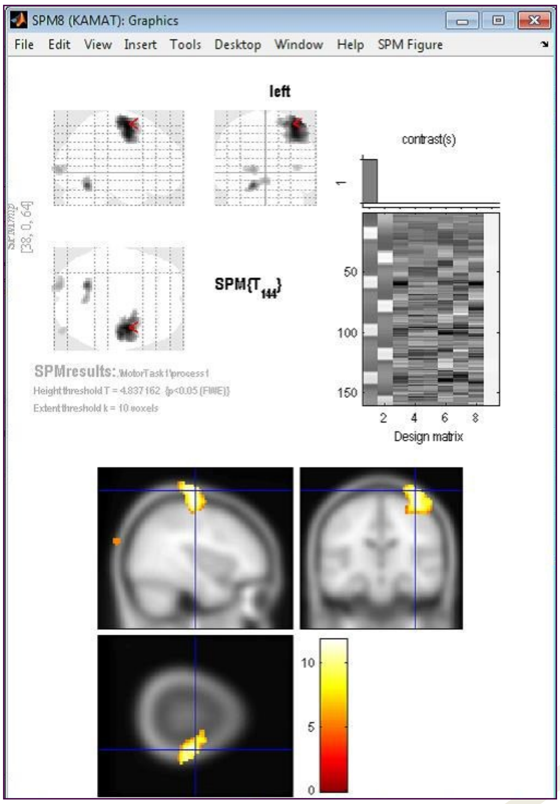

Fig. 13- Sectional Overlay on standard template

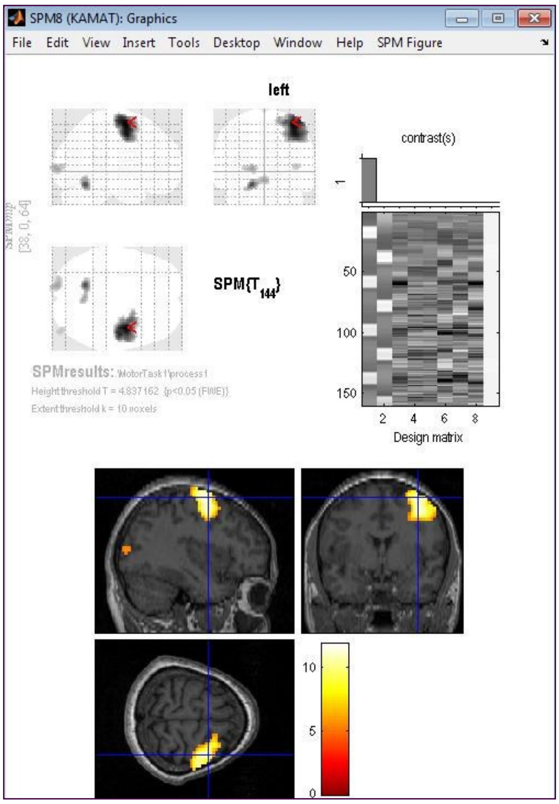

Fig. 14- Sectional Overlay on wmrs file

Table 1- Statistical Result in SPM

X,y,z{mm}	X,y,z{mm}	X,y,z{mm}	Record Number	X coor	Y coor	Z coor
38	0	64	1	33.39	-7.52	61.78
38	0	49	2	33.57	-6.22	48.4
47	-9	64	3	41.7	-15.95	61.13
-16	-57	-14	4	-15.8	-53.57	-13.68
-1	-57	-11	5	-1.95	-53.9	-10.77
-16	-93	4	6	-16.1	-88.68	-0.79
41	-87	7	7	36.63	-83.62	3.28

Table 2- Converted Co Ordinates from SPM To GingerALE

Cluster Equivk	Cluster P(unc)	Peak P(FEW-cor)	Peak P(FDR-cor)	Peak T	Peak equivZ	P(unc)
445	4.18E-18	0	6.5752E-11	10.5896664	65535	4.44089E-16
		0	1.69275E-10	9.78150845	65535	4.44089E-16
139	9.99E-09	4.2678E-10	6.88473E-08	8.59751797	7.70738467	6.43929E-15
100	3.77E-07	2.675E-09	2.63122E-07	8.27753353	7.47294422	3.91909E-14
56	4.32E-5	1.051E-08	7.90918E-07	8.0355835	7.29142555	1.53322E-13
20	0.006356	0.00411215	0.12050192	5.47607517	5.21032532	9.42549E-08
		0.00589082	0.153580594	5.38866472	5.13439141	1.41529E-07

Table 3- Output in Talairach

Record Number	X coor	Y coor	Z coor	Level-1	Level-2	Level-3	Level-4	Level-5	Appended Data
1	33.39	-7.52	61.78	Right Cerebrum	Frontal Lobe	Middle Front	Gray Matter	Brodmann	Area6
2	33.57	-6.22	48.4	Right Cerebrum	Frontal Lobe	Precentral G	Gray Matter	Brodmann	Area6
3	41.7	-15.95	61.13	Right Cerebrum	Frontal Lobe	Precentral G	Gray Matter	Brodmann	Area6
4	-15.8	-53.57	-13.68	Left Cerebellum	Posterior Lobe	Declive	Gray Matter	*	
5	-1.95	-53.9	-10.77	Left Cerebellum	Anterior Lobe	Culmen	Gray Matter	*	
6	-16.1	-88.68	-0.79	Left Cerebrum	Occipital Lobe	Lingual Gyru	White Matter	*	
7	36.63	-83.62	3.28	Right Cerebrum	Occipital Lobe	Middle Occir	White Matter	*	

Conflicts of Interest: None declared.

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