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Increased Activity of the Ipsilateral Motor Cortex during a Hand Motor Task in Patients with Brain Tumor and Paresis

Takashi Yoshiura, Kanehiro Hasuo, Futoshi Mihara, Kouji Masuda, Takato Morioka, and Masashi Fukui

PURPOSE: To look for changes in the motor cortex in patients with brain tumors. **METHODS:** Both cerebral hemispheres in seven patients with brain tumors were examined with functional MR imaging during a motor task performed by the hand opposite the site of tumor. The ratio of the activated area in the motor cortex ipsilateral/contralateral to the tested hand was calculated for each subject. Twenty healthy subjects were also examined in the same manner for comparison. **RESULTS:** The ratio of the ipsilateral/contralateral activated area was abnormally high in three patients with tumor-related paresis of the tested hand. The ratio was significantly greater in patients with paresis than in healthy subjects. **CONCLUSION:** This study demonstrated increased activity in the ipsilateral (unaffected) motor area during a hand motor task in patients with brain tumor and paresis, which was thought to reflect compensatory reorganization induced by the functional damage.

It is known that functional reorganization of the brain can occur after unilateral brain infarction. Chollet et al (1) studied the regional cerebral blood flow changes in patients with hemiplegic stroke by means of positron emission tomography. They found a significant change in regional cerebral blood flow during the motor task in the ipsilateral sensorimotor cortex as well as on the contralateral side. Using magnetoencephalography, Lewine et al (2) demonstrated reorganization of the somatosensory function in a patient's brain who had experienced an infarct in the unilateral cerebral hemisphere. The purpose of our study was to detect possible topographic changes of the human motor area in patients with brain tumor.

Materials and Methods

We examined two groups of subjects separately. All subjects were right handed. The first group consisted of 20 healthy volunteers (19 men and one woman; mean age, 26 years). The second group was composed of seven patients who had tumors in the pericentral region of the brain (Table 1); two of these patients had recurrent tumor. Four patients had tumor-related paresis of the corresponding hand.

The subjects were instructed to perform a motor task of self-paced apposition between the thumb and the fourth finger. For patients who were not able to perform this task successfully because of a motor disturbance, a hand grip task was used. In the patients, the hand contralateral to the affected hemisphere was tested; the volunteer subjects performed the task with either the right or left hand: 10 performed a right-hand task and 10 carried out a left-hand task. A single session consisted of three rest periods alternating with two task periods, each lasting approximately 40 seconds.

Magnetic resonance (MR) imaging was performed on a 1.5-T unit. To obtain the functional images, a single-shot blipped spin-echo echo-planar sequence was used. To simultaneously observe both hemispheres, 10 axial sections with a thickness of 3 mm were sequentially obtained downward from the vertex. Other parameters were set as follows: echo time, 18 milliseconds; field of view, 300 mm; matrix size, 128 × 128; pixel size, 2.34 × 2.34 mm. The measurement time was 226 milliseconds per section. In each task or rest period, the 10 sections were each imaged

TABLE 1: Neurologic symptoms and conventional and functional MR findings

Patient	Age, y/Sex	Tumor Location	Disorder	MR Findings		Paresis		Threshold z Score	No. of activated pixels		Ipsilateral Activation Index
				Edema	Distortion	Degree	Duration		Contralateral Motor Area	Ipsilateral Motor Area	
1	46/F	L middle frontal	Meningioma	Slight	Moderate	...	...	1.0	21	0	0
2	27/M	R precentral	Glioma	...	...	...	...	1.3	135	3	0.02
3	60/M	R middle frontal	Metastasis	Severe	Severe	...	...	1.645	149	48	0.32
4*	22/M	R parietal	Metastasis	Mild	Mild	Moderate	3 wk	1.0	50	0	0
5	40/M	L middle frontal	Recurrent glioblastoma	Slight	Slight	Mild	4 mo	1.645	50	29	0.58
6	43/F	L parietal	Recurrent meningioma	Slight	Severe	Mild	2 mo	1.645	7	31	4.43
7	65/M	R middle frontal	Meningioma	Mild	Moderate	Mild	>3 wk	1.645	45	46	1.02

* Patient 4 performed a hand grip task.

TABLE 2: Results of functional MR imaging in healthy volunteers

Tested hand (n)	No. of Activated Pixels, mean ± SD (range)		Ipsilateral Activation Index, mean ± SD (range)
	Contralateral Motor Area	Ipsilateral Motor Area	
R (10)	51.5 ± 45.0 (9–154)	3.8 ± 7.0 (0–20)	0.07 ± 0.10 (0–0.22)
L (10)	66.7 ± 33.8 (19–109)	4.0 ± 3.5 (0–9)	0.08 ± 0.09 (0–0.26)
Total (20)	59.1 ± 39.5	3.9 ± 5.4	0.07 ± 0.09

10 times, and the first image was discarded because of its unsaturated high signal intensity. Imaging during the task periods was begun approximately 5 seconds after the onset of finger motion, when the signal intensity in the activated areas reached a maximum.

Axial T1-weighted spin-echo images (300/14/3 [repetition time/echo time/excitations]) serving as localizers were obtained at exactly the same planes as the functional images. In addition, surface anatomy scanning (SAS) based on turbo spin-echo imaging (5000/130/2) was carried out for all subjects. In all patients with brain tumors, additional conventional noncontrast T1-weighted spin-echo images (464/14/1) and T2-weighted turbo spin-echo images (2805/90/1) and contrast-enhanced T1-weighted spin-echo images (464/14/1) were obtained.

Activated areas were depicted by means of z score maps, on which pixels with a significant increase of signal intensity during the task appeared bright. The threshold for the z score analysis was set at 1.645. When no ipsilateral activation was detected, a lower threshold (1.3 or 1.0) was applied. The z score maps were overlaid on both the corresponding T1-weighted images and the SAS images.

The activated pixels in the motor areas ipsilateral and contralateral to the tested hand were counted separately. In hemispheres without substantial distortion by tumor, we could determine the anatomic central sulcus on axial MR images by using a method first described by Kido et al (3). Although some researchers have reported that the anatomic precentral gyrus does not always agree with the functional primary motor cortex (4), we did not find such disagreement in our series. In most of our subjects, a small number of activated pixels were observed in the area pos-

terior to the anatomic central sulcus. This may represent sensory activation associated with the apposition task. Thus, we counted only the activated pixels clustering in the area anterior to the central sulcus. The ratio of ipsilateral to contralateral activation was calculated as follows: ipsilateral activation index = number of activated pixels in the ipsilateral motor area/number of activated pixels in the contralateral motor area. In all patients, the location of the motor area in the affected side, which was estimated with the use of functional MR imaging, was compared with that estimated with the intraoperative somatosensory evoked potentials.

Results

The experimental procedures were successfully carried out in all subjects. The findings in the volunteer group are summarized in Table 2. The precentral gyrus contralateral to the exercising hand was included in the activated areas in all subjects. The ipsilateral precentral area was activated by the right-hand task in four subjects, whereas it was activated by the left-hand task in seven subjects. Typically, the activated area in the ipsilateral motor area was much smaller than that in the contralateral motor area. The mean ipsilateral activation index was 0.07 in the right-hand task group and 0.08 in the left-hand task group. There was no sig-
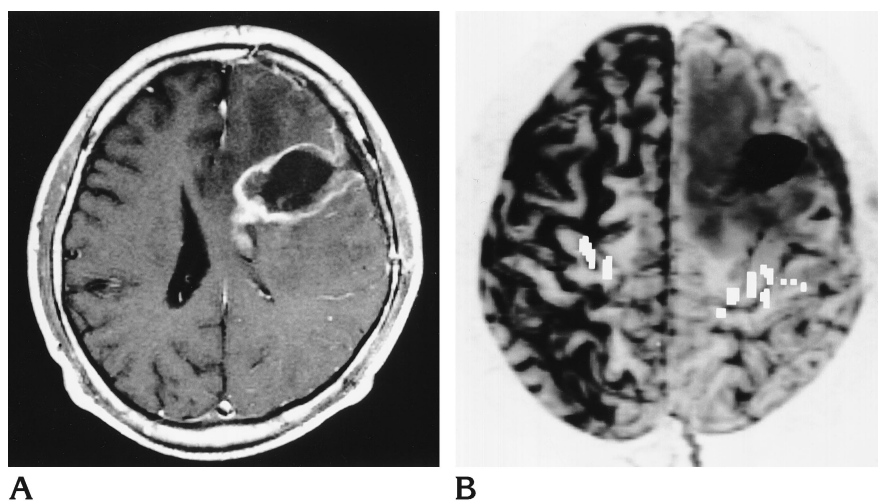
Fig 1. Patient 5.

A, Axial postcontrast T1-weighted MR image shows a recurrent glioblastoma in the left frontal lobe.

B, Motor functional MR mapping during the performance of a right-hand apposition task. The *z* score map is projected on an SAS image. The ipsilateral (right-sided) activation is substantial (the ipsilateral activation index = 0.58).
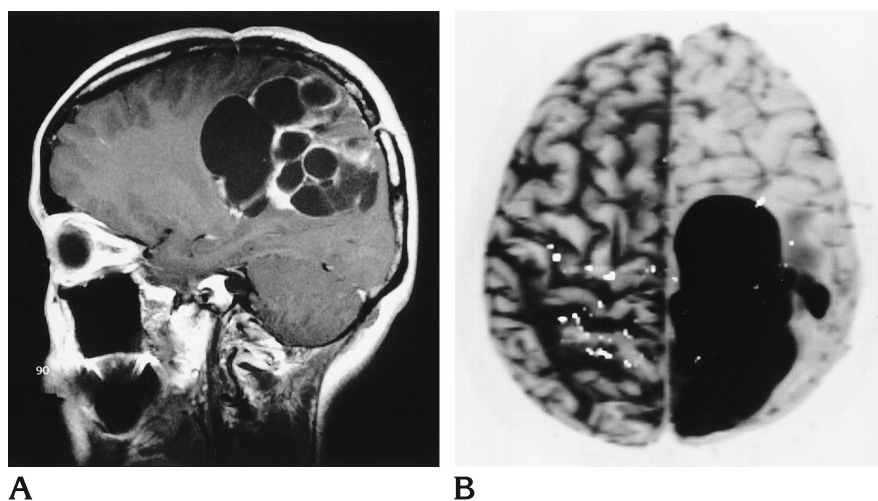

Fig 2. Patient 6.

A, Sagittal postcontrast T1-weighted MR image shows a recurrent cystic meningioma in the left parietal lobe.

B, Motor functional MR mapping during the performance of a right-hand apposition task. The activated area in the ipsilateral (right) motor area is larger than that of the contralateral (left) side (the ipsilateral activation index = 4.43).

nificant difference in the ipsilateral activation index between these two groups.

In the patient group, the location of the motor area estimated with functional MR imaging correlated well with the result of intraoperative somatosensory evoked potentials. Five patients showed ipsilateral activation. Although the mean value of the ipsilateral activation index was greater for the patients (0.91) than for the volunteers, no significant difference was found between these two groups.

As shown in Table 1, the ipsilateral activation index was extremely high in three patients (0.58 for patient 5, 4.43 for patient 6, and 1.02 for patient 7). The results for patients 5 and 6 are shown in Figs 1 and 2, respectively. All three of these patients had paresis of the tested hand. A comparison of the ipsilateral index in patients with paresis of the tested hand with that in healthy subjects showed that the index was sig-

nificantly higher in the patients (Mann-Whitney test, $P < .05$). In comparing the index in patients with paresis and those without paresis, however, we found no significant difference between these two groups.

Discussion

There have been many functional MR studies on the activation of the human motor cortex (4–9). Kim et al (5) reported smaller and weaker activation in the ipsilateral motor cortex as compared with the contralateral side using a 4.0-T MR imaging unit. Our findings in the healthy subjects closely correlate with those results. The less frequent appearance of ipsilateral activation in our series might be attributed to the lower magnetic field (1.5 T) of our MR imaging unit.

As stated earlier, activation of the ipsilateral motor cortex was abnormally stronger in three patients (patients 5, 6, and 7) than in healthy subjects. Bilateral activation of the sensorimotor cortex was observed on positron emission tomography scans obtained during a motor task performed by the hand recovering from hemiplegic stroke (1). Although the primary motor area was not affected in that series, our findings in the patients with a brain tumor may represent an equivalent of this phenomenon, which reflects reorganization of the brain induced by functional damage. Another possible explanation for the high ipsilateral activation index in our three patients is the loss of signal intensity change in the contralateral motor area by either tumors or coexisting edema. Morioka et al (10) suggested that edematous areas do not yield a strong signal intensity change because of the relative paucity of blood flow and lower metabolic demand. In our three patients, slight to mild edema was observed around the activated area in the contralateral hemispheres. However, edema in the contralateral motor area was also seen in patients 1, 3, and 4, who showed clear contralateral activation and a much lower ipsilateral activation index. Moreover, the numbers of activated pixels in these three patients were comparable with those of healthy subjects (Tables 1 and 2). It is thus likely that the higher ipsilateral activation index in these three patients was due to a stronger activation in the ipsilateral motor area. It is also possible that the strong activation in the ipsilateral motor area in these three patients represents contamination from associated movements of the hand ipsilateral to the tumor (untested hand). We found no apparent movement of the untested hand during the examination in any of the patients. Because electromyographic monitoring is not available in functional MR experiments, minor muscular activity in the untested hand cannot be completely ruled out. Such a small amount of activity in one hand, however, cannot fully explain the ipsilateral activation that was larger than the contralateral activation in two patients (patients 6 and 7).

As mentioned, the ipsilateral activation index in patients with paresis of the tested hand (patients 4, 5, 6, and 7) was significantly higher than that of healthy subjects. Patient 4, however, showed no detectable ipsilateral activation despite the appearance of moderate hemiparesis of the tested hand. One possible explanation

for this discrepancy could be the duration of damage. A rapidly progressing hemiparesis in this patient occurred only 3 weeks before functional brain mapping. On the other hand, a relatively long period of subclinical or clinical damage to the motor cortex could be postulated in the remaining three patients (patients 5, 6, and 7). Patients 5 and 6 had recurrent tumors. In patient 5, mild right hemiparesis due to tumor occurred shortly before the first craniotomy was performed and approximately 4 months before the functional MR mapping. Although this paresis improved slightly after partial removal of the tumor, it thereafter deteriorated with regrowth of tumor. Patient 6 had undergone her first craniotomy 7 years before functional MR brain mapping. She had a mild but progressive weakness of the right hand for approximately 2 months. Patient 7 was not aware of the minimal paresis of her left hand, owing to a meningioma that had been diagnosed when she first visited our hospital, 3 weeks before undergoing functional MR mapping.

Preliminary reports have documented the clinical value of preoperative functional MR mapping of eloquent cortex in patients with brain tumors (7, 8). Our study suggests that functional MR imaging may also be useful for identifying tumor-induced reorganization of motor function across hemispheres. Further studies may reveal that this finding can be a predictive factor for recovery of motor function after brain tumor surgery.

Acknowledgments

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