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Functional magnetic resonance imaging to word generation task in a patient with Broca's aphasia

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Abstract We describe the findings of functional magnetic resonance imaging (fMRI) in a patient with Broca's aphasia. The patient was a 45-year-old, right-handed woman who developed Broca's aphasia after infarction in the left frontal lobe. The first fMRI showed no signals in the left frontal lobe during verbal tasks, 2 weeks after the onset of infarction. Four weeks later, when the patient's symptom had improved, the second fMRI showed some increase in the fMRI signals in the left frontal lobe. Seven months later, she had completely recovered the ability to speak. The last fMRI then showed

that the increment in signal activity in the left frontal lobe during verbal tasks had recovered to the level seen in normal subjects. There was a good correlation between the increase in task-related signals in Broca's area and the recovery of language function. Our findings show that fMRI has can be important in assessing cognitive functions in patients with Broca's aphasia.

Key words Functional magnetic resonance imaging · Cerebral infarction · Broca's aphasia

Introduction

Since Ogawa et al. [8] reported the imaging of brain function using a relative decrease in deoxyhemoglobin (blood oxygenation level dependent) functional magnetic resonance imaging (fMRI) has been used to study the effect of various stimuli such as exercise, somatic stimulation, visual stimulation, auditory stimulation, speech, memory, and learning. There have been some studies of fMRI findings obtained with word-generation tasks in normal subjects [1, 2, 5, 7, 9] but not in patients with Broca's aphasia. Our study was designed to study the fMRI findings in a patient with Broca's aphasia.

Patient and methods

A Magnetom Vision 1.5-T system (Siemens, Erlangen, Germany) was used for fMRI. For anatomical positioning 15 axial slice im-

ages (3 mm thick, gapless) were obtained from the frontal to parietal regions by the T1-weighted spin echo method (repetition time/echo time = 500/15). From the T1-weighted images the slice planes containing the inferior frontal gyrus and insula were selected, and fMRI was performed using the fast low angle shot technique with a gradient echo sequence (repetition time/echo time/flip angle = 90 ms/56 ms/40, matrix = 128 × 256, slice thickness = 3 mm, field of view = 250 mm, acquisition time/image = 14 s). The verbal task used in the analysis was repeated vocalization of a stereotyped sentence "Tonari no Kyaku ha yoku Kaki kyu Kyaku da," which is very familiar with almost of all Japanese as a tongue twister. It is not difficult for subjects to recall. The patient was asked to repeat it precisely, and as steady paced as possible. Each series consisted of five images obtained at rest and during the verbal task. Three series were obtained.

The activated sites were evaluated with the following three-step procedure. Firstly, a functional map was produced from the images obtained using the Z-score [6]. To test for differences in signal between activation and rest the normal standard deviate, Z, was calculated for each pixel, as $Z = (\mu_A - \mu_R)/SD$, where μ_A is the mean signal intensity during activation, μ_R is the mean signal intensity during rest, and SD is the standard deviation of the measurements. In theory, activation would be considered significant if Z is larger than a given threshold. Secondly, the functional map

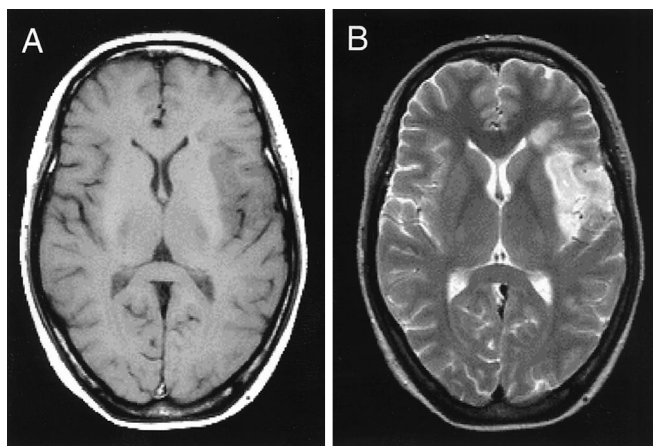


Fig. 1 A, B MRI in a 45-year-old, right-handed woman with right hemiparesis and motor aphasia. **A** Spin-echo TR/TE: 500/15. **B** Spin-echo TR/TE: 4200/90. Her MRI reveals the presence of infarct lesions in the left inferior frontal gyrus, insula, white matter in the middle frontal gyrus, and the inferior area in the precentral gyrus

was superimposed over the images of the same slices obtained by the T1-weighted spin echo method, and the activated sites were identified. Finally, at least two regions of interest (ROI) were established at the activated sites in the left inferior frontal gyrus and insula. In each ROI, a time-intensity curve was produced and evaluated. Changes were evaluated by this procedure 2 weeks, 4 weeks, and 7 months after the infarction. The Japanese Standard Language Test for Aphasia (SLTA) [4] was used to evaluate language functions. The SLTA is the standardized battery test most commonly used in Japan. Briefly, the correct responses in the SLTA testing are shown from 0% = most severe to 100% = normal. The following categories of the SLTA were analyzed in this study: auditory comprehension (to obey verbal commands), speaking (object naming, word repetition, sentence repetition), reading comprehension (follow written commands, sentence picture matching, etc.), writing (dictation of kana letters and dictation of short sentence), and calculation.

Patient

A 45-year-old, right-handed woman noticed mild headache and difficulty in speech at about 6:00 a.m. on 28 May 1995, and was admitted to hospital. On admission, mild paresis was observed in the right upper and lower limbs. Seven days later, MRI showed infarct lesions in the left inferior frontal gyrus, insula, white matter in the middle frontal gyrus, and the inferior area in the precentral gyrus (Fig. 1). Magnetic resonance angiography, which was performed simultaneously, revealed a stenotic lesion in the middle cerebral artery M1 portion. On admission, neurological examination showed no abnormality in articulation of speech or the production of sound, but her spontaneous speech was not fluent. Writing short sentences to dictation was impossible. Sentence and word repetitions were less impaired than in short sentence dictation. Also, her handwriting was poor. On the other hand, her recognition was not so badly affected, although both auditory and reading comprehension was mildly impaired. In general, expression was more impaired than comprehension. The finding of the first examination of SLTA was compatible with Broca's aphasia (Table 1). The time course of aphasia is shown in Table 1. Two months later, the second SLTA was performed; values had returned to normal except in some subset items of both speaking and writing cate-

Table 1 Patient's profile based on the SLTA: after 2 weeks expression in speaking and writing categories was more impaired than comprehension categories, after 2 months marked improvement was noted in the speaking and writing categories, and 7 months later the last SLTA showed full recovery to normal values

	2 weeks	2 months	7 months
Auditory comprehension	65	100	100
Auditory word recognition	100	100	100
Sentence comprehension	90	100	100
Follow verbal commands	20	100	100
Kana letter discrimination	50	100	100
Speaking	55.3	97	99.5
Objective naming	55	100	100
Word repetition	100	100	100
Describe behaviors	40	100	100
Explain picture story	0	80	100
Sentence repetition	60	100	100
Listing words (words fluency)	8	90	95
Read aloud kanji words	100	100	100
Read aloud kana letters	90	100	100
Read aloud kana words	100	100	100
Read aloud short sentence	0	100	100
Reading comprehension	82.5	100	100
Kanji word-picture matching	100	100	100
Kana word-picture matching	100	100	100
Sentence picture matching	90	100	100
Follow written commands	40	100	100
Writing	30	91.1	100
Write kanji words	40	80	100
Write kana words	0	98	100
Narrative writing	0	80	100
Dictate kana letters	90	100	100
Dictate kanji words	60	100	100
Dictate kana words	20	100	100
Dictate short sentences	0	80	100
Calculation	50	90	98

Unit: %

gories. Seven months later, the last SLTA showed improvement to the upper limit for almost all subsets.

She gave informed consent, and the procedure for fMRI study was approved by the local ethics committee.

Results

fMRI performed 2 weeks after infarction showed no signals in response to the verbal tasks. Four weeks later, T1-weighted spin echo MRI revealed lesions in the left frontal regions (Fig. 2A). There were no definite signals in response to the verbal tasks in the infarct lesions, but there was an increase in blood flow in the left sylvian fissure (Fig. 2B). Seven months later, T1-weighted MRI revealed old lesions in the left frontal regions (Fig. 3A). Definite signals were elicited in response to the verbal

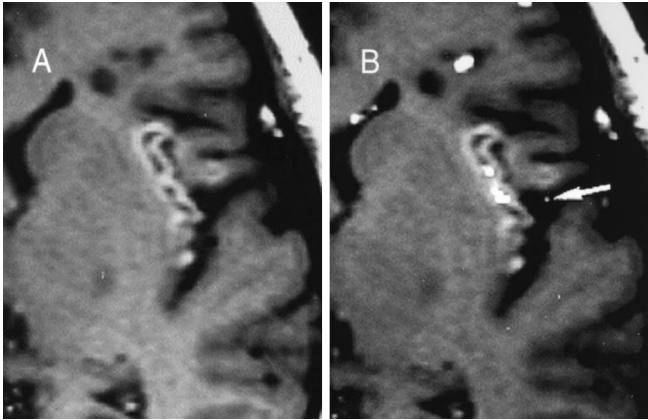


Fig. 2 A, B Four weeks later. **A** T1-weighted spin-echo imaging shows lesions in the left frontal regions. **B** fMRI shows no signals in response to word generation task in the infarct lesions but the increase in blood flow in the left sylvian fissure (*arrow*)

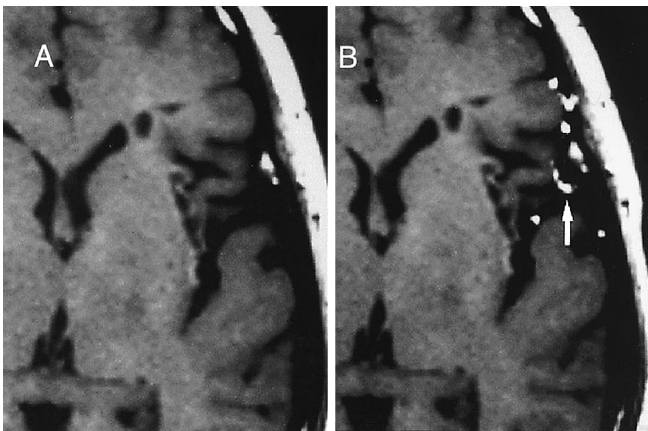


Fig. 3 A, B Seven months later. **A** T1-weighted MRI shows old lesions in the left frontal regions. **B** fMRI shows definite signals with word generation task in the left inferior frontal gyrus, sylvian fissure, and precentral gyrus but no signals in the infarct lesions

tasks in the left inferior frontal gyrus, sylvian fissure, and the precentral gyrus, but no signals appeared in the infarct lesions (Fig. 3B). ROIs were established at the activated sites in the left inferior frontal gyrus. Figure 4 shows the time-intensity curve on the ROI. The signal in ROI significantly increased about 20% when the task was performed. This level was maintained during the verbal tasks but decreased after their discontinuation.

Discussion

fMRI can reveal the location of MRI signal changes associated with cerebral activity. There have been previous fMRI studies of word generation tasks in normal subjects; however, this technique has not been used to study word generation in patients with Broca's aphasia. Broca's area

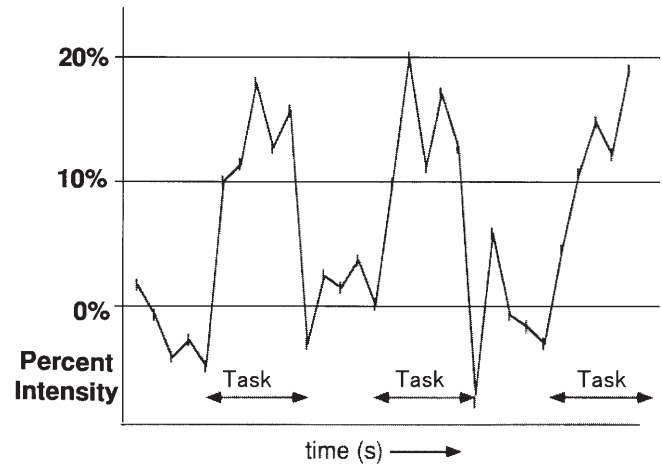


Fig. 4 ROI established at the activated sites in the left inferior frontal gyrus (*arrow*) in Fig. 3B. The time-intensity curve on the ROI: signal increased by 20% with vocalization but decreased after the discontinuation of speech

comprises the left inferior frontal gyrus (operculum, trigone) and inferior part of the precentral gyrus [3]. Our patient's clinical symptoms suggested Broca's aphasia, and MRI showed infarct lesions in the inferior frontal gyrus, insular cortex, and precentral gyrus. fMRI performed 2 weeks later, when marked impairment of expression was observed, showed no signals with the verbal tasks. After 4 weeks, when repetition and comprehension had partially recovered, but she still could not recall the name of some materials, the increase in signals in the second fMRI study was not observed in the infarct lesions, but in the left sylvian fissure. Seven months later, when her clinical symptoms had improved, the last fMRI revealed an even greater increase in task-related signals with the verbal tasks in the left inferior frontal gyrus, sylvian fissure, and the precentral gyrus. Thus the fMRI findings showed functional recovery to the verbal tasks in the inferior frontal gyrus, which is the region responsible for speech, and also which reflected the course of recovery from Broca's aphasia. Cuenod et al. [2] found that the fMRI signals with the word generation task was observed predominantly in the left cerebral hemisphere, mainly in the frontal lobe (Broca's area). The fMRI findings in our patient after she had completely recovered from motor aphasia were consistent with those in their study.

The mechanism of recovery from Broca's aphasia may be reductions in brain edema in damaged tissues and the development of collateral circulation. Two categories of brain edema are recognized, vasogenic and cellular. In general, even when vasogenic edema improves, cellular edema persists for 3–4 weeks. Therefore the increase in brain blood flow in fMRI observed with the word generation task 4 weeks later suggested improved microcirculation due to reduced cellular edema. On the other hand, the greater increase in task-related signals in the left infe-

rior frontal gyrus 7 months later could represent functional recovery due to the development of collateral circulation.

When Broca's area (opercular and triangular portions of the left inferior frontal gyrus, or Brodmann's areas 44, 45) is damaged, a transient or mild motor aphasia is observed [10]. Persistent Broca's aphasia is thought to be due to damage not only in Broca's area but also in more

extensive areas containing the insula, frontal operculum, middle frontal gyrus, corona radiata, and arcuate fasciculus. However, these regional limits are not distinct. In our patient it was of interest to note that the increase in task-related signals in Broca's area was associated with the recovery of language function. Our findings show that fMRI can be of importance in assessing cognitive functions in patients with Broca's aphasia.

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