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Introduction

Sensory extinction denotes a failure to appreciate a stimulus when a similar stimulus is applied to a corresponding part of the body simultaneously. The patient is quite able to report a tactile stimulus from either side of the body when it presented alone. It is only when the stimuli are presented simultaneously that the disorder comes to light. Although various theories have been developed, exact mechanisms of tactile extinction phenomena are far from clear.

The increased regional cerebral blood flow (rCBF) in human first somatosensory cortex to vibrotactile stimulation is well documented[1]. The rCBF responses to vibrotactile hand stimulation do not change with normal aging[2]. Assuming rCBF to be an indicator of local neuronal activity, we examined the rCBF response in human somatosensory cortex to either unilateral or bilateral vibratory stimuli in patients with tactile extinction and age-matched controls.

Clinical Material and Methods

Five patients who were suffered from cerebrovascular disease and demonstrated tactile extinction phenomena were selected. Four patients had right-sided lesions and one had left-sided lesion. Table 1 details clinical data on the patients. A rCBF study was performed more than three months after ictus. At this stage all of them were alert and cooperative and demonstrated multi-modal extinction phenomena on the side contralateral to the lesion. Four normal volunteers were studied in the same manner. There was no significant difference in age between patient and control groups (Table 2).

PET (Model PT931, CTI) was used for measuring the rCBF with $C^{15}O_2$ steady state inhalation method. This system simultaneously acquires seven parallel slices, 8 mm in thickness, and has an inplane resolution of 8 mm (full width at half maximum). Prior to all emission measurements, a seven-slice tomographic transmission image was obtained for calculation of regional attenuation coefficients.

The subjects were placed supine. A radial arterial catheter under local anesthesia was inserted to permit frequent sampling of arterial blood. Head position was adjusted with the aid of laser alignment beams, and bed position was not changed throughout an examination. During each PET scan, the subject's eyes were closed in the dimly lit room. Ears were not plugged, but ambient room noise during the scans was almost entirely from cooling fans for the electronic equipment. Each subject was specifically instructed to relax with eyes closed, and not to grasp the vibrator (passive vibration). Written informed consent was obtained for all subjects before each PET study.

Cerebral blood flow was measured using an emission scan following the inhalation of $C^{15}O_2$(10-15 mCi/min) for seven minutes. Arterial blood samples were obtained at 1, 2, and 3 minutes after starting scan acquisition. All subjects had measurements of CBF in the following conditions: Cl) the resting baseline state; C2) during vibrotactile stimulation with a commercially available vibrator held to all five finger pads of right hand by a band; C3) during vibrotactile stimulation to left hand in the same manner; C4) during vibrotactile stimulation to both hands simultaneously; C5) the resting baseline state. For two of the five patients, conditions C2 and C3 were studied in reverse order to balance the experimental design. All stimuli were started 240 sec. prior to start of the data accumulation and continued throughout the 210 sec. data accumulation period. An interscan interval was 240 sec. Regional CBF was calculated according to Frackowiak et al[3)].

Data Analysis

Global CBF values were calculated for each scan. To prevent confounding task-induced focal CBF changes with effectively random global CBF changes, rCBF levels were analyzed after normalization. It consisted of multiplying every pixel of each CBF scan by a normalization factor, calculated as the mean global CBF at baseline divided by the scan global CBF.

We used subtraction image techniques to analyze regional blood flow responses. Subtraction images were constructed by a pixel-by-pixel subtraction of the appropriated resting-state from activated-state images. Thirty square regions of interest, 4×4 pixels in size, were then placed from frontal to occipital cortex at the level of slice which includes first somatosensory cortex for the hand. Identification of the postcentral gyrus was ensured by way of matching CT slices obtained for the same patient and the anatomical atlas[4)]. Relative rCBF changes in % were calculated with respect to the baseline rCBF values. Comparisons among more than two conditions were made with a one-way repeated-measures analysis of variance. Comparisons among two conditions were made with a t-test. Data in the right and left hemispheres were analysed separately in the patient group.

Results

Mean global CBF in the first baseline state (before stimulation studies) was significantly higher than that in the second baseline state (after stimulation studies) in the right hemisphere of the right-sided stroke patients ($p<0.05$). There was the similar trend in the control group. The second baseline state was used as a reference, because many factors such as anxiety might affect the first baseline state.

In the control group, rCBF increased more than three percent in the right inferior parietal lobule in all the three activated-states. In the right- and left-sided stroke group, however, rCBF increase in the right inferior parietal lobule was not obvious in any condition.

Regional CBF changes in the somatosensory cortex during vibrotactive stimulation are represented in table 3. Concerning the first somatosensory cortex contralateral to the stimuli, significant increase in rCBF was observed with both unilateral and bilateral stimulation in the control group. In the right-sided stroke group, rCBF in the left somatosensory cortex increased significantly with right-sided stimulation. However, increase in rCBF in the left somatosensory cortex was small with bilateral stimulation, and was significantly different from that with unilateral right-sided stimulation. In the right somatosensory cortex, no significant rCBF response was obtained in any conditions. In a left-sided stroke patient, rCBF increase was observed in the right somatosenstory cortex with contralateral and bilateral stimulation.

Discussion

We found rCBF increase in the right inferior parietal lobe in the control group in all the three activated-states, but not in the patients with right- or left-sided cerebral infarction. The unique role of the inferior parietal lobe in regulating sensory integration and attention in primates has been suggested by ablation studies[5)], axonal tracing investigations[6)], and single cell recordings[7)]. Clinical data suggest that lesions in this area are more likely to be associated with hemispatial neglect and multimodal extinction phenomena[8)]. Visual and verbal stimulation caused asymmetrical increase in local cerebral glucose metabolism in the inferior parietal lobule, reflecting relatively greater right metabolism in stimulated subjects[9)]. This finding is in accordance with our results with vibrotactile stimulation. Furthermore, in the patient group, decreased capacity to respond to the vibrotactile stimulation in the inferior parietal lobule may have relation to the extinction phenomena.

Regional CBF response in the left somatosensory cortex was significantly greater with right-sided unilateral stimuli than with bilateral stimuli in patients with right-sided cerebral infarction. The similar tendency was observed in the control group. These findings suggest the reciprocal inhibition between right and left hemispheres during the simultaneous stimulation to both sides. This reciprocal inhibition could be one of the causes for extinction phenomena. Regional CBF in the right somatosensory cortex, however, did not change significantly in any conditions in right-sided stroke patients. It may be due to decreased ability to respond to stimulation in the side of stroke, even at the chronic stage.

Our results suggest that impaired directed attention and the reciprocal inhibition between two hemispheres cause vibrotactile extinction phenomena. Further studies are necessary to reveal the mechanism of visual and auditory extinction phenomena.

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Table 1. Clinical Data.

No.	Age/Sex (yr)	Education (yr)	Months to PET	Lesions	Extincion	Sensory Deficiency
1	73/M	9	6	Rt.F-P	tac,vis,vib	none
2	54/M	6	12	Rt.BG,CR	tac,vis,vib	mild
3	66/M	12	3	Rt.watershed	tac, vib	mild
4	65/M	9	5	Rt.F-P	tac, vib	mild
5	46/M	9	6	Lt.P	tac, vib	mild

F = frontal lobe; P = parietal lobe; BG = basal ganglia; CR = corona radiata;

Rt. = right-sided; Lt. = left-sided; tac = tactile; vis = visual; vib = vibratory.

Table 2. Patient and control groups for rCBF study.

		patient	control
No.		5	4
Age(yr)	Mean	60.8	73.0
	SD	9.58	5.79

yr = year; SD = standard deviation.

Table 3. Regional CBF changes in the somatosensory cortex during vibrotactile stimulation.

	Vibration		
	Contralateral	Ipsilateral	Bilateral
Control-SI	19.02+7.36*[a]	1.46+6.95*[b]	7.76+18.38*
Patient with Right-sided stroke			
Right-SI	16.18+10.68	4.24+10.18	15.68+12.45
Left-SI	20.68+10.33*[c]	0.72+18.72*[d]	5.98+6.78*[e]
Patient with Left-sided stroke			
Right-SI	10.45	-2.57	11.24
Left-SI	17.77	12.03	11.57

All response increases in local cerebral blood flow (CBF) are expressed in percentages.

*$p<0.05$ (ANOVA), a x b $p<0.05$ (t-test), c x d $p<0.05$ (t-test), c x e $p<0.02$ (t-test). SI = first somatosensory cortex.