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Study on the primary visual cortex of visually impaired subjects by means of ^{123}I-IMP SPECT and MRI

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We conducted a study of rCBF in the primary visual cortex of visually impaired subjects who have not been subjected to external stimulation for a long period, by means of ^{123}I-IMP SPECT and MRI. The four subjects had lost their sight due to brain tumors (n = 2), glaucoma (n = 1) and trauma (n = 1). ^{123}I-IMP SPECT showed no differences between the visually impaired group and a visually sound control group on visual analysis as well as semiquantitative analysis. MRI of the visually impaired subjects showed no organic changes, such as atrophy, in the occipital cortex.

In conclusion, visually impaired subjects have no decrease in rCBF and no anatomical changes in the primary visual cortex.

Key words: visual cortex, rCBF, SPECT, MRI, ^{123}I-IMP

INTRODUCTION

THE CLINICAL SIGNIFICANCE of measuring regional cerebral blood flow (rCBF) with N-Isopropyl-*p*-[^{123}I] iodoamphetamine (^{123}I-IMP) and technetium-99m-*d,l*,-hexamethyl propylene amine oxime (^{99m}Tc-HMPAO), a lipophilic brain perfusion scanning agent, has already been recognized. It is effective in predicting cerebral infarction at an earlier stage than CT or MRI in patients with cerebrovascular disease, and can even detect a minor decrease in rCBF that has not caused organic changes.[1,2] This method is also useful in diagnosing or observing the progress of degenerative diseases such as mitochondrial encephalomyopathy with lactic acidosis and stroke-like episode (MELAS) syndrome and Alzheimer's disease, as well as functional diseases including epilepsy.[3,4] Recently, the method has been applied to assessing the functional responses of parts of the brain to visual stimuli or finger loading.[5,6]

The primary visual cortex is located in the occipital lobe and normally has an abundant blood flow. It is of interest to determine the rCBF in the visual cortex after it has been closed to external stimulation for a long period because of the complete loss of eyesight, though the rCBF was assumed to decrease shortly after the eyesight loss.

In individuals who lost their sight after birth, we conducted a study of the rCBF in the primary visual cortex with the ^{123}I-IMP SPECT and on the same day performed MRI for assessment of anatomical changes.

SUBJECTS AND METHODS

The subjects were four adult men aged between 23 and 39 years (mean age: 31.75 years old), who lost their sight at the ages of 1 to 25, and their duration of visual impairment was from 7 to 28 years. They were all right-handed and had no psychoneurological disorders. Two of them lost their sight before surgery for brain tumors which cannot be detailed, one as a result of glaucoma, and one because of left eyeball injury when hit by a ball at 25 years old and followed by sympathetic ophthalmopathy of the right eye at 26 years old (Table 1). Four age-matched individuals with hardness of hearing but otherwise normal were selected as controls (mean age: 29.50 years). All subjects were informed of the purpose, possible risks and methods of the experiments, after which they gave informed consent.

For ^{123}I-IMP SPECT, all subjects rested in the supine

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Table 1 Characteristics of subjects

Visually impaired group

Case	Age	Sex	Etiology for impairment	Duration (years)	Visual Cortex Accumulation Index right	Visual Cortex Accumulation Index left
1	39	M	brain tumor at 11 years old	28	1.276	1.323
2	23	M	brain tumor at 1 year old	22	1.259	1.399
3	32	M	glaucoma (right: 8 years old; left: 10 years old)	22	1.258	1.370
4	33	M	injury of eyeball (left: 25 years old followed by right: 26 years old)	7	1.318	1.337
(mean)	31.75			(mean ± SD)	1.277 ± 0.281	1.357 ± 0.341
					1.317 ± 0.051	

Visually sound group

Case	Age	Sex	Visual Cortex Accumulation Index right	Visual Cortex Accumulation Index left
1	28	F	1.347	1.336
2	19	F	1.278	1.251
3	44	M	1.380	1.393
4	27	M	1.246	1.251
(mean)	29.50	(mean ± SD)	1.312 ± 0.615	1.307 ± 0.695
			1.310 ± 0.061	

position for 15 minutes with their eyes closed. They were then intravenously injected with ^{123}I-IMP (111 MBq). Fifteen minutes later, data were collected with a SPECT unit designed exclusively for the brain (SET 050; Shimadzu Seisakusho Co.) with a high resolution collimator. Data reconstruction was done with a filtered back-projection algorithm and a Butter-Worth filter. Attenuation correction was done using the method recommended by the machine maker.

MRI was done by means of a superconducting MR unit with a static magnetic field strength of 1.5 T (Singa Advantage; General Electric Co.). T1-weighted spin echo images (TR/TE = 80/30) and T2-weighted images (TR/TE = 3,000/60) were acquired.

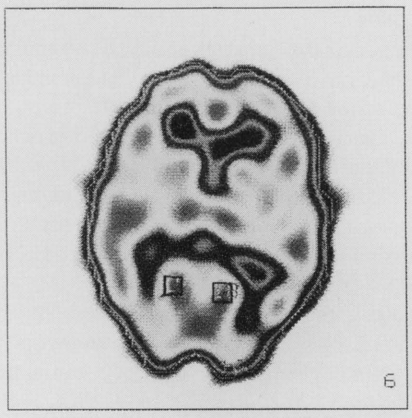
Two methods were used for image analysis: one was visual diagnosis by 3 certified nuclear medicine specialists and the other was semiquantitative assessment of the accumulation of radioactivity. For semiquantitative assessment, the visual cortex accumulation index (VAI) was calculated as follows:

$$\mathrm{VAI} = \frac{\text{mean visual cortical counts}}{\text{mean whole brain counts}}$$

The outlines of 10 SPECT transaxial images (each 10 mm thick) were extracted by the 40% cut-off method. Then the mean counts per pixel (3.28 mm × 3.28 mm) of the five successive slices out of these 10 with higher radioactivity levels were calculated. The counts of these five slices having a higher accumulation agreed with those of contiguous slices including the basal ganglia. The mean counts per pixel in rectangular regions of interest (ROI) (6.56 mm × 6.56 mm) set over both primary visual cortices were used to calculate the VAI (Fig. 1).

RESULTS

Visual analysis: The perfusion SPECT images of the visual cortex of the visually impaired subjects were enough and almost symmetrical, and estimated to be almost identical to those of the control subjects. In addition, no changes such as atrophy of the visual cortex were found by MRI. MRI of one subject who had lost his sight due to a brain tumor revealed an asymptomatic tumor in the right basal temporal lobe. His SPECT image also revealed a perfusion defect in the same region. The brain MRI of the other subject with a history of the brain tumor resection at eleven revealed an infarcted area in the bilateral frontal medulla, corresponding to slightly decreased rCBF in the



ROI#	Max	Min	Counts	Pixels	Mean	S.D.	
Whole Brain							
1	65	11	44952	1548	29.04	11.55	
2	64	9	48279	1548	31.19	14.03	
3	62	8	56329	1548	36.39	12.77	
4	61	12	64125	1548	41.42	10.41	
5	65	14	70512	1548	45.55	9.49	
6	63	23	70831	1548	45.76	9.60	
7	63	13	66207	1548	42.77	9.93	mean
8	63	9	62221	1548	40.19	11.53	43.13
9	62	5	58182	1548	37.59	13.88	
10	55	6	48334	1548	31.22	13.87	
Visual Cortex							VAI
right	62	52	930	16	58.13	3.36	1.347
left	62	51	922	16	57.63	3.32	1.336

Fig. 1 Example of calculation of the visual cortex accumulation index. Five out of ten SPECT images with higher counts were used to calculate the mean counts for the whole brain. The mean counts for the visual cortex were calculated in the rectangular ROI (6.56 mm × 6.56 mm).

^{123}I-IMP SPECT.

Semiquantitative analysis: The VAI of the visually impaired subjects was 1.317 ± 0.051 (mean ± SD), while that of the control group was 1.310 ± 0.061, and there was no significant difference ($p > 0.05$, unpaired t-test) (Table 1). There was also no significant difference in VAI between the right and the left visual cortex of both groups ($p > 0.05$, unpaired t-test).

DISCUSSION

Visual information reaches the primary visual cortex of the occipital lobe at first, followed by transmission to the associated fields of the parieto-occipital lobe, parietal lobe, and occipital lobe. The primary visual cortex has a comparatively high blood flow like the cerebellum when a subject is at rest with the eyes closed. Generally, the regional blood flow of the visual cortex is said to decrease when the eyes are closed. Measurement of rCBF in the primary visual cortex by ^{18}F-deoxyglucose PET has indicated an increase in metabolism and perfusion with light stimulation.[7] The intricacy of the stimulus increases the response of the visual cortex and the involvement of the visual associated fields. By means of SPECT, Wood et al. found a significant increase in perfusion of 16.8% in the occipital lobe after stimulation with a stroboscopic light.[5]

Brain perfusion SPECT is generally performed with the patient resting with the eyes closed, since visual stimulation affects rCBF. A significant difference exists from person to person with regard to accumulation in the visual cortex, making it fairly difficult to define a true baseline blood flow. In our semiquantitative study, the VAI values in each person tested were similar to the results of Wood et al, although the method differs slightly from that used by them.[5] There were also no significant differences from the results in the control subjects. Measuring rCBF is considered to yield good results when the cerebellum is used as a reference region, but we could not prove it this time because of mechanical constraints.

Our visual analysis showed no significant difference in the rCBF of the primary visual cortex between the visually impaired and control subjects, and no anatomical abnormalities were found by MRI. Four subjects with hardness of hearing were used as the control, their age matching that of visually impaired subjects. It is feared that the rCBF of these subjects decreases, but this was not confirmed in ^{123}I-IMP SPECT.[8]

The age at which our subjects lost their sight was between 1 and 25 years, but we could not find any definite relationship between the time of visual loss and the rCBF. Blood flow in the primary visual cortex and the occipital lobe reaches the adult level at an early age and visual defects that occur later may not adversely affect the growth of the occipital lobe.[9] The occipital lobe of visually impaired patients is said to have a much richer blood flow than that of visually normal individuals, in despite of the lack of external stimuli, because they are very imaginative and resultant feedback may contribute to maintaining this blood flow. The reason for this may be determined in the future by using a higher resolution PET and by studying associated fields. The rCBF baseline may be obtained by resting with eyes closed in the brain perfusion study with ^{123}I-IMP.

MRI showed that all subjects had normal occipital lobes and no abnormalities such as atrophy were found, but one subjects had an asymptomatic brain tumor as well as a history of brain tumor resection and another one with history of brain tumor had brain infarctions in the bilateral frontal lobe. But no other abnormal changes were observed. These patho-histologies might be craniopharyngioma, teratoma or pinealoma. MRI can show the activation of cranial nerves by demonstrating changes in cerebral blood flow.[10]

In conclusion, despite the chronic loss of vision and continuous interruption of external stimuli in our blind subjects, no differences in occipital blood flow were noted on ^{123}I-IMP SPECT in comparison with the control group. Also, no anatomical abnormalities were found on MRI.

CONCLUSION

Regional blood flow in the primary visual cortex was the same in subjects with secondary blindness and controls, and no anatomical changes were found by MRI.

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