Brain Atrophy and Cerebral Infarction

SHUMPEI TAKEDA, TAIJU MATSUZAWA and HARUTSUGU YAMAURA

The Department of Radiology and Nuclear Medicine, the Research Institute for Tuberculosis and Cancer, Tohoku University, Sendai 980

TAKEDA, S., MATSUZAWA, T. and YAMAURA, H. *Brain Atrophy and Cerebral Infarction*. Tohoku J. exp. Med., 1984, **144** (4), 361-367 — The subjects of the study (109 males, 48 females) were all diagnosed to have cerebral infarction by computerized tomography (CT). The cerebrospinal fluid (CSF) space volume and cranial cavity volume in the normal hemisphere of the patients were estimated using CT at the time from 1 to 3 weeks after the attack of cerebral infarction. The percentage of the CSF space volume to the cranial cavity volume was calculated as an indicator for brain atrophy and called brain atrophy index (BAI): $\text{BAI} (\%) = 100 (\%) \times (\text{CSF space volume} / \text{cranial cavity volume})$. The BAI immediately after the attack of infarction (6.6 ± 2.2 , $n=15$), during which no detectable change occurred on CT examination, was the same as the BAI at the time from 1 to 332 days after the attack (6.6 ± 2.4 , $n=20$). Therefore we compared the BAI in patients without infarction with the BAI in patients with infarction irrespective of secondary atrophy of the brain after the attack. The BAIs in males with infarction were significantly greater than the BAIs in males without infarction in the age of fifties, sixties and seventies. The BAIs in females with infarction were significantly greater than in females without infarction in the age of fifties, sixties and eighties. — computerized tomography (CT); brain atrophy index (BAI); cerebral infarction

Human population contains more and more aged people and the death rate from cerebral infarction increases, especially in the developed societies in recent years. Since Hounsfield (1973) and Ambrose (1973) developed x-ray computerized tomography (CT), it becomes able to examine exactly the cerebral lesions without any invasive procedures, and the techniques of diagnosis and treatment of cerebral infarction have progressed significantly. However, after being attacked by the disease there remains more or less an irreversible neurological symptoms hardly responsible to treatment, and severely damaged patients find hard not only in the social life but also in the usual life. Therefore considerable effort has been devoted to prediction of the risk of the disease.

It was found by many authors (Kannel 1976; Omae 1977; Takeshita 1977; Takeshita and Omae 1977) that hypertension, diabetes mellitus, hypercholesterolemia and abnormalities in ECG and in ocular fundus vessels were risk factors in

cerebral infarction. The prevention against cerebral infarction is made by way of the treatment of these risk factors, resulting in the reduced incidence of the disease. Of these risk factors, hypertension, diabetes mellitus and hypercholesterolemia are all thought to be causes of cerebral arteriosclerosis, which is the most important and direct cause of cerebral infarction. Abnormalities in ECG and in ocular fundus vessels might reflect in part the severity of cerebral arteriosclerosis, but no exact relationship could be confirmed between them.

As Yamaguchi et al. (1983) reported that brain atrophy was caused by the decreased cerebral blood flow mainly due to cerebral arteriosclerosis, brain atrophy might be an indicator of cerebral arteriosclerosis. We have previously reported that brain atrophy increased exponentially to the increasing age (Takeda and Matsuzawa 1984), we studied brain atrophy in the normal hemisphere of the patients with infarction using CT and investigated the relationship between brain atrophy and cerebral infarction.

MATERIALS AND METHODS

X-ray scanner. Brain CT examination was performed with the General Electric CT/T 8800 whole-body scanner. The thickness of the brain slice for scanning was 10 mm. Each pixel represented tissue $1.0 \times 1.0 \times 10.0 \text{ mm}^3$ in volume. Serial brain scanning was performed on planes parallel to the supraorbitomeatal line. Seven slice images were obtained 30, 40, 50, 60, 70, 80 and 90 mm above the line.

Subjects. The subjects of the study (109 males, 48 females) were selected from patients who received CT examinations in Watanabe Hospital, Haranomachi, Fukushima Prefecture during the period from May 1980 to July 1982. All of them were diagnosed to have cerebral infarction by CT examination. Their ages ranged from 43 to 86 years in males and 51 to 84 years in females. They were divided into 10 years of age groups for convenience of statistical analysis. CT examination for measurement of brain atrophy was performed 1 to 3 weeks after cerebral infarction, during which no cerebral edema or atrophy occurred and

Fig. 1. Schematic representation of the tomographic scan of the head. Left-sided low density area (⊗) shows an infarct. Both cranial cavity volume and cerebrospinal fluid (CSF) space volume in the normal hemisphere were measured and brain atrophy index (BAI) was calculated as $100 (\%) \times (\text{CSF space volume} / \text{cranial cavity volume})$.

precise measurement of brain atrophy could be made.

Measurement of volume of the CSF space and cranial cavity. The technique for measuring intracranial tissue volume using the General Electric CT/T 8800 whole-body scanner was developed and previously described in detail by us (Takeda and Matsuzawa 1984). As seen in Fig. 1, the cerebrospinal fluid (CSF) space volume and cranial cavity volume were estimated in the normal hemisphere of the patients with cerebral infarction as follows :

The CSF space volume (ml) = (number of all pixels of which CT numbers are less than 19) $\times$ pixel volume.

The cranial cavity volume (ml) = (number of all pixels of which CT numbers are less than 101) $\times$ pixel volume.

Pixel volume = $1.0 \times 1.0 \times 10.0 \text{ mm}^3$.

Indicator of brain atrophy. The percentage of the CSF space volume to cranial cavity volume was calculated as an indicator of brain atrophy in order to allow for the difference in head size among individuals, and was called brain atrophy index (BAI) : $\text{BAI (\%)} = 100 (\%) \times (\text{CSF space volume} / \text{cranial cavity volume})$. The BAI in patients with infarction was compared with the BAI in patients of the same age group without infarction, which has previously been reported by us (Takeda and Matsuzawa 1984).

All data were evaluated statistically by Student's *t*-test, and the least significant difference was examined for each age group.

RESULTS

Changes of the BAI after the attack of cerebral infarction

We selected 15 cases which showed no abnormal findings immediately after being attacked by cerebral infarction on CT examination, and then manifested low density area in the brain. When we studied the changes of the BAI at the time from 1 to 332 days after the attack (Fig. 2), the BAI did not change even after the attack ; the BAI immediately after the attack was 6.6 ± 2.2 ($n = 15$) and the BAI at the time from 1 to 332 days after the attack was 6.6 ± 2.4 ($n = 20$).

Fig. 2. Changes of the BAI in 15 patients who were diagnosed to have cerebral infarction. The BAIs were 6.6 ± 2.2 ($n = 15$) immediately after the attack ($\uparrow$). The BAIs were 6.6 ± 2.4 ($n = 20$) at the time from 1 to 332 days after the attack.

Therefore we can compare the BAI in patients without infarction with the BAI in patients with infarction irrespective of the secondary atrophy of the brain after the attack (Machida 1981).

Fig. 3. The age-related distribution of the BAI in male patients with cerebral infarction. 82% of the male patients with infarction had the BAIs located higher than the regression line for the BAIs in male patients without infarction.

Fig. 4. The age-related distribution of the BAIs in female patients with cerebral infarction. 84% of the female patients with infarction had the BAIs located higher than the regression line for the BAIs in female patients without infarction.

Difference of the BAIs between the patients with and without infarction

Of all the patients with infarction 82% of males and 84% of females (Figs. 3, 4) showed the BAIs located higher than the regression line for the BAIs in the patients without infarction, which increased exponentially to the increasing age after forties: $\log(\text{BAI}) (\%) = 0.0151 \times \text{age (years)} - 0.270$ in males; $\log(\text{BAI}) (\%) = 0.0174 \times \text{age (years)} - 0.497$ in females (Takeda and Matsuzawa 1984).

The BAI in males with infarction was significantly greater than the BAI in males without infarction in the age of fifties, sixties and seventies (Table 1). The

TABLE 1. *Comparison of the BAI between the patients with and without infarction in males*

Age groups (years)		Infarction	Non-infarction*	Statistical significance (<i>t</i> -test)
40-49	BAI	3.3±0.9 (8)	3.1±1.9 (93)	NS
	Mean age	45.1±2.4	44.9±3.1	NS
50-59	BAI	6.8±4.3 (21)	3.7±2.4 (116)	$p < 0.005$
	Mean age	54.5±2.7	54.4±2.7	NS
60-69	BAI	7.5±2.7 (39)	5.6±2.6 (104)	$p < 0.001$
	Mean age	64.3±2.5	64.2±2.8	NS
70-79	BAI	9.5±3.9 (37)	8.0±3.3 (55)	$p < 0.001$
	Mean age	73.4±2.2	73.3±2.8	NS
80-89	BAI	13.2±6.2 (4)	11.7±5.8 (12)	NS
	Mean age	82.5±2.4	83.3±2.7	NS

Means and standard deviations are given.

The number of cases was given in parenthesis.

* Takeda and Matsuzawa (1984).

TABLE 2. *Comparison of the BAI between the patients with and without infarction in females*

Age groups (years)		Infarction	Non-infarction*	Statistical significance (<i>t</i> -test)
50-59	BAI	5.1±2.5 (13)	3.1±1.7 (134)	$p < 0.02$
	Mean age	54.3±2.3	54.3±2.8	NS
60-69	BAI	8.5±3.5 (15)	4.6±2.2 (97)	$p < 0.001$
	Mean age	64.5±2.6	64.5±2.8	NS
70-79	BAI	8.3±4.5 (16)	6.9±2.8 (74)	NS
	Mean age	73.4±2.2	73.3±2.4	NS
80-89	BAI	14.9±3.8 (4)	10.3±3.1 (7)	$p < 0.01$
	Mean age	82.8±1.0	82.4±2.2	NS

Means and standard deviations are given.

The number of cases was given in parenthesis.

* Takeda and Matsuzawa (1984).

BAI in females with infarction was significantly greater than in females without infarction in the age of fifties, sixties and eighties (Table 2). Therefore the greater the BAI, the more prone to cerebral infarction in these age groups.

DISCUSSION

We confirmed the intimate relation between brain atrophy and cerebral infarction in the age of fifties, sixties and seventies in males and in the age of fifties, sixties and eighties in females. Yamaguchi et al. (1983) reported that brain atrophy was caused by decreased cerebral blood flow mainly due to cerebral arteriosclerosis. Therefore it is possible to diagnose cerebral arteriosclerosis from brain atrophy, which might be conversely a candidate for a risk factor in cerebral infarction. Usual risk factors (hypertension, diabetes mellitus, hypercholesterolemia, etc.) may considerably change at all times, so that they must be frequently checked to be maintained normal. As brain atrophy, on the other hand, might be caused by the long-term decrease in the cerebral blood flow, the BAI increased maximally only by 0.4% in a year. Therefore once brain atrophy is estimated, it is not necessary to reexamine it in several years. From these results it is worthy to estimate brain atrophy in as many persons as possible in physical check. We are going to follow up the several hundred patients who had no abnormal findings on CT examination in order to confirm the intimate relation between them.

Acknowledgments

We are very grateful to Dr. Hisao Ito of the Department of Radiology and Nuclear Medicine, Tohoku University School of Medicine for supporting the study. The technical assistance of Mr. Yasuhiro Sugawara is greatly appreciated.

References

- 1) Ambrose, J. (1973) Computerized transverse axial scanning (tomography): Part 2. Clinical application. *Brit. J. Radiol.*, **46**, 1023-1047.
- 2) Hounsfield, G.N. (1973) Computerized transverse axial scanning (tomography): Part 1. Description of system. *Brit. J. Radiol.*, **46**, 1016-1022.
- 3) Kannel, E.B. (1976) Epidemiology of cerebrovascular disease. In: *Cerebral Arterial Disease*, edited by R.W.R. Russel, Churchill Livingstone, Edinburgh-London, pp. 1-23.
- 4) Machida, T. (1981) Cerebrovascular diseases. *Medicina*, **18**, 2031-2049. (Japanese)
- 5) Omae, T. (1978) Prevention of ischemic heart disease and stroke in Japan. Proceedings of VIII World Congress of Cardiology. In: *International Congress Series No. 470*, pp. 140-144.
- 6) Takeda, S. & Matsuzawa, T. (1984) Brain atrophy during aging: A quantitative study using x-ray computed tomography. *J. Amer. Geriat. Soc.*, **32**, 520-524.
- 7) Takeshita, S. (1977) Risk factors in cerebrovascular disease and its prevention. *Rinsho to Kenkyu*, **55**, 3609-3614. (Japanese)
- 8) Takeshita, S. & Omae, T. (1977) Correlation and independency between risk factors. *Saishin Igaku*, **32**, 2270-2276. (Japanese)
- 9) Yamaguchi, T., Hatazawa, J., Kubota, K., Abe, Y., Fujiwara, T. & Matsuzawa, T. (1983) Correlation between regional cerebral blood flow and age-related brain atro-

phy : a quantitative study with computed tomography and the Xenon-133 inhalation method. *J. Amer. Geriat. Soc.*, **31**, 412-416.