QUANTITATIVE DETECTION OF CEREBRAL ARTERIOSCLEROSIS BY MEANS OF THE PRESSURE-VELOCITY HYSTERESIS TECHNIQUE

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IT is well known that quantitative detection of cerebral arteriosclerosis plays an important role in the treatment of cerebral vascular disorders. However, the ideal technique for clinical use in this field has not yet been developed because of methodological difficulty.

The present author has pointed out that the continuity grade of the cerebral blood flow pattern measured by the ultrasonic Doppler technique and the severity of the cerebral arteriosclerosis is much more significant and therefore the technique is useful for the quantitative detection of cerebral arteriosclerosis.¹

On the other hand, the pressure and volume pulse pattern of the artery involved several hemodynamic characteristics, i.e., arterial elasticity, dynamics of systole of the left ventricle of the heart and peripheral vascular resistance. Therefore, it may be possible to detect the cerebral arteriosclerosis quantitatively by means of the cerebral arteriogram technique.²⁻⁴

In this study, the quantitative detection of the cerebral arteriosclerosis by means of the pressure-velocity hysteresis technique, a combination of the cerebral blood velocity pattern technique and the cerebral pressure pulse pattern technique, was investigated.

MATERIALS AND METHODS

Materials consist of 17 cases, i.e., 5 normal young males, 6 normal middle-aged males (40 to 59 years old) and 6 patients over 70 years of age with cerebral vascular disorders.

Key Words:

Ultrasonic Doppler technique
Pressure-velocity hysteresis technique

The resistance of cerebral blood flow was measured by the following combination of the cerebral blood velocity pattern and the cerebral pressure pulse pattern.

The cerebral blood velocity pattern was obtained by the ultrasonic Doppler technique in the internal carotid artery.⁵ On the other hand, the cerebral pressure pulse pattern was obtained by

$$\text{Resistance} = \frac{X}{Y} = \tan \theta$$

Fig.1. Calculation of resistance.

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Fig.2. Block diagram of apparatus.

Fig.3. Resistance of cerebral blood flow measured by the pressure-velocity hysteresis technique in normal young male.

the non-invasive sphygmography in the common carotid artery, close to the bifurcation. In the detection of the cerebral pressure pulse pattern, care was exercised in the attachment of the sphygmograph, not to affect the original blood velocity pattern, by cautious monitoring.

Both the cerebral blood velocity pattern and the cerebral pressure pulse pattern were recored on the direct oscillograph and tape, simultaneously and continuously. Further, the Lissajous figure per each heart beat was recorded on the

XY-recorder by a combination of the cerebral blood velocity pattern and the cerebral pressure pulse pattern.

As for the calibration of Lissajous figure recording, the figure was obtained under the condition that the peak amplitude of the cerebral blood velocity pattern and the cerebral pressure pulse pattern were quite equal.

As for the measurement of the resistance of the cerebral blood flow, on the other hand, the value which represents the ratio of blood

TABLE I RESISTANCE OF CEREBRAL BLOOD FLOW MEASURED BY THE PRESSURE-VELOCITY HYSTERESIS TECHNIQUE IN NORMAL YOUNG MALES, NORMAL MIDDLE-AGED MALES AND PATIENTS WITH CEREBRAL VASCULAR DISORDERS

Case No.	Normal young males		Normal middle-aged males		Patients with cerebral vascular disorders	
	Age (Yrs)	Resistance	Age (Yrs)	Resistance	Age (Yrs)	Resistance
1	21	0.56	41	0.58	76	0.85
2	20	0.60	36	0.60	73	0.85
3	24	0.62	38	0.64	76	0.92
4	23	0.64	45	0.65	68	0.94
5	27	0.67	51	0.71	69	0.96
6			56	1.30	78	1.30
Mean $\pm$ S.E.		0.618 $\pm$ 0.019		0.747 $\pm$ 0.112		0.970 $\pm$ 0.069

$p < 0.01$

Fig.4. Resistance of cerebral blood flow measured by the pressure-velocity hysteresis technique in normal middle-aged male.

pressure and blood velocity (blood pressure / blood velocity) in the maximum blood velocity was used as a measure of resistance of the cerebral blood flow in this experiment (Fig. 1).

Fig. 2 shows the block diagram of the apparatus.

RESULTS

1. Resistance of cerebral blood flow in each group (Tab. I) (Fig. 3–5).

The resistance of the cerebral blood flow in each group was as follows: normal young males 0.618 ± 0.019 , normal middle-aged males 0.747 ± 0.112 and patients with cerebral vascular disorders 0.970 ± 0.069 .

From the above results, it is suggested that

Fig.5. Resistance of cerebral blood flow measured by the pressure-velocity hysteresis technique in patient with cerebral vascular disorder.

Fig.6. Resistance of cerebral blood flow measured by the pressure-velocity hysteresis technique (peak amplitude of blood pressure equal to that of blood velocity).

the resistance of the cerebral blood flow was significantly increased in the patients with cerebral vascular disorders over that in the normal young males ($P < 0.01$). The resistance of cerebral blood flow in the middle-aged males was prone to be intermediate between the former two.

2. Calibration of the resistance measurement (fig. 6–8).

The resistance of the cerebral blood flow was altered in accordance with the inequality of the peak amplitude of the cerebral blood velocity pattern and the cerebral pressure pulse pattern. This suggests that equality of the peak amplitude

Fig.7. Resistance of cerebral blood flow measured by the pressure-velocity hysteresis technique (peak amplitude of blood pressure more increased than that of blood velocity).

Fig.8. Resistance of cerebral blood flow measured by the pressure-velocity hysteresis technique (peak amplitude of blood velocity more increased than that of blood pressure).

Fig.6, Fig.7 and Fig.8 show the patterns in the same case.

of both patterns is the fundamental item.

3. Resistance of cerebral blood flow under induced hypertension (Fig. 9)

The resistance of the cerebral blood flow was altered under the induced hypertension (intravenous noradrenalin).

The above results suggest that the marked

fluctuation in the blood pressure should be taken into consideration in the study.

DISCUSSION

1. Cerebral arteriosclerosis and cerebral blood velocity pattern.

The present author¹ has previously investi-

Fig.9. Resistance of cerebral blood flow measured by the pressure-velocity hysteresis technique (intravenous noradrenalin). Fig. 6 and Fig. 9 show the patterns in the same case.

gated the correlation between the continuity grade of the cerebral blood velocity pattern, measured by the ultrasonic Doppler technique during life, and the severity of cerebral arteriosclerosis (intracerebral arteriolosclerosis and extracerebral atherosclerosis) in the same subject autoptically. A significant correlation between the two observed.

From the above results, it was suggested that the ultrasonic Doppler technique is useful for the quantitative detection of cerebral arteriosclerosis and therefore, anticipation of cerebral vascular disorders.

However, consideration of the following factors affecting the cerebral blood velocity patterns is essential in the application of the technique, i.e., (1) factors contributing to cerebral vascular resistance such as blood pressure, heart rate and blood chemical agents, etc. (2) factors contributing to several pseudotypes of the cerebral blood velocity pattern such as marked fluctuation in blood pressure and heart disorders, etc.

2. Cerebral arteriosclerosis and carotid arteriogram

The pressure and volume pulse pattern of the carotid artery involve several hemodynamic characteristics, i.e., elasticity of the carotid artery, dynamics of systole of the left ventricle of the

heart and cerebral vascular resistance.^{2-4,6,7}

Therefore, carotid pressure pulse pattern alters in accordance with the various kinds of disorders of the above characteristics, i.e., catacrotic wave in the normal carotid arteriogram vs. anacrotic wave in the patients with cerebral arteriosclerosis, etc.

The above concept suggests that cerebral vascular resistance and therefore the cerebral arteriosclerosis may be detected quantitatively by the carotid arteriogram technique. However, factors other than the cerebral vascular resistance, affecting the carotid arteriogram such as heart failure and carotid atherosclerosis, etc. must be considered.

3. Cerebral arteriosclerosis and resistance of cerebral blood flow

From the above-mentioned two items, a more significant correlation between the cerebral vascular resistance and the resistance of the cerebral blood flow composed of the cerebral blood velocity pattern and the cerebral pressure pulse pattern is suggested. In fact, the concept is supported by the findings in the present experiment.

However, the consideration for the following items is essential in the application of the technique, i.e., clearcut discrimination of the factors affecting the cerebral vascular tone, functionally and organically, such as cerebral arteriosclerosis, cerebral vasoconstriction or dilation due to marked fluctuation in the blood pressure and blood chemical agents, etc.

As for the calibration of the resistance measurement, it may be most important that the peak amplitude of the cerebral blood velocity pattern and the cerebral pressure pulse pattern are equal.

In conclusion, the pressure-velocity hysteresis technique is more advantageous than the cerebral blood velocity pattern technique and the cerebral pressure pulse pattern technique in the quantitative detection of cerebral vascular resistance and therefore, cerebral arteriosclerosis in terms of the consideration of several factors related to cerebral vascular resistance. On the other hand, the correlation between the measure of resistance of the cerebral blood flow in this experiment (the ratio of blood pressure/blood velocity in the maximum blood velocity) and the frequency characteristics of the impedance should be considered.

SUMMARY

The quantitative detection of cerebral arterio-

sclerosis by means of the pressure-velocity hysteresis technique composed of the cerebral blood velocity pattern (blood velocity pattern in the internal carotid artery measured by the ultrasonic Doppler technique) and the cerebral pressure pulse pattern (common carotid arteriogram measured by non-invasive sphygmography) was investigated in 17 normal young males, normal middle-aged males and patients with cerebral vascular disorders. The ratio of blood pressure/blood velocity in the maximum blood velocity was used as a measure of resistance of the blood flow.

The resistance of the cerebral blood flow was significantly increased in the patients with cerebral vascular disorders compared to that in the normal young males. The resistance of cerebral blood flow in the middle-aged males was prone to be intermediate between the former two. The results suggest that the pressure-velocity hysteresis technique is useful for the quantitative detection of cerebral vascular resistance as well as cerebral arteriosclerosis. Several factors

related to the technique were discussed.

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