Measurement of Cerebral Blood Flow by Ultrasonic Doppler Technique

Quantitative Detection of Cerebral Arteriosclerosis

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The clinical characteristics of the method by ultrasonic Doppler technique are as follows. (1) The dynamic change of the blood flow at the vessel resulting from the various stresses to circulatory system can be observed instantaneously and non-operatively. (2) The cerebral vascular resistance or cerebral arteriosclerosis are objectively and simply evaluated. \(^1\)\(^-\)\(^2\)

The measurement of cerebral vascular resistance is based on the grade of continuity grade of Doppler beat pattern in cerebral artery (internal carotid or vertebral artery): The more the discontinuity of blood flow pattern is increased, the more the cerebral vascular resistance or cerebral arteriosclerosis is increased.

The above concept is supported by the following studies, i.e., the comparative study between the normal young man and the old man, the normotensive old man and hypertensive old man. In addition, the several hemodynamic studies in the upper extremity produced by various maneuver, i.e., hand-grasping, brachial-binding, cold and warm-stimulating study\(^1\)\(^-\)\(^2\), etc. However, the retrospective post-mortem study is essential in order to support the above concept, since the above evidence are all indirect.

In this study, the correlation between the continuity grade of the cerebral blood flow pattern by ultrasonic Doppler technique during life and the severity of the cerebral arteriosclerosis in the same subject was investigated.

Materials and Methods

Materials consist of 23 subjects over 60 years old. The correlation between the continuity grade of the blood flow pattern in internal carotid artery by ultrasonic Doppler technique and the severity of the cerebral arteriosclerosis (extracerebral atherosclerosis and intracerebral arteriolosclerosis) was investigated.

The blood flow patterns in internal carotid artery by ultrasonic Doppler technique are classified according to the continuity grade of the patterns into the following three types, i.e., continuous type, discontinuous type and intermediate type (Fig. 1)\(^1\)\(^-\)\(^2\). In addition, the correlation between the type of the cerebral blood flow pattern in internal carotid artery and retinal arteriosclerosis (by Schiiz's classification), blood pressure was examined.

Results

(1) Correlation of cerebral blood flow pattern and intracerebral arteriolosclerosis (Fig. 2).

![Classification of cerebral blood flow pattern](image)

**Fig. 1.** Classification of cerebral blood flow pattern (internal carotid artery).

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The intracerebral arteriolosclerosis is prone to be more increased in discontinuous type than that in continuous type. On the other hand, the intracerebral arteriolosclerosis in intermediate type is intervened them.

The correlation between the continuity grade of the blood flow pattern (namely, the type of blood flow pattern) and the severity of intra-

Fig. 2. Correlation of cerebral blood flow pattern and intracerebral arteriolosclerosis.

Fig. 3. Correlation of cerebral blood flow pattern and extracerebral atherosclerosis.

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cerebral arteriolosclerosis is much more significant \( (P<0.01) \).

(2) Correlation of cerebral blood flow pattern and extracerebral atherosclerosis (Fig. 3).

Identical to the intracerebral arteriolosclerosis, the extracerebral atherosclerosis is prone to be more increased in discontinuous type than that in continuous type. The extracerebral atherosclerosis in intermediate type is also intervened them.

Although the correlation between the continuity grade of the blood flow pattern (namely, the type of blood flow pattern) and the severity of extracerebral atherosclerosis is significant \( (P<0.01) \), the correlation is less significant than that in intracerebral arteriolosclerosis.

(3) Correlation of cerebral blood flow pattern and blood pressure (Fig. 4).

The discontinuous type in hypertensive subjects are prone to be more frequently observed than that in normotensive subjects. On the other hand, the continuous types in normoten-

![Fig. 4. Correlation of cerebral blood flow pattern and blood pressure.](image)

![Fig. 5. Correlation of cerebral blood flow pattern and retinal arteriosclerosis (by Scheie's classification).](image)
Table I Criteria for Quantitative Detection of Cerebral Arteriosclerosis by Ultrasonic Doppler Technique

<table>
<thead>
<tr>
<th>type of cerebral blood flow pattern</th>
<th>severity of cerebral arteriosclerosis</th>
<th>note</th>
</tr>
</thead>
<tbody>
<tr>
<td>continuous type</td>
<td>both extracerebral atherosclerosis and intracerebral arteriolosclerosis are no or minimal.</td>
<td>pseudocontinuous type</td>
</tr>
<tr>
<td>discontinuous type</td>
<td>both extracerebral atherosclerosis and intracerebral arteriolosclerosis are severe. Among them, intracerebral arteriolosclerosis is much more severe than extracerebral atherosclerosis.</td>
<td>pseudodiscontinuous type</td>
</tr>
<tr>
<td>intermediate type</td>
<td>both extracerebral atherosclerosis and intracerebral arteriolosclerosis are intervened the continuous and discontinuous type.</td>
<td>pseudointermediate type</td>
</tr>
</tbody>
</table>

Discussion

The correlation between the continuity grade of the blood flow pattern (namely, the type of blood flow pattern) and the severity of blood pressure is significant (P<0.01).

(4) Correlation of cerebral blood flow pattern and retinal arteriosclerosis (Fig. 5).

The discontinuous types in severe retinal arteriosclerosis are prone to be more frequently observed than that in mild retinal arteriosclerosis. The correlation between the continuity grade of the blood flow pattern (namely, the type of blood flow pattern) and the severity of retinal arteriosclerosis is significant (P<0.01).

Cases

Case 1) 75-year-old
cause of death: gastric cancer
blood pressure: 130/60 mmHg
retinal arteriosclerosis: grade 0 (Scheie's classification)
cerebral blood flow pattern: continuous type (Fig. 6A)
cerebral arteriosclerosis: both extracerebral atherosclerosis and intracerebral arteriolosclerosis are minimal or none (Fig. 6B)

Case 2) 82-year-old
cause of death: intracerebral hemorrhage
blood pressure: 230/110 mmHg
retinal arteriosclerosis: grade I (Scheie's classification)
cerebral blood flow pattern: discontinuous type (Fig. 7A)
cerebral arteriosclerosis: both extracerebral atherosclerosis and intracerebral arteriolosclerosis are markedly severe (Fig. 7B).

Case 3) 72-year-old

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sive subjects are prone to be more frequently observed than that in hypertensive subjects.

The correlation between the continuity grade of the blood flow pattern (namely, the type of blood flow pattern) and the severity of blood pressure is significant (P<0.01).

(2) The factors causing the pseudodiscontinuous type: severe decrease of diastolic pressure and increase of pulse pressure, e.g., aortic insufficiency, bradycardia or several arrhythmia, and disorders of blood chemical agent (anoxia, hypercapnia)\(^b\), etc.

(4) Correlation of cerebral blood flow pattern and retinal arteriosclerosis (Fig. 5).

The discontinuous types in severe retinal arteriosclerosis are prone to be more frequently observed than that in mild retinal arteriosclerosis. The correlation between the continuity grade of the blood flow pattern (namely, the type of blood flow pattern) and the severity of retinal arteriosclerosis is significant (P<0.01).

Discussion

The quantitative analysis of cerebral arteriosclerosis, especially intracerebral arteriolosclerosis, is of most clinical importance in order to anticipate the cerebral vascular accidents (cerebral hemorrhage or infarction). However, the ideal technique for clinical use has not yet been developed, since the detection of cerebral arteriosclerosis is more difficult methodologically.

From this point of view, the results in this study are very remarkable. In addition, it is not too much to say that this technique may well be useful to anticipate the cerebral accidents, since the most of cerebral accidents in Japan should be resulted from the disorders of intracerebral arteriolosclerosis (size of arteriole ranging from 50 to 200 \(\mu\))\(^b\).

On the other hand, in applying the ultrasonic Doppler technique to clinical use, the following items must be considered.

(1) The factors causing the pseudodiscontinuous type: severe hypertension\(^a\), tachycardia or several arrhythmia, and disorders of blood chemical agent (anoxia, hypercapnia)\(^b\), etc.

(2) The factors causing the pseudodiscontinuous type: severe decrease of diastolic pressure and increase of pulse pressure, e.g., aortic insufficiency, bradycardia or several arrhythmia, and disorders of blood chemical agent (hypocapnia)\(^b\), etc.

These factors are mostly non-specific in nature and thus resembles to electrocardiographic patterns such as ST-T patterns. (Table I) represents the criteria for quantitative detection of cerebral arteriosclerosis by ultrasonic Doppler technique.
MEASUREMENT OF CEREBRAL BLOOD FLOW

75 Yrs. cause of death: gastric cancer
B. P. 130/60 mmHg
Retinal arteriosclerosis: grade 0
(Scheie's classification)
(A) Blood flow pattern in internal carotid artery, continuous type

(B) Intracerebral arteriolosclerosis (Pons) 
H. E.

In this case, both extracerebral atherosclerosis and intracerebral arteriolosclerosis are minimal or none.

Fig. 6. Correlation of cerebral blood flow pattern and cerebral arteriosclerosis.

82 Yrs. cause of death: intracerebral hemorrhage
B. P. 230/110 mmHg
Retinal arteriosclerosis: grade I (Scheie's classification)
(A) Blood flow pattern in internal carotid artery discontinuous type

(B) Intracerebral arteriolosclerosis (Pons) 
H. E.

In this case, both extracerebral atherosclerosis and intracerebral arteriolosclerosis are markedly severe.

Fig. 7. Correlation of cerebral blood flow pattern and cerebral arteriosclerosis.

cause of death: cerebral infarction
blood pressure: 190/100 mmHg
retinal arteriosclerosis: grade II (Scheie's classification)
cerebral blood flow pattern: discontinuous type (Fig. 8A)
cerebral arteriosclerosis: the intracerebral arteriolosclerosis is markedly severe, although the extracerebral atherosclerosis is relatively mild (Fig. 8B).

(Case 4) 83-year-old
cause of death: pulmonary tuberculosis
blood pressure: 150/90 mmHg
retinal arteriosclerosis: grade 0 (Scheie's classification)
cerebral blood flow pattern: intermediate type (Fig. 9A)
cerebral arteriosclerosis: both extracerebral atherosclerosis and intracerebral arteriolosclerosis are mild (Fig. 9B).

(Case 5) 64-year-old
cause of death: subarachnoid hemorrhage
blood pressure: 220/120 mmHg
retinal arteriosclerosis: grade III (Scheie's classification)
cerebral blood flow pattern: intermediate type (Fig. 10A)
cerebral arteriosclerosis: both extracerebral atherosclerosis and intracerebral arteriolosclerosis are markedly severe (Fig. 10B). The intermediate type in this case may be resulted from the secondary cerebral vasodilation due to severe hypertension (namely, pseudointermediate type).

(Case 6) 31-year-old
clinical diagnosis: aortic insufficiency
blood pressure: 110/25 mmHg.
retinal arteriosclerosis: grade 0 (Scheie's classification)

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72 Yrs. cause of death: cerebral infarction
B. P. 190/100 mmHg
Retinal arteriosclerosis: grade II
(Scheie's classification)
(A) Blood flow pattern in internal carotid artery
discontinuous type

(B) Intracerebral arteriolosclerosis (Pons)
H. E.

In this case, the intracerebral arteriolosclerosis is markedly severe, although the extracerebral atherosclerosis is relatively mild.

Fig. 8. Correlation of cerebral blood flow pattern and cerebral arteriosclerosis.

cerebral blood flow pattern: discontinuous type
(Fig. 11A)

(Case 7) 62-year-old
clinical diagnosis: aortic insufficiency
blood pressure: 170/40 mmHg
retinal arteriosclerosis: grade 0 (Scheie's classification)
cerebral blood flow pattern: discontinuous type
(Fig. 11B)

The discontinuous types in these cases (Case 6, 7) may be resulted from severe decrease of diastolic pressure and increase of pulse pressure due to aortic insufficiency (namely, pseudodiscontinuous type).

**SUMMARY**

The correlation between the continuity grade of the cerebral blood flow pattern (blood flow pattern in internal carotid artery) by ultrasonic Doppler technique during life and the severity of the cerebral arteriosclerosis (intracerebral arteriolosclerosis and extracerebral atherosclerosis) in the same subject was investigated.

The correlation between the continuity grade of the cerebral blood flow pattern and the severity of the cerebral arteriosclerosis is much more significant. The result suggests that the ultrasonic Doppler technique is useful for the quantitative detection of cerebral arteriosclerosis, i.e., anticipation of the cerebral vascular accidents. However, the consideration for several factors affecting the cerebral blood flow patterns are essential in application of the method.

**APPENDIX**

The author devised a word "Continuous Index (CI)" as a objective measure of the grade of the cerebral blood flow pattern (Fig. 12).

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MEASUREMENT OF CEREBRAL BLOOD FLOW

64 Yrs. cause of death: subarachnoid hemorrhage
B. P. 220/120 mmHg
Retinal arteriosclerosis: grade III
(Scheie's classification)

(A) Blood flow pattern in internal carotid artery
intermediate type

The intermediate type in this case may be resulted from
the secondary cerebral vasodilation due to severe hyper-
tension (namely, pseudointermediate type)

(B) Intracerebral arteriolosclerosis (Pons)
H. E.

In this case, both extracerebral atherosclerosis and
intracerebral arteriolosclerosis are markedly severe.

Fig. 10. Correlation of cerebral blood flow pattern
and cerebral arteriosclerosis.

(A) 31 Yrs. B. P. 110/25 mmHg
Retinal arteriosclerosis: grade O
(Scheie's classification)

(B) 62 Yrs. B. P. 170/40 mmHg
Retinal arteriosclerosis: grade O
(Scheie's classification)

The discontinuous type in these cases may be resulted
from severe decrease of diastolic pressure and increase
of pulse pressure due to aortic insufficiency (namely,
pseudodiscontinuous type).

Fig. 11. pseudodiscontinuous type in patients with
aortic insufficiency (blood flow pattern in
internal carotid artery).

The correlation between CI and the type of
Continuous Index (CI).

\[
CI(\%) = \frac{X \times Z}{Y} \times 100
\]

X: The most smallest amplitude in diastole (namely,
the most slowest portion of blood flow velocity)
Y: The most largest amplitude in systole (namely, the
most fastast portion of blood flow velocity)
Z: The time needed one cardiac cycle blood flow pat-
tern

Fig. 12. A calculation of Continuous Index (CI).

Fig. 13. Correlation of cerebral blood flow pattern
and Continuous Index (CI).

the cerebral blood flow pattern was as follows:
CI in continuous type over 150 per cent, dis-
continuous type under 70 per cent, and inter-
mediate type from 70 to 150 per cent (Fig. 13).

The clinical usefulness of CI are supported
by the following facts.

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bral blood flow pattern in patient with severe arrhythmia is possible (Fig. 14).

REFERENCES


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