To-and-Fro Movement and External Escape of Carotid Arterial Blood in Brain Death Cases. A Doppler Ultrasonic Study

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Abstract:
In brain death cases who showed nonfilling phenomena in the internal carotid angiograms, the blood flow velocity patterns of the common carotid arteries were characterized by involvement of a single systolic peak and a marked reverse flow component which had never been observed in healthy subjects.

The individuality of each blood flow velocity pattern in the common, internal and external carotid arteries was made clear by placing the transducer in contact with the respective artery in a certain case. The Doppler signal from the internal carotid artery involving a signal from a reverse flow was slightly detectable, even if the blood pressure was elevated by norepinephrine infusion and the external carotid artery was temporarily compressed. The blood flow velocity pattern of the external carotid artery was similar to the pattern of the common carotid artery. The peculiar flow pattern indicates that a brain death case has a to-and-fro movement in the internal carotid blood flow and an external carotid escape of common carotid arterial blood.

Introduction
Individuals with brain death have effectively lost cerebral circulation. This evidence has been shown with angiography, the radioisotope method and the N2O method. Since Satomura (1960) developed an ultrasonic flowmeter based upon the Doppler effect, and Franklin (1961) used it in blood flow measurement of animals, further progress in the instrumentation led to the development of a transcutaneous Doppler flowmeter by which blood flow velocity was able to be detected through the skin. Ultrasonic Doppler technique as a noninvasive method has been used for detecting carotid blood flow and has been applied to extracranial vascular diseases. It may be possible to assume cerebral hemodynamics by measurement of carotid blood flow velocity.

The purpose of the present investigation was to study blood flow velocity patterns of carotid arteries in patients with brain death whose cerebral circulation was extremely disturbed.

Methods
The series consisted of ten patients with brain death. The primary diseases were cerebral contusion (three), subarachnoid hemorrhage (three), subdural hematoma (two), epidural hematoma (one) and intraperitoneal hemorrhage (one). The criteria of brain death were followed according to the Ad Hoc Committee of the Harvard Medical School. Carotid angiography, electroencephalography and Doppler flowmetry were performed in all cases.

The carotid blood flow velocity pattern was detected by a directional Doppler rheogram (HITACHI EUD-2A, 5 M Hz). The method was originally described by Kato and Izumi.

Results
The medical records of ten cases are summarized in table 1. Age, sex, diagnosis, findings of carotid angiogram (CAG) and electroencephalogram (EEG), pressure of cerebrospinal fluid (CSF) and systemic arterial blood pressure were presented in this table. In all cases, the carotid angiograms revealed nonfilling phenomena (figs. 1 and 2).

Figures 3 through 6 show the blood flow velocity patterns of the common carotid arteries in cases 4, 6, 8 and 9. The blood flow velocity patterns in these four cases were characterized by a single systolic peak and a reverse flow component. The patterns in the other six cases also showed the same pattern as shown in these figures (table 2).

It is possible that the transducer was placed in contact with the common, internal and external carotid arteries of case 9. As shown in figure 6, the blood flow velocity pattern of the common carotid...
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Table 1

Cases of Brain Death

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>CAG</th>
<th>EEG</th>
<th>CSF pressure (mm Hg)</th>
<th>Blood pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51</td>
<td>M</td>
<td>Subdural hematoma</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>96/68</td>
</tr>
<tr>
<td>2</td>
<td>43</td>
<td>M</td>
<td>Cerebral contusion</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>100</td>
<td>116/70</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>M</td>
<td>Subdural hematoma</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>80</td>
<td>96/68</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>M</td>
<td>Subarachnoid hemorrhage</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>110/70</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>M</td>
<td>Epidural hematoma</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>80/30</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>F</td>
<td>Subarachnoid hemorrhage</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>110/90</td>
</tr>
<tr>
<td>7</td>
<td>23</td>
<td>M</td>
<td>Cerebral contusion</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>120/60</td>
</tr>
<tr>
<td>8</td>
<td>17</td>
<td>M</td>
<td>Cerebral contusion</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>130/80</td>
</tr>
<tr>
<td>9</td>
<td>29</td>
<td>M</td>
<td>Subarachnoid hemorrhage</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>94/70</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>F</td>
<td>Intraperitoneal hemorrhage</td>
<td>Nonfilling</td>
<td>Flat</td>
<td>—</td>
<td>120/90</td>
</tr>
</tbody>
</table>

CSF: cerebrospinal fluid.
CAG: carotid angiography.
EEG: electroencephalography.

artery in this case was similar to the transcutaneous Doppler pattern which consisted of a single systolic peak and a reverse flow. The Doppler signal from the internal carotid artery producing the signal from reverse flow was barely detectable. The blood flow velocity pattern of the external carotid artery was similar to the pattern of the common carotid artery. With temporal compression of the external carotid artery, the Doppler signal from the common carotid artery became scarcely detectable (fig. 7). An increase in systolic arterial blood pressure by norepinephrine infusion (from 94/70 to 220/174 mm Hg) produced little change in blood flow velocity pattern of the internal carotid artery. The blood flow velocity pattern of the common carotid artery was similar to the pattern of the external carotid artery (fig. 8).

Discussion

It is known that the blood flow velocity pattern of the common carotid artery in healthy subjects shows two systolic peaks (S₁ and S₂) and a following diastolic peak (D) and that a slight reverse flow between systole and diastole is sometimes observed (fig. 9). The reverse flow in patients with brain death was prominent in comparison with a slight reverse flow in healthy subjects. Matsuo and Nimura described patients with aortic valvular insufficiency (AI) and

FIGURE 1
Carotid angiogram of case 1. Nonfilling phenomena of the internal carotid angiogram and external carotid angiogram were observed.

FIGURE 2
Carotid angiogram of case 5. Internal carotid angiogram did not appear, while external carotid angiogram was observed.
with idiopathic hypertrophic subaortic stenosis (IHSS) who had a reverse flow component in their common carotid artery. The cases in this study did not have AI and IHSS. A single systolic peak of the blood flow velocity pattern which was not observed in normal subjects appeared in the common and external carotid arteries of brain death cases.

In one case (case 9) whose blood flow velocity was measured by placing the transducer in contact with the carotid arteries, the blood flow velocity pattern of the common carotid artery producing the reverse flow was similar to the pattern of the external carotid artery. The Doppler signal from the internal carotid artery producing the signal from reverse flow could be barely detected, even if arterial blood pressure was elevated. With temporal compression of the external carotid artery, the Doppler signal from the common carotid artery became scarcely detectable. These findings indicated that almost all of the blood of the common carotid artery flowed into the external carotid artery. In other words, there was an external carotid escape of common carotid arterial blood. It is accepted in brain death that the cerebral angiogram shows nonfilling phenomena and that cerebral blood flow is extremely reduced. It also is known that the intracranial pressure of patients with brain death increases to the same level as arterial blood pressure. Therefore, the cerebral perfusion pressure is equal to or near zero. The previous reports about

TABLE 2

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Reverse flow</th>
<th>Single systolic peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>+ +</td>
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<tr>
<td>10</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

+: Mild reverse flow, ++: moderate reverse flow, +++: marked reverse flow.
The blood flow velocity pattern of case 6. Marked reverse flow was presented in the blood flow velocity pattern of the common carotid artery.

**FIGURE 4**

The blood flow velocity pattern of case 8. The blood flow velocity pattern of the common carotid artery showed marked reverse flow and a single systolic peak.

**FIGURE 5**

DOPPLER SONOGRAMS OF THE CAROTID ARTERIES OF BRAIN DEATH

A. M., 29, male

Brain death after head injury with contused wound of the neck

Impossible to detect
the internal carotid flow
by the percutaneous method

Int. Carotid A. (percutaneous)

Comm. Carotid A. (percutaneous)

Ext. Carotid A. (percutaneous)

**FIGURE 6**

The blood flow velocity pattern of case 9. "Direct" showed the blood flow velocity pattern that a transducer was placed in contact with the common, internal and external carotid arteries respectively. Doppler signal from the internal carotid artery was slightly detectable.
The blood flow velocity pattern of case 9 at compression of the external carotid artery. Doppler signal from the common carotid artery was scarcely detected.

The blood flow velocity pattern of case 9 at elevation of arterial blood pressure (from 94/70 to 220/174 mm Hg). The blood flow velocity pattern of the internal carotid artery was barely observed.
brain death support the existence of external carotid escape of common carotid arterial blood.

It had been reported that percutaneous injection of $^{133}$Xe, even if it was performed selectively into the internal carotid artery with the catheter tip near to the siphon, was always followed by extracranial tracer contamination and clearance. It was considered, therefore, that the blood flow velocity pattern of the internal carotid artery indicated a to-and-fro movement of internal carotid arterial blood synchronizing with each heart beat. The blood flow velocity pattern of the common carotid artery may originate from a to-and-fro movement of the blood in the internal carotid artery and some factors in the periphery of the external carotid artery.

References

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FIGURE 9
The blood flow velocity pattern of the common carotid artery in a normal subject. Note two systolic peaks ($S_1$ and $S_2$), a diastolic peak ($D$) and a little reverse flow.
DOPPLER ULTRASONIC STUDY


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