Cerebral circulation time with ruptured intracranial aneurysms

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The cerebral blood circulation time (CT), including the length of the arterial phase, was obtained from rapid serial angiograms in 114 patients with ruptured intracranial aneurysms. The average CT of 7.2 sec, with a mean arterial phase of 3.1 sec, was much longer than the normal average CT of 5.4 sec with its 2.4 sec arterial phase. Longer circulation times were observed with the higher Botterell grades of clinical condition, high arterial perfusion and CSF pressures, and in cases with angiographic evidence of arterial spasm, hematoma, or hydrocephalus. Values of CT greater than 8.0 sec were associated with increased mortality and morbidity and vice versa. The value of the cerebral blood circulation time as a guide to preoperative treatment and to the prognosis of cases of ruptured intracranial aneurysm is suggested.

KEY WORDS • ruptured intracranial aneurysm • cerebral circulation time • serial angiography

The development of rapid serial angiography and radioisotope techniques for circulation time (CT), cerebral blood flow (CBF), and cerebral blood volume (CBV) have produced important advances in our understanding of cerebral hemodynamics.

In this study, the CT in cases of ruptured intracranial aneurysm was calculated from rapid serial angiograms and the findings coordinated with clinical features and data obtained from isotope studies of CBF and CBV.

Materials and Methods

We studied 114 cases of ruptured and operated single intracranial aneurysms (Table 1). Preoperative angiographies were performed as selective three- or four-vessel studies through transfemoral catheterization, and 10 to 14 films were taken over a 7- to 11-sec range. For postoperative study, catheter or direct percutaneous carotid angiographies were done as soon as the patient's condition became stable.

To measure CT, initial demonstration of the carotid siphon was taken as the starting point and maximal demonstration of parietal veins the terminal point. Therefore, in this study the normal average is longer than that of Greitz because of the earlier starting point. The average value taken from 30 normal studies was 5.4 ± 0.53 sec, with an arterial phase of 2.4 ± 0.49 sec.

Results

General Observations

The average preoperative CT for the 114 cases was 7.2 sec with an arterial phase of 3.1 sec, and the postoperative value was 6.7 sec with an arterial phase of 2.9 sec. In the 42...
TABLE 1

Relation of the location of aneurysms to circulation time

<table>
<thead>
<tr>
<th>Location of Aneurysm</th>
<th>No. of Cases</th>
<th>Average Circulation Time (sec)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Preoperative</td>
</tr>
<tr>
<td>suprachiasmoid internal carotid</td>
<td>2</td>
<td>11.0 (4.0)</td>
</tr>
<tr>
<td>peripheral anterior cerebral</td>
<td>3</td>
<td>9.0 (4.0)</td>
</tr>
<tr>
<td>internal carotid-post, comm.</td>
<td>35</td>
<td>7.7 (3.4)</td>
</tr>
<tr>
<td>ant. communicating</td>
<td>22</td>
<td>7.4 (3.2)</td>
</tr>
<tr>
<td>middle cerebral</td>
<td>31</td>
<td>7.0 (3.0)</td>
</tr>
<tr>
<td>cavernous int. carotid</td>
<td>8</td>
<td>6.7 (2.7)</td>
</tr>
<tr>
<td>int. carotid bifurcation</td>
<td>5</td>
<td>6.3 (2.8)</td>
</tr>
<tr>
<td>post. inf. cerebellar</td>
<td>3</td>
<td>6.0 (2.5)</td>
</tr>
<tr>
<td>basilar</td>
<td>5</td>
<td>5.8 (2.5)</td>
</tr>
<tr>
<td>total</td>
<td>114</td>
<td>7.2 (3.1)</td>
</tr>
</tbody>
</table>

*Arterial phase is shown in brackets.

men the average CT was 6.6 sec with a 3.0-sec arterial phase; in the 72 women, it was 7.6 sec with a 3.2-sec arterial phase. As age advanced, the average CT increased from 6.0 sec in the third decade to 7.8 sec in the seventh (Fig 1). In patients above the age of 40, the prolongation of CT was less pronounced. In spite of gradual prolongation of CT with increasing age, the arterial phase remained almost constant around 3.0 ± 0.2 sec. Therefore, it is thought that CT prolongation with increasing age results mainly from prolongation of the capillary and venous phases.

The average CT for each aneurysmal site is shown in Table 1. The longest average CT of 11.0 sec occurred with aneurysms at the suprasellar internal carotid artery; the shortest was 5.8 sec for basilar artery aneurysms. Not all cases of the posterior fossa aneurysms showed prolongation of CT preoperatively, but all cases of basilar artery aneurysms that had been operated on through the subtemporal approach showed an extremely prolonged postoperative CT compared to the preoperative value.

Clinical Condition of Patients

The average CT for each clinical grade according to the Botterell classification is shown in Fig. 2, which also demonstrates identical trends for the mortality-morbidity rate. The CT, therefore, can be considered a sensitive index of the patient's condition and prognosis.

Blood Pressure

The average CT was related to changes of systolic, diastolic, and mean arterial blood pressures, and to the intracranial perfusion pressure (Fig. 3).

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Fig. 1. Relation of average circulation time to age of patient.

Fig. 2. Relation of average circulation time to clinical grading (Botterell).
Circulation time with ruptured aneurysms

Systolic Blood Pressure. The average CT remained almost constant (6.2 to 6.6 sec) up to a pressure of 160 mm Hg; at higher pressures it increased sharply, reaching a maximum of 11.0 sec at 200 to 220 mm Hg.

Diastolic Blood Pressure. The average CT increased steadily from 6.4 sec with a diastolic pressure of 60 to 80 mm Hg to 11.0 sec with a pressure of 120 to 140 mm Hg. The early CT plateau noted with increasing systolic pressures was not observed with diastolic pressures.

Mean Arterial Pressure. The CT changed almost in the same relationship as with diastolic pressure, again without the initial plateau. The range was from 6.5 sec with a mean arterial pressure of 95 mm Hg, to 11.0 sec, with a pressure of 145 mm Hg.

Perfusion Pressure. The CT change with perfusion pressure paralleled that with the mean arterial blood pressure. The range was from 5.0 sec with a perfusion pressure of 55 mm Hg, to 11.0 sec with 115 mm Hg. It might have been expected that an increase in perfusion pressure would have increased the CBF; actually, the CT lengthened, suggesting a decrease in CBF.

Cerebrospinal Fluid

The average CT was shortest (6.4 sec) when the CSF was clear. The CT was 7.3 sec with grossly bloody CSF and 8.1 sec when the CSF was xanthochromic. When the CSF pressure was below 200 mm H2O, the average CT did not vary much with increasing CSF pressure; the range was 6.5 sec with pressures of 100 to 150 mm H2O and 6.6 sec for 150 to 200 mm H2O (Fig. 4). With CSF pressures above 200 mm H2O, the average CT remained higher, between 7.0 and 8.1 sec, without any particular relationship to the pressure increase.

Cerebral Angiography

Arterial Spasm. Of the 114 cases, 81 (78%) showed arterial spasm on the angiograms. The severity of the spasm was graded into three groups: 45 patients with mild spasm had an average CT of 7.1 sec, 27 patients with moderate spasm had a CT of 8.1 sec, and nine patients with severe spasm had a CT of 10.5 sec (Fig. 5 upper). The average CT for the group without spasm was 5.7 sec and for those with spasm, 7.8 sec, a difference of 2.1 sec; the difference in the mortality-morbidity rate for these two groups was 19% (Fig. 5 center).

Hematoma. In 21 (18%) of the cases, intracranial hematoma was suspected from the angiograms. The average CT for the group without hematoma was 7.1 sec and for the group with hematoma, 7.9 sec; however, the difference in the mortality-morbidity rate for these two groups was great (48%) (Fig. 5 center).

Hydrocephalus. In 30 (26%) of the cases, hydrocephalus was suggested by the angiograms. The average CT for the non-hydrocephalic group was 6.9 sec and for the hydrocephalic group 8.1 sec. The difference in the morbidity-mortality rate was 21% (Fig. 5 center).

Combined Angiographic Findings. To observe possible interrelations of these three findings shown on the angiograms, the CT
and morbidity-mortality rates were compared for each combination of these three signs (Fig. 5 lower).

The average CT was shortest (5.8 sec), and the mortality-morbidity rate was lowest (18%) in the group without any of these three findings. The average CT was longest (10.0 sec) and the mortality-morbidity rate highest (100%) in the group with all three findings. The more signs that existed simultaneously in one patient, the greater were the CT and mortality-morbidity rates observed.

Results of Treatment

Mortality-Morbidity Rate. This rate varied from 0 when the CT was 4.0 sec to 100% when it was 11.0 sec. There was a slow increase in the mortality-morbidity rate up to a CT of 7.9 sec and then a steeper increase from 40% at a CT of 8 sec to 100% at 11.0 sec (Fig. 6). An overall mortality-morbidity rate of 31.6% corresponds to a CT of 8.0 sec as extrapolated from the graph. The relationship between the CT and mortality-morbidity rate was treated statistically and showed significant positive correlation with $p < 0.01$ (chi square test).

Operation. Another observation was made on the average CT for groups classified according to the result of the operative treatment (Fig. 7). The groups categorized as “full recovery” and “partially disabled” showed a similar low CT, 6.9 and 6.6 sec respectively. On the contrary, the group labeled as “severely disabled” and “death” exhibited circulation times of 8.5 and 8.6 sec respectively.

Thus, the group of patients whose CT was greater than 8 sec had a markedly higher mortality-morbidity rate (average 58.3%) than the group with a CT less than 8 sec (18.5%).

Discussion

The hemodynamics of cerebral circulation are expressed as velocity (1/CT) and cerebral blood flow (CBF). The CT can be obtained either from serial cerebral angiograms or by radioisotope techniques. It has been shown that CT's obtained by these two methods are comparable.

The following factors may alter the cerebral CT: cardiac output, blood viscosity, blood pressure, vascular obstruction, and brain vascular resistance. The interrelation of these factors is therefore important to an interpretation of cerebral CT. The basic equations have been expressed elsewhere.
Circulation time with ruptured aneurysms

The CT has been reported to be faster in children, and slower at increasing age. We have observed the same prolongation of CT with age accompanied by a comparable increase in the mortality-morbidity rate.

Friedmann, et al., studying the CT of 62 patients with various intracranial lesions found close correlation between prolongation of CT and the degree of impaired consciousness. Symon, et al., reported that, in their CBF studies of 17 aneurysmal cases with isotope methods there was a strong correlation between CBF and the level of consciousness. As CBF can be expressed as a function of the reciprocal of CT, these conclusions can be interpreted as observations on the change in CT. Our observation has been also that prolongation of CT is associated with more severe clinical conditions as expressed in Botterell's grading.

Prolongation of CT with increased intracranial pressure has been documented both clinically and experimentally in the Valsalva maneuver, jugular compression, and in the standing-on-head position. When intracranial pressure increases, the venous pressure rises with the result of the increasing cerebral blood pool and obstruction to venous flow. All of these factors combine to produce prolongation of CT and decrease of CBF.

While the intracranial pressure rises and the autoregulation of the brain pushes perfusion pressure up by increasing the mean arterial pressure in order to increase and maintain CBF in normal range, in fact the CT lengthens, suggesting a decrease of CBF.

**Arterial Spasm**

Arterial spasm prolongs the CT inversely by the fourth power of the arterial diameter. Experimentally, a decrease in the vascular diameter caused by lowering the arterial PCO₂ is known to produce prolongation of CT and a decrease of the CBF. Taylor and Bell studied the mean CT with an isotope method on 50 patients with subarachnoid hemorrhage and found a longer CT in the patients with angiographic evidence of arterial spasm. However, he found no correlation between the CT of operative survivors with or without complications. In this study, a positive correlation was shown between the severity of arterial spasm, the prolongation of CT, and the mortality-morbidity rate.

A high intracranial pressure, which may produce acute hydrocephalus, decreases the perfusion pressure and prolongs CT. A general decrease in the CBF in cases of subarachnoid hemorrhage suggests a general loss of autoregulation, probably due to acute hydrocephalus which can affect the whole cerebral circulation simultaneously. In our study, hydrocephalus is second only to arterial spasm in its association with a marked prolongation of CT and a higher mortality-morbidity rate.

**Conclusion**

Circulation time is one of the important aspects of the hemodynamics of cerebral cir-
calculation. It is a sensitive indicator of the clinical condition of the patient with ruptured intracranial aneurysm and shows a high positive correlation with certain clinical features and the patient's prognosis. In our study a CT of more than 8.0 sec indicated severe impairment of the cerebral circulation. In general we believe a prolonged CT indicates the need for the correction of changes before surgical treatment is undertaken. The CT can easily be studied during angiographic studies of intracranial aneurysms. We believe this is a valuable procedure.

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References


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