Long-term Follow-up of Cerebral Blood Flow in Patients with Ruptured Cerebral Aneurysm

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Abstract

The xenon-133 inhalation technique was used to make three measurements of regional cerebral blood flow (CBF) in 34 patients with ruptured cerebral aneurysm: in the acute period (<14 days) after subarachnoid hemorrhage, in the subacute period (15-30 days), and in the chronic period (12-24 months). The hemispheric mean value of initial slope index was used as the mean CBF. The clinical outcomes were classified into good recovery (GR) (24 cases), moderate disability (MD) (5), and severe disability (SD) (5) on the Glasgow Outcome Scale. In all periods, the mean CBF significantly correlated with the outcome. GR patients had the highest mean CBF, MD patients the intermediate mean CBF, and SD patients the lowest mean CBF. GR patients had a near-normal mean CBF by the chronic period, while SD patients showed no significant CBF recovery throughout the course.

Key words: aneurysm, cerebral blood flow, subarachnoid hemorrhage

Introduction

The xenon-133 (\(^{133}\)Xe) inhalation method for measuring cerebral blood flow (CBF) is a noninvasive technique allowing repeated measurements of regional CBF (rCBF) in the same patient.\(^{14,15}\) We previously used this method to perform two consecutive rCBF measurements before and after intravascular volume expansion to investigate the effect on CBF in subarachnoid hemorrhage (SAH) patients.\(^{21}\) Most recent rCBF studies of SAH patients also employed the \(^{133}\)Xe inhalation method and have established relationships between CBF and angiographic vasospasm, symptomatic vasospasm (or delayed ischemic neurological deficits due to vasospasm), and neurological conditions.\(^{10,12,19,20,22,23}\)

Other investigators have also studied CBF changes in SAH patients, but mostly in the acute and/or subacute periods,\(^{8,12,17}\) with little attention paid to the chronic period (>1 year after SAH).\(^{3,10,22}\) In the present study, we performed rCBF measurements in SAH patients using the \(^{133}\)Xe inhalation method in the acute, subacute, and chronic periods after ictus, to clarify long-term alterations of CBF in SAH patients.

Materials and Methods

The present study included 34 patients, 11 males and 23 females, aged 38-65 years (mean: 54 years) who underwent aneurysm clipping in Kimitsu Central Hospital during 1985-1987. Clinical grades (Hunt and Kosnik) on admission were: 12 cases of grade I or II, 16 of grade III, five of grade IV, and one of grade V. The site of the ruptured aneurysm was confirmed by angiography and surgery as: 12 on the internal carotid artery, 11 on the anterior communicating artery, eight on the middle cerebral artery, and one each of the distal anterior cerebral, anterior choroidal, and posterior inferior cerebellar arteries. This study excluded all patients with multiple aneurysms. Clipping was performed within 3 days of SAH in 25 of 34 patients. The present study also excluded patients who developed either hydrocephalus or postoperative complications caused by surgical manipulation such as brain contusion, arterial obliteration, etc.

rCBF was measured using the \(^{133}\)Xe inhalation method (Novo Cerebrograph; Novo Diagnostic Systems, Bagsvaerd, Denmark). The procedure employed was described in detail in our previous reports elsewhere.\(^{14,15,20,22}\) All 34 patients underwent three rCBF measurements: the first in the acute period (<14 days) after SAH, the second in the...
CBF Changes After SAH

subacute period (15-30 days), and the third in the chronic period (12-24 months). CBF was calculated as an initial slope index (ISI), and the hemispheric mean value of ISI was calculated to give the mean CBF in the cerebral hemisphere ipsilateral and contralateral to the craniotomy. rCBF was measured in eight volunteers (age: 29-48 years) without neurological or cardiopulmonary diseases, to obtain the control CBF value.

Two years after SAH, the clinical outcome of each patient was classified, using the Glasgow Outcome Scale (GOS), into good recovery (GR), moderate disability (MD), and severe disability (SD). The present study excluded all clinical outcomes of vegetative or dead.

The group CBF values were compared by analysis of variance and the Bonferroni t-test. The acute, subacute, and chronic CBF data for each group were compared by repeated-measures analysis of variance and the paired t-test corrected by the Bonferroni inequality. A p value < 0.05 was considered statistically significant.

Results

Table 1 gives the results of rCBF measurement in the 34 SAH patients. The control value of mean CBF obtained in the eight volunteers (16 hemispheres) was 70 ± 8 ml/100 gm/min.

Figure 1 indicates the results of statistical analysis for the acute, subacute, and chronic stages. In the acute period, the mean CBF values of three patient groups were significantly lower than the control value in both hemispheres. The differences between each two patient groups were also significant. In the subacute period, the mean CBF values of three patient groups were also significantly lower than the control value in both hemispheres. SD patients had the significantly lower mean CBF than both of the GR and MD patients. However, the difference between GR and MD patients was not significant. In the chronic period, the mean CBF value of GR patients was not significantly different from the control value, while those of the MD and SD patients were still significantly lower than the control in both hemispheres. The mean CBF of GR patients was not significantly different from that of MD patients, but was from that of SD patients.

Figures 2 shows the statistical analysis of the whole course in each group. In GR patients, the ipsilateral mean CBF showed a significant recovery from subacute to chronic periods, although the change between acute and subacute periods was not significant. In MD patients, the ipsilateral mean CBF showed a significant recovery from acute to chronic periods. However, the ipsilateral mean CBF of SD patients did not show any significant change throughout the study period. The statistical analysis of the contralateral mean CBF obtained the same result as in the ipsilateral hemisphere.

Discussion

The CBF and clinical outcome were clearly related in all periods after SAH. The mean CBF was significantly higher in patients with favorable outcomes than in patients with poor outcomes. Our results validated the prognostic value of rCBF studies in SAH patients previously reported. Previous rCBF studies have demonstrated that patients with decreased CBF achieve poor outcomes, but the extent of CBF reduction necessary varied depending on the method employed. Ishii reported the critical level as 30 ml/100 gm/min. Using the same 133Xe inhalation method as the present study, Géraud et al. found the critical flow level to be 35 ml/100 gm/min. Our study showed that the critical flow level in the acute period resulting in a poor outcome (SD by GOS) was 40% of the control value (30 ml/100 gm/min). Another critical flow level in this study was 70% of the control value (50 ml/100 gm/min). A mean CBF value over this level in the acute period resulted in good outcome (GR by GOS), and CBF suppression in the acute period (30% of the control) was revers-

Table 1 rCBF measurements in SAH patients

<table>
<thead>
<tr>
<th>Outcome</th>
<th>No. of patients</th>
<th>Acute period</th>
<th>Subacute period</th>
<th>Chronic period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ipsilateral</td>
<td>Contralateral</td>
<td>Ipsilateral</td>
</tr>
<tr>
<td>GR</td>
<td>24</td>
<td>52 ± 10 (74%)</td>
<td>55 ± 12 (79%)</td>
<td>50 ± 10 (71%)</td>
</tr>
<tr>
<td>MD</td>
<td>5</td>
<td>40 ± 3 (57%)</td>
<td>40 ± 3 (57%)</td>
<td>44 ± 8 (63%)</td>
</tr>
<tr>
<td>SD</td>
<td>5</td>
<td>30 ± 3 (43%)</td>
<td>30 ± 6 (43%)</td>
<td>29 ± 7 (41%)</td>
</tr>
</tbody>
</table>

Values are means ± SD (ml/100 gm/min). Numerals in parentheses indicate percentage of control value (70 ± 8 ml/100 gm/min).

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Fig. 1 Ipsilateral (left) and contralateral mean CBF (right) in the acute (A), subacute (B), and chronic periods (C) after SAH. Data are means ± SD. *: statistically significant (p < 0.05), NS: not significant.

Fig. 2 Temporal change in the ipsilateral (left) and contralateral mean CBF (right) following SAH up to the chronic period. Data are means ± SD. *: statistically significant (p < 0.05), NS: not significant. ○: acute period, ●: subacute period, □: chronic period.
ible and disappeared 2 years after SAH.

Our results showed that 2 years after SAH, the mean CBF of patients with good outcome (GR and MD by GOS) had significantly recovered, but not in the cases of poor outcome (SD by GOS). In the acute period, CBF may be reduced by various factors including 1) angiographic vasospasm,5,8,12,17,18,20,22) 2) hydrocephalus,11,15) 3) increased intracranial pressure,6,10) 4) brain edema, 5) surgical manipulations such as brain retraction,1,2,22) and 6) depressed cerebral metabolism.9,17) The CBF reduction in the chronic period may be caused by depressed cerebral metabolism. The significant mean CBF recovery in SAH patients with good outcome between the acute and chronic periods suggests that the pathological factors have disappeared by the chronic period. Our results demonstrate that the mean CBF recovers between the subacute and chronic periods, not the acute and subacute periods. Most pathological factors above may suppress CBF up to 30 days after SAH, but cease by 12-24 months postictus. The CBF recovery after the subacute period correlates with the frequent neurological recovery in the follow-up outpatient clinic.

Hyperemia occasionally occurs in SAH patients.3,7,17) In the present study, the mean CBF reduction was related to the clinical outcome. No hyperemia was associated with poor outcome. Hyperemia in SAH patients is usually focal and associated with contiguous ischemia.17) The present study used the 133Xe inhalation method to investigate the mean CBF only. Therefore, focal hyperemia found in the border of ischemia will not have been indicated.

CBF in the chronic period after SAH has not been widely investigated. Yamamoto et al.23) reported that the CBF in SAH patients and normal subjects is similar 3 months to 6 years after SAH. Matsuda et al.10) reported that a significant CBF reduction continues for several months in elderly SAH patients with good outcome. The present study demonstrated that in the chronic period, GR patients have near-normal CBF, but MD and SD patients still have significantly decreased CBF compared to the control value. In the chronic period, the CBF may directly reflect the cerebral metabolism and correlate well with the neurological condition. Therefore, the cerebral metabolism of GR patients may have recovered to normal by the chronic period.

Clearly, the rCBF is related to patient outcome and has prognostic value, especially in the acute period.

References


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