SUMMARY The development of a non-invasive technique for simultaneous bihemispheric measurement of regional cerebral blood flow (rCBF) by inhalation of 133Xenon made available a safe method for evaluation of cerebral circulation under various cardiac conditions. Regional cerebral blood flow was measured by 133Xenon inhalation in 31 patients with chronic atrial fibrillation without symptoms of heart failure and free from neurological diseases. The age ranged from 35 to 91 (mean 60.3 years). In 27 out of the 31 patients rCBF was found to be lower than for age-matched normal control subjects. A reduction in cerebral blood flow from 17.5% to 5.5% in various age groups was found. The highest reduction in mean rCBF (17.5%) was found in the younger age group (35-50 years). In the group of patients between 51-65 years, the reduction was 13.4% and in the patients above 65, only 5.5%. The reduction of rCBF observed in our patients apparently did not reach the level required to produce cerebral manifestations. However, it is plausible to assume that any superimposed rhythm or rate pathology and/or cerebral arteriosclerosis may further compromise the cerebral circulation.

Although cerebral emboli are a frequent cause of cerebral manifestations in cardiac arrhythmia, a chronic reduction in cerebral perfusion consequent to rate or rhythm disturbances in patients with cerebral vascular diseases should be considered. Early recognition and therapy of chronic arrhythmia with reduced cerebral perfusion may prevent neurological complications at a later stage.

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for simultaneous bihemispheric measurement of regional cerebral blood flow (rCBF) by inhalation of $^{133}$Xenon a safe method for evaluation of cerebral circulation under various cardiac conditions has become available. In this study rCBF was measured in a group of patients with chronic atrial fibrillation (AF). Since the rCBF tends to decrease with normal aging, $^{133}$Xenon values obtained in our patients with chronic atrial fibrillation were compared with flow data obtained in age-matched normal control subjects.

**Material and Methods**

Thirty-one patients with chronic AF were studied; all were ambulatory and had no symptoms of heart failure. Their resting ventricular rate ranged between 70-85/min either with or without digitalis therapy. The patients were divided into 3 groups according to the underlying disease:

A. Rheumatic heart disease with valvular disease, before or after cardiac surgery (11 patients).

B. Patients with arteriosclerotic heart disease. In this group were included only patients above 50 years in whom the diagnosis of arteriosclerotic heart disease was based on symptoms of angina pectoris. Evidence was obtained by coronary arteriography or myocardial infarction in the past (12 patients).

C. Patients with idiopathic AF in whom no underlying cardiac condition was established, and in whom all thyroid function tests were found to be normal (8 patients).

Among the 31 patients, 14 were males, 17 females. Ages ranged from 35 to 80 (mean 60.3 years). Blood pressure was normal in 30 patients; only one had hypertension. Each patient had a detailed history and complete physical, cardiovascular, and neurological examination. ECG and EEG recordings were obtained. Patients with previous history of cerebral vascular disease, mental impairment, head trauma, residual neurological findings or focal, regional or hemispheric EEG abnormalities were not included, and none who was included had neurological manifestations. Because of the Xenon inhalation technique requirements patients with pulmonary dysfunction were excluded.

**rCBF measurement**

rCBF was determined by the $^{133}$Xenon inhalation technique, of Obrist et al. The study was carried out with patients lying on a bed with closed eyes and plugged ears in a quiet, semi-darkened room. After a period of adjustment, each subject breathed $^{133}$Xenon in a concentration of 2.5 mCi/liter mixed with air, for one min. The radioactive gas was administered through a close fitting face mask with one-way valve in a non-rebreathing system. Air drawn directly from the face mask by a thin catheter was continuously monitored by a separate detector in order to record the $^{133}$Xenon concentration in the expired air.

The end-tidal values of this “air” curve were used to correct the “head” curves for the re-circulation of the inhaled radioisotope. The expired air was also monitored for CO$_2$ content. Blood pressure was determined by auscultation.

The rCBF was computed according to Risberg et al. as the initial slope index (ISI) derived from the initial slope of the clearance curves between the second and third minute. The ISI values in our patients were compared with those obtained in a series of 50 normal non-hospitalized, normotensive control subjects with ages ranging from 35 to 80 (mean 56.8 years).

**Results**

rCBF in patients with chronic AF was found to be lower than the expected age-matched value in 27 out of the 31 patients. rCBF levels were higher in the anterior than in the posterior regions of both hemispheres, as in the controls. There were no significant differences in the mean hemispheric and the individual rCBF rates obtained from parallel regions between the right and left hemisphere. Figure 1 shows the correlation between age and the mean rCBF values in AF patients and in normal subjects. The computed regression line of normal subjects shows a significant reduction of rCBF with advancing age ($r = 0.42$, $p < 0.01$), and all but 4 AF patients had values below the regression line.
ATRIAL FIBRILLATION AND rCBF/Lavy et al.

The reduction in rCBF in the AF patients compared to the normal subjects is not the same for all age groups. Figure 2 demonstrates the rCBF values in AF patients grouped according to age as compared to normal controls. It can be seen that a highly significant 17.5% reduction in rCBF occurs in AF patients in the age group between 35-50 years (43.6 ± 2.4 as compared to the control values for the same age group of 52.9 ± 1.7, p < 0.01). The rCBF in the group of patients between the ages of 51-65 years was also significantly reduced by 13.4%, as compared with normal controls (42.5 ± 1.5 vs. 49.4 ± 1.2, p < 0.01). In the third group of patients, all of them older than 66 years, the mean rCBF was 42.5 ± 1.5, a value only 5.5% lower than the control value (45.0 ± 1.8), the difference being statistically insignificant. The patients were also divided into 3 groups according to the etiology of the AF. The table shows the mean rCBF values in patients with AF due to ischemic or rheumatic heart disease, and of undetermined origin. It can be seen that very similar blood flow values were observed in all 3 groups, independent of the etiology, with no statistical significance in the slight flow differences among the groups.

Cerebral Blood Flow in Patients with Chronic Atrial Fibrillation as Compared with Normal Controls

A reduction in cardiac output consequent to chronic AF seems to depend on the functional state of the myocardium. In patients with chronic AF and heart disease, the cardiac output may be 20% reduced, while in subjects without other cardiac disease the cardiac output may remain within normal limits in spite of the chronic arrhythmia. Cerebral blood flow does not necessarily change parallel with the cardiac output because of the autoregulation mechanisms in normal brain. Due to these mechanisms, it was generally accepted in the past that the CBF will not drop until the cardiac output is sharply reduced. Our results seem to contradict this assumption. We have demonstrated a significant reduction in cerebral blood flow, ranging on average from 5.5% to 17.5% in various age groups both in patients with rheumatic or arteriosclerotic heart disease, as well as in patients with no demonstrable underlying cardiac disease. The reduction in mean rCBF was most significant (17.5%) in the younger age group, in whom the expected rCBF is higher. In the group of patients between 51-65 the reduction was 13.4% and in the patients above 65 only 5.5%. Interestingly, the mean rCBF in all 3 age groups averaged 42-43 ISI. However, since we chose only subjects free of neurological symptoms or signs, this perhaps systematically excluded elderly patients with flows below that of their age-matched controls; such low absolute flow values could very likely be accompanied by such neurological signs. A similar mean rCBF was calculated also if the patients were selected according to the AF etiology.

The reduction of rCBF observed in all our patients apparently did not reach the level required for cerebral manifestations, since none of these patients had overt neurological symptoms. However, it is plausible to assume that if superimposed rapid ventricular rate should ensue at a later stage or if any other cardiac complication should further compromise the cardiac output, this might bring the rCBF to such a level that clinical manifestations would appear. Another mechanism which might lead to development of overt cerebral manifestations is the development of cerebral

**Table** Mean Hemispheric Blood Flow and Etiology of Chronic Atrial Fibrillation. Despite Different Etiologies and Mean Ages, Decrease in Mean Hemispheric Flow from Age-Matched Expected Values Are Similar in 3 Groups.

<table>
<thead>
<tr>
<th>Etiology of Chronic Atrial Fibrillation and Mean Hemispheric Blood Flow</th>
<th>ISCHEMIC HEART DISEASE</th>
<th>RHEUMATIC HEART DISEASE</th>
<th>UNDETERMINED ORIGIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Age</td>
<td>66.9</td>
<td>52.0</td>
<td>54.7</td>
</tr>
<tr>
<td>Mean Hemispheric Flow</td>
<td>61.1</td>
<td>68.1</td>
<td>61.6</td>
</tr>
<tr>
<td>Age-matched Expected Flow</td>
<td>72.4</td>
<td>72.4</td>
<td>72.4</td>
</tr>
</tbody>
</table>

Discussion

A reduction in cardiac output consequent to chronic AF seems to depend on the functional state of the myocardium. In patients with chronic AF and heart disease, the cardiac output may be 20% reduced, while in subjects without other cardiac disease the cardiac output may remain within normal limits in spite of the chronic arrhythmia. Cerebral blood flow does not necessarily change parallel with the cardiac output because of the autoregulation mechanisms in normal brain. Due to these mechanisms, it was generally accepted in the past that the CBF will not drop until the cardiac output is sharply reduced. Our results seem to contradict this assumption. We have demonstrated a significant reduction in cerebral blood flow, ranging on average from 5.5% to 17.5% in various age groups both in patients with rheumatic or arteriosclerotic heart disease, as well as in patients with no demonstrable underlying cardiac disease. The reduction in mean rCBF was most significant (17.5%) in the younger age group, in whom the expected rCBF is higher. In the group of patients between 51-65 the reduction was 13.4% and in the patients above 65 only 5.5%. Interestingly, the mean rCBF in all 3 age groups averaged 42-43 ISI. However, since we chose only subjects free of neurological symptoms or signs, this perhaps systematically excluded elderly patients with flows below that of their age-matched controls; such low absolute flow values could very likely be accompanied by such neurological signs. A similar mean rCBF was calculated also if the patients were selected according to the AF etiology.

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**Figure 2.** Cerebral blood flow in patients with chronic atrial fibrillation as compared with normal controls. The mean flows of the AF patients in the 3 age groups show insignificant age dependence. The difference in flow between normal controls and AF patients is statistically significant in the 2 younger age groups (p < 0.01).
arteriosclerosis, and a patient will be prone to develop cerebral manifestations if the basic rCBF was already decreased as a result of the long-standing arrhythmia. It has already been observed that there is frequent occurrence of cerebral manifestations such as dizziness, syncope, convulsions, visual disturbances, regional paresis or paralysis in patients with cardiac arrhythmia and cerebral vascular insufficiency.1-3 Although cerebral emboli are an extremely frequent cause for cerebral manifestations in cardiac patients,4-6 the possibility of a reduction in cerebral perfusion consequent to arrhythmias should be considered in such patients as well, especially if an unequal distribution of the available blood supply prevails also.

It is our conclusion that chronic fibrillation reduces the cerebral blood flow, especially in younger individuals, and that the early recognition and therapy of this arrhythmia may improve the blood supply to the brain and prevent neurological complications at a later stage.

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