SUMMARY: The development of a non-invasive technique for simultaneous bihemispheric measurement of regional cerebral blood flow (rCBF) by inhalation of $^{133}$Xenon made available a safe method for evaluation of cerebral circulation under various cardiac conditions. Regional cerebral blood flow was measured by $^{133}$Xenon inhalation in 31 patients with chronic atrial fibrillation without symptoms of heart failure and free from neurological diseases. Their 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.

Stroke, Vol 11, No 1, 1980

AUTOREGULATION is the ability of the cerebral vasculature to vary its resistance in response to changes in perfusion pressure. This mechanism is considered to be the main protective factor of the brain against ischemia. In the normal brain a moderate increase or decrease in cerebral perfusion pressure is accompanied by a reciprocal change in cerebral vascular resistance and thus, the cerebral blood flow (CBF) will remain constant. In spite of this mechanism, acute hemodynamic changes under certain circumstances may temporarily or permanently alter the cerebral circulation.1, 6 Acute myocardial infarction or acute heart failure may result in a significant decrease of cardiac output below a critical level with a consequent decrease in CBF, leading frequently to the appearance of diffuse or regional neurological symptoms and signs.3, 7 On the other hand, chronic reduction of the cardiac output has been reported to be followed by a chronic reduction of CBF only if the heart failure is long-standing and severe and especially if the patient suffers also from cerebral arteriosclerotic changes, which prevent the autoregulatory mechanism from compensating for the fall in the systemic arterial pressure.

Acute cardiac arrhythmias may reduce cardiac output to a degree where the cerebral circulation is also compromised and neurological manifestations may appear.1 However, the effect of chronic impairment of the cardiac rhythm on cerebral circulation has not yet been thoroughly investigated. Corday and associates6 performed pioneering investigations in experimental animals on this subject and demonstrated that the CBF may be reduced by an average of 8 percent during frequent premature atrial systoles and by 12 percent during premature ventricular systoles. During atrial tachycardia, fibrillation, or flutter with rapid ventricular rates, the average reduction in CBF was 23 percent, and a 40 percent decrease was observed during extremely rapid ventricular rates. Corday et al.6 expressed the view that normal subjects may tolerate significant reduction in CBF following cardiac arrhythmias without having symptoms or signs of cerebral ischemia, but patients with cerebral vascular diseases are prone to develop neurological manifestations as a result of disturbances of heart rate or rhythm.

With the development of a non-invasive technique
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, $^{10}$ rCBF 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.$^{11, 12}$ 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.$^{13}$ 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.

![Figure 1](http://stroke.ahajournals.org/)

**Figure 1.** Mean brain rCBF values, calculated from 16 bihemispheric ISI data in 50 normal controls aged 35–80 years (points) and in 31 patients with atrial fibrillation aged 35–80 years (triangles), plotted against age. The computed regression line through normal flow values shows a statistically significant ($p < 0.01$) decline of rCBF during aging in the normal subjects.
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 *r*CBF in the group of patients between the ages of 51-65 years was also significantly reduced by 13.4%, as compared with normal controls (42.8 ± 2.2 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**

![Cerebral Blood Flow in Patients with Chronic Atrial Fibrillation](image)

**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).

**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 ISL. 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. |
|---------------------------------|-----------------|-----------------|-----------------|
| **The Etiology of Chronic Atrial Fibrillation and Mean Hemispheric Blood Flow** |
| ** ISCHEMIC HEART DISEASE ** | ** RHEUMATIC HEART DISEASE ** | ** UNDETERMINED ORIGIN ** |
| ** n ** | 12 | 11 | 6 |
| ** Mean Age ** | 66.9 | 52.0 | 54.7 |
| ** ISL - Mean Hemispheric Flow ** | ** ISL - Expected Flow ** | ** ISL - Expected Flow ** | ** ISL - Expected Flow ** |
| 41.2 | 44.6 | 43.3 |
| 51.1 | 51.7 | 52.4 |
| 47.0 | 52.6 | 50.0 |

*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.*
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.\textsuperscript{1, 9} Although cerebral emboli are an extremely frequent cause for cerebral manifestations in cardiac patients,\textsuperscript{15, 16} 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.

References
Effect of chronic atrial fibrillation on regional cerebral blood flow.
S Lavy, S Stern, E Melamed, G Cooper, A Keren and P Levy

Stroke. 1980;11:35-38
doi: 10.1161/01.STR.11.1.35

Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1980 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/11/1/35.citation

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in
Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office.
Once the online version of the published article for which permission is being requested is located, click Request
Permissions in the middle column of the Web page under Services. Further information about this process is
available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/