Crossed Hemispheric Diaschisis in Unilateral Cerebellar Lesions

M. Rousseaux, MD, PhD, and M. Steinling, MD, PhD

Background and Purpose: We studied 12 patients with unilateral cerebellar hemorrhage to look at its effect on regional cerebral blood flow.

Methods: We used single-photon emission computed tomography by continuous inhalation of xenon-133. The blood flow was quantified in the cerebellum and in nine areas of interest on the slice passing through the basal ganglia.

Results: The comparison of the blood flow values of the patients and control subjects showed a significant reduction in the contralateral hemisphere of the patients, predominantly in the frontal region and in the lenticular nucleus of the contralateral hemisphere but also in the anterointernal frontal area of the ipsilateral hemisphere. The analysis of the asymmetry indexes revealed in the same way significant differences between patients and control subjects in the frontal cortex and in the lenticular nucleus.

Conclusions: These results provided concordant evidence suggesting a blood flow reduction in the contralateral hemisphere. This phenomenon of “crossed hemispheric diaschisis” is probably related to the interruption of cerebellocortical tracts. (Stroke 1992;23:511–514)

A reduction in metabolic activity and blood flow in the cerebellum contralateral to lesions of one cerebral hemisphere was first demonstrated by Baron et al. Since that time, other studies have confirmed this phenomenon, which has also been observed in a limited number of frontal, thalamic, or putaminal lesions. The work of Martin and Raichle has suggested effects on the ipsilateral cerebellum.

We studied the regional cerebral blood flow (rCBF) of 12 patients with cerebellar lesions to determine whether there are changes in the rCBF of the cerebral hemispheres and, more particularly, in the contralateral one.

Subjects and Methods

We examined 12 consecutive patients who had experienced a cerebellar hemorrhage without any effects on the brain stem. There were nine men and three women ranging in age from 40 to 76 (median 65) years of age. The lesion revealed by computed tomographic (CT) scan was lobar and unilateral in seven cases (left in three cases, right in four) and lobar and vermicinal in five cases (left in two cases, right in three). Two patients had undergone surgery to evacuate the hematoma.

We conducted the cerebral blood flow (CBF) studies 13–79 (median 26.5) days after the hemorrhage. At that time, level of consciousness was normal in all patients, and examination revealed a classic cerebellar syndrome. The degree of ataxia of the upper limb was assessed on a scale of 0 (absent) to 4 (major, absence of functional use); the same procedure was adopted for ataxia of the trunk. The total cerebellar score was the sum of the previous two scores.

The CBF was analyzed using single-photon emission computed tomography, by continuous inhalation of xenon-133, with an apparatus of the Tomomatic 64 type (Medimatic, Copenhagen). The examination was conducted under standard conditions, after a 15-minute adaptation period, in dim light and silence. The ears were not plugged, but the eyes were closed. This examination lasted 4.5 minutes. The partial alveolar pressure for CO₂ (Paco₂) was recorded with a Beckman LB2 capnograph.

The measurements were obtained from three 2-cm-thick scanner slices of brain tissue from 1, 5, and 9 cm above the orbitomeatal (OM) plane (i.e., OM+1+5+9 cm). The full-width half-maximum was 12 mm and the pixel 25 mm². The reproducibility of the method has been previously described.

Blood flow values were quantified in the cerebellum on the lower slice and in nine areas (size: 650–800 mm²; 25 pixels at least) traced manually on each cerebral hemisphere on the intermediate slice (Figure 1) passing through the basal ganglia: frontal anterointernal, anterexternol, and posteroexternal; temporal anterior and posterior; temporop-occipital; internal occipital; lenticular; and thalamic. The mean hemisphere CBF was the average of the local values. As previously described, we later calculated the cerebellar asymmetry indexes [AI%=(healthy side rCBF−lesion side rCBF)×100/ (healthy side rCBF+lesion side rCBF)/2], and then the asymmetry indexes of the hemisphere areas [AI%=(lesion side rCBF−healthy side rCBF)×100/ (lesion side rCBF+healthy side rCBF)/2].
Stroke subjects in hemisphere ipsilateral ("lesion" side) and contra-
lateral ("healthy" side) to cerebellar hemorrhage.

The rCBF values and then the asymmetry index values were compared with those of 24 control subjects, 14 men and 10 women, ranging in age from 21 to 73 years. For each patient, two controls were matched in terms of side of the cerebellar lesion and age. In this way, the "lesion" side at the level of the cerebellum and cerebral hemispheres was left in 10 control subjects and right in 14 others. To ensure correct matching for age, we corrected the CBF values for the control subjects, taking into account the regression lines of rCBF versus age for each area.

The rCBF values were significantly lower on the lesion side in the patients than in controls for each area of interest. A repeated-measures ANOVA analyzing the variations of the hemisphere rCBF values with one between-subjects factor (group, patients versus controls) and one within-subjects factor (side, lesion versus healthy) found a significant side effect (F = 52.8, df = 1, p = 0.0001) and a significant group x side interaction (F = 45.0, df = 1, p = 0.0001). The post hoc analysis showed that CBF values were significantly lower on the lesion side in the patient group.

On the hemisphere ipsilateral to the cerebellar lesion (lesion side), the mean CBF values were generally lower than those of the control subjects but the differences were small, with the exception of the anterointernal frontal area. In the cerebral hemisphere contralateral to the lesion (healthy side), the mean rCBF values were significantly lower in the patients than in controls for each area of interest. A repeated-measures ANOVA analyzed the variations of the hemisphere rCBF values with one between-subjects factor (group, patients versus controls) and two within-subjects factors (side, lesion versus healthy; and area, frontal anterointernal to thalamic). We found a significant main effect for the side (F = 11.02, df = 1, p = 0.002) and for the area (F = 45.7, df = 8, p = 0.0001) and a strong tendency for the group x side interaction (F = 4.06, df = 1, p = 0.051); the CBF values were lower on the healthy side. The following interactions were also significant: group x side (F = 11.9, df = 1, p = 0.001), group x area (F = 2.04, df = 8, p = 0.042), and group x side x area (F = 2.4, df = 8, p = 0.018).

In addition, in the majority of cases, the CBF reduction on the healthy hemispheric side was "harmonious." This was shown by the highly significant coefficients of correlation between the CBF values on the frontal and temporal cortex and on the lenticular nucleus (frontal anterointernal 0.789, p = 0.0023; frontal posteroexternal 0.896, p = 0.0001; temporal anterior 0.940, p = 0.0001; temporal posterior 0.867, p = 0.0003; and temporo-occipital 0.801, p = 0.0018). The same coefficients between cortex and thalamus were lower (frontal anterointernal 0.612, p = 0.034; frontal posteroexternal 0.718, p = 0.008; temporal anterior 0.818, p = 0.001; temporal posterior 0.732, p = 0.007; and temporo-occipital 0.712, p = 0.009).
which was probably the consequence of the “dissociation” observed in some patients.

The mean cerebellar AI index of the patients (29.5%) was significantly higher ($p=4.1 \times 10^{-4}$) than that of the control subjects (1.3%). In the cerebral hemispheres, the mean asymmetry indexes of the patients were positive (frontal anterointernal 2.1%; frontal anteroexternal 9.1%; frontal posteroexternal 10.4%; temporal anterior 7.1%; temporal posterior 8.9%; temporo-occipital 0.7%; internal occipital 1.6%; lenticular 9.9%; and thalamic 4.2%). A repeated-measures ANOVA analyzed the variations of AI, with one between-subjects factor (group, patients versus controls) and one within-subjects factor (site, frontal anterointernal to thalamic). There was a significant group effect ($F=16.01; df=1; p=0.0003$), with AI being more elevated in patients, and a significant group x site interaction ($F=2.38; df=8; p=0.017$); post hoc analysis showed that AI was significantly higher for patients in the anteroexternal frontal area, the posteroexternal frontal area, and the lenticular area.

Time after stroke and the cerebellar clinical score were not correlated with rCBF.

Discussion

These results, obtained in 12 patients, provided concordant evidence suggesting a reduction in the CBF for the hemisphere contralateral to a unilateral cerebellar lesion. This phenomenon has been suggested in a previous case report, but in that case the cerebellar infarction was associated with a brain stem lesion that could have caused its occurrence.

It was the reverse of the crossed cerebellar diaschisis described by Baron et al and subsequently encountered by many other authors. Interruption of the corticopontocerebellar tracts was, indeed, proposed as an explanation of this remote effect. Nonetheless, the fact that reduced cerebellar metabolism or low flow can be found in strictly thalamic lesions suggested that a retrograde mechanism or cortical hypometabolism may also play a part.

The reduction in hemispheric CBF that we observed had a number of particular features that should be emphasized. It especially involved the frontal regions of the cortex and the deeper lenticular area; the distribution was the same in the case previously described. It was also more discrete than the reduction of cortical CBF associated with thalamic or capsulolenticular lesions. This contralateral effect may be related to the essential anatomic connections between the cerebellum and the hemispheric structures.

| Table 1. Mean (ml/100 g/min) and Standard Deviation Values of the rCBF |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                | Patients        | Controls        | Healthy side    | Controls        |
|                                | Mean  | SD   | Mean  | SD   | Mean  | SD   | Mean  | SD   |
| Cerebellum                     | 40.6  | 6.0  | 50.5  | 8.6  | 55.3  | 11.3 | 51.1  | 8.4  |
| Frontal anterointernal         | 53.2  | 11.5 | 62.1  | 10.0 | 52.7  | 14.2 | 62.2  | 10.9 |
| Frontal anteroexternal         | 46.7  | 10.5 | 49.1  | 7.2  | 42.4  | 8.1  | 49.4  | 7.3  |
| Frontal posteroexternal        | 51.6  | 10.9 | 53.2  | 9.1  | 46.5  | 9.3  | 55.7  | 9.2  |
| Temporal anterior              | 51.1  | 9.5  | 54.3  | 8.8  | 47.7  | 9.5  | 53.5  | 9.4  |
| Temporal posterior             | 52.9  | 10.9 | 56.7  | 9.6  | 49.0  | 13.2 | 55.7  | 8.1  |
| Temporo-occipital              | 39.8  | 9.1  | 44.4  | 6.5  | 39.5  | 8.8  | 44.8  | 6.1  |
| Internal occipital             | 51.7  | 12.2 | 56.4  | 9.5  | 52.7  | 12.1 | 55.5  | 9.5  |
| Lenticular                     | 58.1  | 14.5 | 64.5  | 11.3 | 52.0  | 11.5 | 64.8  | 12.6 |
| Thalamic                       | 52.5  | 13.0 | 59.9  | 11.9 | 50.0  | 10.1 | 59.9  | 12.9 |

Mean values are milliliters per 100 grams per minute.
nuclei of the thalamus. The ventrolateral nucleus projects onto the anterior motor and premotor cortical areas. The interruption of this circuit in the region of the cerebellar nuclei (or their connections) was possibly responsible for the CBF reduction in the hemisphere, predominating in the frontal structures. Nonetheless, a retrograde mechanism through an interruption of the corticopontocerebellar tracts could not be excluded. An argument in favor of this phenomenon was the observation in one patient of a decrease in the cortical CBF in conjunction with a paradoxical increase in thalamic rCBF. This increase could be linked with an abnormal activation of the thalamus by the cerebellar nuclei through the removal of the inhibitory effect exerted by the cerebellar cortex.\textsuperscript{14,15}

The second phenomenon observed was a CBF reduction ipsilateral to the cerebellar lesion. It was more limited, chiefly involving the anterior frontal region, and was the reverse of the reduction in CBF and oxygen extraction previously described in the cerebellum ipsilateral to frontal lesions.\textsuperscript{7} Several mechanisms require discussion. Hydrocephalus can develop in the first few days after a cerebellar hemorrhage.\textsuperscript{16} However, in this study, the patients were examined at a stage at which they no longer displayed symptoms suggesting such a complication. The possibility of hypoactivity secondary to an extension of the lesions toward the vermis cannot be excluded. It is also possible that this phenomenon may be linked with the interruption of ipsilateral cerebellum–hemisphere tracts, the existence of which was suggested by anatomic studies.\textsuperscript{17}

According to the Von Monakow concept,\textsuperscript{18} diaschisis is a phenomenon that is transient, or at least continuously regressive in time, thus explaining the functional recovery. In our work, we have not observed any significant correlation between the time elapsed since the stroke and the rCBF values. This could represent an argument in favor of the stable nature of the reduction in CBF and metabolic activity. Nonetheless, the CBF studies were conducted within relatively short periods of time (13–79 days) after the strokes. In the crossed cerebellar diaschisis of hemispheric lesions, Baron et al\textsuperscript{1} suggested a progressive regression in their first work, but, in a later study, Pantano et al\textsuperscript{9} showed that hypoactivity persisted without any correlation with time after stroke. They have thus considered that these elements ran counter to the concepts of Von Monakow. Our data support their conclusions with regard to hemispheric diaschisis.

Acknowledgments

The authors wish to thank Dr. Jean Louis Edmey for technical assistance in statistical analysis and Dr. Claude Onckelynck for reviewing the manuscript.

References

18. Von Monakow C: Diaschisis: Die Lokalisation im Grosshirn und der Abbau der Funktion durch kortikale Herde. Wiesbaden, Germany, Bergmann, 1914
Crossed hemispheric diaschisis in unilateral cerebellar lesions.
M Rousseaux and M Steinling

Stroke. 1992;23:511-514
doi: 10.1161/01.STR.23.4.511

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/23/4/511

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/