Phoria Adaptation in Patients With Cerebellar Dysfunction

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The authors studied phoria adaptation to horizontal base-out prism in 17 patients with well-documented cerebellar lesions. There was no significant difference between mean adaptation measured in the patients and ten normal controls. Individually, normal adaptation was found in 12 patients. Abnormal adaptation was found in five patients, all but one of which had other neurologic lesions. These results suggest that phoria adaptation to base-out prism is not diminished by a cerebellar lesion unless it is accompanied by another nervous system lesion(s). Invest Ophthalmol Vis Sci 31:1394-1397, 1990

When a small wedge prism is placed horizontally in front of one eye, normal subjects experience double vision and will converge or diverge their eyes so as to compensate for the prism. A realignment obtaining fusion is usually accomplished in less than 1 sec. Immediately thereafter a slower readjustment of the resting ocular alignment begins. Over minutes, the phoria, which is the difference in position of the eyes with one eye viewing for a given viewing distance, changes by an amount opposite in direction and equal in amount to the prism used. This process is termed phoria adaptation. About 85% of phoria adaptation is complete after 3.5 min. After the prism is removed, the phoria gradually returns toward the value that was present before the prism was placed. Adaptation to vertical prism has also been shown to occur with a similar time course.

Phoria adaptation is thought to exist to compensate for ongoing changes in ocular alignment. For example, weakening of a medial rectus muscle might cause divergence of the eyes and a sensory situation analogous to placement of a base-out prism. To obtain fusion in this situation, convergent movement of the eyes is required, which reduces the "fusional reserve"—which is the ability to respond to further disparity. However, once phoria adaptation has readjusted ocular alignment, the subject's fusional limits can be restored to those present before prism placement.

Considering the gradual changes in orbital mechanics that occur with age and the ocular muscle or nerve lesions that could occur during life, the existence of an adaptive mechanism capable of dealing with such situations would not be surprising. Because phoria adaptation is rapid, it would also be ideally suited to combat fatigue in the accommodative vergence response.

Many types of oculomotor adaptation require an intact cerebellum for their normal performance (see Berthoz and Jones for a review). Accordingly, it might be expected that people with cerebellar lesions would show less phoria adaptation than normal subjects and Milder and Reinecke found phoria adaptation to be significantly reduced in five patients with cerebellar deficits. In an effort to confirm their results and to determine which part of the cerebellum might mediate phoria adaptation, we studied a larger group of subjects with cerebellar dysfunction.

Materials and Methods

We studied 17 patients with cerebellar dysfunction who ranged in age from 15 to 82 yr (mean: 47 ± 22 standard deviation [SD]). We also studied ten normal subjects ranging in age from 26 to 75 (mean, 36 ± 14). We excluded patients who were unable to converge or who had a tropia to cover-uncover testing. Informed consent was obtained from all subjects.

Table 1 summarizes findings on oculomotor and neurologic examination. Patients 1–8 had cerebellar degenerations. Of these, patients 1–3 had paraneoplastic cerebellar degenerations with high-titer Purkinje cell antibodies accompanied by gait ataxia, limb dysmetria, downbeat nystagmus, skew deviation, and
Table 1. Clinical features of patients

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<th>Patient</th>
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<tbody>
<tr>
<td>Impaired PA</td>
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<td>Lesion</td>
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<td>Gait ataxia</td>
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<td>Impaired pursuit</td>
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<td>Downbeat nystagmus</td>
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<td>Skew deviation</td>
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<td>Limb dysmetria</td>
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<td>Saccades dysmetria</td>
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<td>Slowed saccades</td>
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<td>Impaired scanning speech</td>
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PA, phoria adaptation; PCA, Purkinje cell antibody-associated cerebellar degeneration; SCA, spinocerebellar degeneration; CV, caudal vermis lesion; RV, rostral vermis lesion; MSC, miscellaneous localizations (see text).

impaired pursuit. Patient 3 also had serum antibodies to neurons in general in addition to the antibodies directed against cerebellar Purkinje cells. Patients 4 and 5 had familiar cerebellar degenerations with slowed saccades. Patients 6-8 had nonfamiliar cerebellar degenerations. Patient 6 had cerebellar, brain stem, and cortical atrophy, whereas patient 7 had cerebellar atrophy alone. Patient 8 had a cerebellar degeneration resulting from a mitochondrial complex-III deficiency but normal imaging studies.

The remainder of patients had cerebellar lesions resulting from tumor, infarct, the Arnold-Chiari malformation, or focal lesions of uncertain origin. Patients 9-12 all had focal lesions of the caudal cerebellar vermis. This was of unknown origin in patient 9, it resulted from tumor removal in patient 10, and it resulted from the Arnold-Chiari malformation in patients 11 and 12. Patients 13 and 14 had lesions of the rostral vermis resulting from an infarct (patient 13) and resection of tumor (patient 14). Patient 14's lesion also involved the dorsal vermis. Patients 15-17 had lesions that included the cerebellar hemispheres. Patient 15 had a large cystic lesion resulting from removal of a tumor that involved both hemispheres as well as the entire vermis. Additionally, there was an old infarct of the right parieto-occipital white matter and a history of radiation to the brain stem. Patient 16's lesion, also resulting from removal of a tumor, was confined to the left cerebellar hemisphere. Patient 17 had infarction of the right cerebellar hemisphere and medulla resulting from occlusion of the right posterior inferior cerebellar artery.

Of the 17 patients, 8 had evidence of lesions in extracerebellar pathways related to visual processing. In five patients this conclusion was based on clinical or imaging data that included atrophy of the pons in patient 6, slowed saccades in patients 4 and 5, the occipital-parietal infarct of patient 17, and the medullary infarct in patient 17. In the remaining three patients, the presence of extracerebellar lesions was presumed from their diagnosis. These patients included patient 3, who had antineuronal antibodies associated with a systemic malignancy, and the remaining patients, who had cerebellar degenerations that were not associated with a specific antibody to Purkinje cells, namely patients 7 and 8.

We measured the horizontal phoria before and after 2 hr of binocular viewing with an 8-diopter base-out prism placed over the right eye. The prism used was of the press-on Fresnel type (Vision Care/3M, St. Paul, MN). Such a prism deviates the visual axes by 4.6° and elicits a convergent response. For patients who habitually wore eyeglasses, the prism was cut to fit their eyeglasses. Otherwise, a set of eyeglasses with plano-lenses was used. All patients had single vision after the prism was placed. During the 2-hr period of viewing, subjects were encouraged to move about the hospital.

Measurements of phoria were made with the use of the Lancaster red–green test. A screen was positioned 2 m from the subjects in a dimly lit room. A green filter was placed over the right eye and a red filter over the left, both superimposed on a set of trial lenses chosen to reproduce the subject's habitual eyeglass correction, if any. A red arrow was projected on the screen directly in front of the subject. The subject then superimposed a green arrow projected by a hand-held light. The horizontal distance between the two arrows was measured by the examiner. The pointing and subsequent measurement was repeated five times. Then an 8-diopter prism was placed over the right eye and the induced displacement of the optical axes measured with the use of the same method. After a 2-hr period of prism viewing, the same procedure was followed, but with reversed order of prism placement. The change in phoria after prism
viewing was calculated by subtracting the mean phoria before and after viewing, for similar measurement conditions (with or without prism on the trial frames). These two numbers were then averaged to produce the net change in phoria.

**Results**

All normal subjects had less than 5° of phoria before adaptation (0.7 ± 1.4°, mean ± SD; a “+” sign indicates exophoria and “−” sign, esophoria). This was also the case in all patients except patient 3, who had a phoria of −7.4°. The mean phoria was −0.4 ± 2.0° in patients before adaptation. After adaptation, a change in phoria angle developed in normal subjects that averaged −4.6 ± 0.8°, or, in other words, the normal subjects on average compensated perfectly for the prism. The patients had a mean change of phoria of −3.5 ± 1.7°. These data are summarized in Figure 1.

The difference in means of phoria adaptation between the patient population and normal subject population are not significantly different (P > 0.05, student t-test). However, the five patients listed in Table 2 adapted less than 2.7°, which is two standard deviations less than the normal mean, whereas all of our normal subjects showed more than 2.7° of adaptation. The mean age of the patients who did adapt was 41 ± 20 yr, whereas that of the patients who did not adapt was 61 ± 20 yr. These means are not significantly different (P > 0.05, t-test).

**Discussion**

Our results do not support the hypothesis that adaptation to base-out prism requires an intact cerebellum. That phoria adaptation does not require the cerebellar cortex is suggested by the observation that two of our three patients with paraneoplastic cerebellar degenerations associated with Purkinje cell antibodies (PCAs) had normal adaptation scores. The pathologic hallmark of paraneoplastic cerebellar degenerations is severe, diffuse loss of Purkinje cells. The presence of high-titer Purkinje cell antibodies in many of such patients suggests that the cell loss is immune related. Because Purkinje cell axons provide the sole outflow pathway from the cerebellar cortex, lesions of the Purkinje cells should reduce or abolish cerebellar function. Consistent with this concept, all three patients of ours as well as others reported in the literature showed a severe pancebellar loss syndrome combining limb dysmetria, gait ataxia, dysarthria, and central oculomotor signs. Two of our three patients with this condition showed normal adaptation to base-out prism, suggesting that Purkinje cells are not required for phoria adaptation.

Many of our other patients having large cerebellar lesions in various locations also showed normal adaptation. These included patients with lesions of the rostral vermis, caudal vermis, and cerebellar hemispheres. It was also striking that patients with evidence of other disorders of oculomotor adaptation showed normal phoria adaptation. For example, patients 7, 8, 12, and 14–16 had dysmetric saccades, but all except patient 15 had normal phoria adaptation.

Five of our patients adapted significantly less than the normal mean (see Table 2). However, there was

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<th>Patient</th>
<th>Adaptation</th>
<th>Diagnosis</th>
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<tbody>
<tr>
<td>1</td>
<td>2.03</td>
<td>Paraneoplastic cerebellar degeneration with anti-Purkinje and antineuronal antibodies</td>
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<tr>
<td>5</td>
<td>−1.10</td>
<td>Cerebellar degeneration with slowed saccades</td>
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<tr>
<td>6</td>
<td>2.48</td>
<td>Cerebellar degeneration with brain stem and cortical atrophy</td>
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<td>13</td>
<td>2.31</td>
<td>Infarct of rostral cerebellar vermis</td>
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<td>15</td>
<td>2.65</td>
<td>Midline cerebellar cyst and occipitoparietal infarct</td>
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no single location of cerebellar lesion shared by these patients. Four of these five patients had evidence of lesions in visual pathways outside the cerebellum. On the other hand, none of the patients with surgically induced lesions of the cerebellum (patients 10, 14, 16) or lesions resulting from the Arnold-Chiari malformation (patients 11 and 12) had impaired phoria adaptation.

Patient 13, the only subject with a purely cerebellar lesion who adapted less than the lower limit of normal, had a lesion confined to the rostral vermis. From this single patient one might speculate that the rostral vermis was the site of phoria adaptation, but patients 9 and 14 had more extensive vermal lesions than patient 13 and they adapted well. Similarly, all but one of our other patients with impaired adaptation were part of a group of other patients with similar locations of lesions but normal adaptation (see Table 1).§ These data could be explained by postulating that phoria adaptation is performed entirely outside the cerebellum, as well as by postulating that phoria adaptation is performed both in the cerebellum as well as elsewhere in the nervous system.

There was a trend for patients who showed poor adaptation to be older than those who adapted normally. We ascribe this effect to the greater opportunity of the older subjects to have neurologic lesions develop. It is possible that age diminishes phoria adaptation, but, to our knowledge, the effect of age on phoria adaptation has not been reported. Mellick found no significant influence of age on the related parameter of fusional amplitude.¹⁰

There have been only two studies of phoria adaptation in animals with cerebellar lesions. Westheimer and Blair reported that total and partially cerebellecotomized monkeys maintain excellent conjugacy of gaze, except for a transient deficit of convergence after surgery.¹¹ The maintenance of ocular alignment over the long term would suggest that phoria adaptation is not impaired by cerebellectomy. Judge reported that monkeys who had previously received lesions of the flocculus and ventral paraflocculus have normal phoria adaptation,¹² which is consistent with our findings that patients with lesions of the vestibulo-cerebellum have normal phoria adaptation.

Our results are in part contrary to those reported by Milder and Reinecke.⁵ They found that in four patients with cerebellar degenerations and one with cerebellar signs accompanying multiple sclerosis that phoria adaptation was significantly less than in five normal subjects. There were two important differences between our study and theirs: (1) Milder and Reinecke used both base-in and base-out prisms, and (2) they studied a smaller patient population, all of whom had multi-focal neurologic lesions. It is unknown whether patients with cerebellar lesions respond differently to base-in than base-out prisms. If phoria adaptation is not mediated by the cerebellum, the most important difference may lie in the other neurologic lesions in the patient population that was studied.

Key words: phoria, cerebellum, vergence, diplopia, strabismus

Acknowledgment

Dr. Walter Royal performed the Purkinje cell antibody titers.

References


§ Patient p15 cannot be compared with the others because he was in the "miscellaneous" group.