a local action of CS-A. In cases of corneal antigen sensitization due to previous corneal graft(s) or to improper immunosuppression and in vascularized recipient cornea, the suppression of graft rejection may often be a problem. Locally applied CS-A was effective in delaying rabbit corneal allograft rejection in spite of strong antigenic sensitization, and CS-A eye drops may prove to be of value for corneal transplantation in humans.

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Key words: corneal allograft, rabbit, cyclosporin A, corneal graft rejection, penetrating keratoplasty, electron microscopy, endothelial rejection line, topical administration, immunosuppression

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The effectiveness of wide-angle fusional stimulation in the treatment of convergence insufficiency. ANDREW E. KERTESZ.

The effectiveness of wide-angle fusional stimulation was evaluated in 13 patients with convergence insufficiency. These patients were referred to us because they either did not respond to or could not tolerate conventional treatment. Wide-angle fusional stimulation resulted in significant enlargement of fusional amplitudes and the alleviation of symptoms for 11 of the patients. Long-term follow-up indicates that these patients remain asymptomatic and that their increased fusional amplitudes persist. (INVEST OPHTHALMOL VIS SCI 22:690-693, 1982.)

Human fusional response to retinal image disparity contains two components: a motor component in the form of compensatory, vergence eye movements, and a nonmotor or sensory component whose magnitude is limited to Panum’s fusion areas. Fusional amplitude, which constitutes the sum of the sensory and motor components of fusional response, may be measured by determining the maximum stimulus disparity that a patient can fuse. The fusional amplitude is a function of stimulus parameters. Stimulus complexity has long been known to be an effective parameter; that is, complex stimuli evoke sig-
nificantly larger horizontal and vertical fusional amplitudes than do simple stimuli.\textsuperscript{1-3} Stimulus size, the visual angle subtended by the stimulus, also has a significant effect on fusional amplitudes. Increasing the stimulus size to include peripheral retinal regions in the fusional stimulation results in significant increases of horizontal and vertical fusional amplitudes.\textsuperscript{2-4} It has also been demonstrated that fusional stimulation of the retinal periphery elicits fusional responses from normal subjects and from some strabismic patients.\textsuperscript{5-9} Thus the important role played by the retinal periphery in normal and binocularly deficient fusional response is well established. It is not known, however, whether wide-angle fusional stimulation could successfully be used for the permanent enlargement of fusional amplitudes.

The identification of stimuli that evoke large fusional amplitudes is of special interest for the clinical treatment of vergence insufficiency in which enlargement of fusional amplitudes is of considerable importance. For wide-angle fusional stimulation to be useful in the treatment of vergence insufficiency, however, it must satisfy two conditions. The larger fusional amplitudes elicited by wide-angle stimulation should cause a significant increase of fusional amplitudes in general and this increase should not be of a temporary nature, so that once the large fusional amplitudes are elicited during wide-angle stimulation, the patient should be able to utilize them under normal circumstances during everyday viewing tasks.

The objective of this report is to evaluate the effectiveness of wide-angle fusional stimulation in the enlargement of fusional amplitudes and its applicability to the treatment of convergence insufficiency.

**Methods.** A large number of different fusional stimulators are in current use. Amblyoscopes, synoptoscopes, and synoptophores that allow for the gradual introduction of stimulus disparity use a narrow field size of 5° to 10°. The disparity may also be introduced by prisms, which have a visual field size of approximately 43°, but they significantly distort the visual image; the greater the prism power the greater the distortion. Vectorgraphic devices and fusion trainers that have a field size of 25° to 40° use fixed three-dimensional patterns containing objects at different depth planes, and patients are instructed to shift their fixation from one object to the other, which in our opinion is not as effective (fusional compelling) as having the entire stimulus pattern exert a slowly increasing vergence demand. It should be emphasized that the objective of this report is not to argue the relative merits of fusional stimulators but to utilize the most compelling wide-angle fusional stimulus that we can construct in order to evaluate its effectiveness. The requirements for such a stimulator were to provide an undistorted wide-angle field of view, to utilize complex fusionaly compelling stimulus patterns, and to be able to introduce the stimulus disparity in a slow, continuous, controlled fashion.

To that end, two wide-angle stimulators of 57° undistorted field of view were constructed. One was a modified synoptoscope and the other was a computer-controlled, projection-type video display. Stimuli were presented dichoptically and were composed of either complex, contoured patterns that contained suppression controls or Julesz-type random dot stereograms. Stimulus disparity could be introduced in a continuum on the synoptoscope and in increments of 0.16 prism diopters on the video stimulator. Stimulus disparity was always changed at a slow rate of approximately 1 Δ/sec.

Treatments were administered, on the average, once a week. The average treatment session, which included rest periods, was of 30 min duration and consisted of vergence exercises on one of the stimulators. Subsequent to the establishment of the patient's subjective superimposition point, a slowly increasing (1 Δ/sec) convergent or divergent horizontal disparity was introduced until the fusional break point was reached, at which time the magnitude of the disparity was slowly (1 Δ/sec) reduced until the patient regained fusion (refusion point). This regimen was repeated several times with interspersed convergence and divergence exercises. The break and refusion points were recorded for each exercise. Fusional amplitudes were then calculated by subtracting the superimposition point from the break and refusion points.

**Results.** Thirteen patients with convergence insufficiency, between the ages of 9 to 53 years, were referred to us by collaborating ophthalmologists. The diagnosis of convergence insufficiency was established on the basis of low convergence amplitudes that were accompanied by one or more of the following symptoms: blurry vision, headaches, burning sensation of the eyes, and intermittent diplopia during reading or during other tasks performed at close range. Patients were referred to us either because they did not respond to or could not tolerate conventional orthoptic treatment. Our treatment objectives were to increase fusional amplitudes in order to relieve the accompanying symptoms of headache, blurry vision, and
Table I. Clinical summary of patients

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age</th>
<th>Refractive status</th>
<th>Visual acuity</th>
<th>Stereo acuity (Titmus)</th>
<th>NPC (cm)</th>
<th>NPA</th>
<th>Vergence abnormality (Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29</td>
<td>No correction</td>
<td>20/20</td>
<td>40 sec</td>
<td>3</td>
<td>Normal</td>
<td>Distance: ortho</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Near: X’ = 2</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>OD -0.75, +0.5 × 10</td>
<td>20/20</td>
<td>40 sec</td>
<td>10</td>
<td>Normal</td>
<td>Distance: ortho</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OS Plano, +0.5 × 115</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Near: X’ = 7</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>OD 7A Base in OS 8A Base in</td>
<td>20/20</td>
<td>40 sec</td>
<td>8</td>
<td>—</td>
<td>Distance: ortho Near: X’(T) = 12OS</td>
</tr>
</tbody>
</table>

NPA = near point of accommodation; NPC = near point of convergence; — = not recorded.

*Prism convergence amplitudes were measured only up to 50Δ.

occasional diplopia. Wide-angle fusional stimulation resulted in significant enlargement of the fusional amplitudes and the alleviation of symptoms of 11 of the 13 patients.

The following are case summaries of three representative patients. Table I provides the ophthalmologic profiles of these three patients, which were taken at the time they were referred to us for wide-angle fusional stimulation. Only prism convergence amplitudes are listed in Table I because they are the most commonly used measures of fusional amplitudes even though significantly greater fusional amplitudes were obtained on the wide-angle stimulators.

Case I. A 29-year-old woman, who suffered from convergence insufficiency, complained of dizziness, blurred vision, and headaches since the age of 7. Conventional prism exercises caused nausea and severe headaches. Five treatments on the wide-angle synoptoscope increased her convergence amplitudes, as measured on the synoptoscope, from 35Δ/30Δ to 70Δ/45Δ (fusional amplitudes are given in prism diopters and are recorded in the form of break point/refusion point as was explained in the Methods section). The corresponding prism convergence amplitudes changed from 20Δ/15Δ to 45Δ/40Δ at distance and from 25Δ/20Δ to greater than 50Δ at near. She became asymptomatic and her convergence amplitudes have been holding for 30 months.

Case II. A 30-year-old woman suffered from convergence insufficiency with symptoms of burning sensation of the eyes, blurring, headaches, and occasional diplopia during reading and driving. Nineteen months of conventional treatment changed her near point of convergence from remote to 10 cm, slightly increased her convergence amplitudes, but did not relieve her symptoms. Twelve wide-angle synoptoscope treatments increased her convergence amplitudes from 22Δ/12Δ to 60Δ/38Δ, with accompanying changes in prism convergence from 12Δ/10Δ to 35Δ/25Δ at distance and from 12Δ/12Δ to 40Δ/35Δ at near. She became asymptomatic and her convergence amplitudes have been holding for 24 months.

Case III. A 9-year-old postoperative patient who was originally an intermittent exotrope was operated on at age 5, subsequent to which she became a left exotrope at distance and near. A second operation was performed in November 1976 (age 6½ years), at which point she became orthophoric at distance and a 12Δ intermittent exotrope at near. She was given prism glasses and underwent conventional orthoptic therapy to enlarge her fusional amplitudes. After 3 years of conventional orthoptic treatment her convergence amplitudes remained sporadic with frequent regressions and her intermittent exotropia persisted. She was referred to us in June 1979. Eight wide-angle treatments increased her prism convergence amplitudes from 20Δ/14Δ to 40Δ/35Δ at distance and from 16Δ/14Δ to 35Δ/30Δ at near. Her intermittent exotropia changed to exophoria and she no longer needed prismatic correction. She was last seen in January 1980 and her convergence amplitudes were holding. Her mother was contacted in February 1982 and stated that her daughter was doing very well.

We also had two patients for whom neither conventional nor wide-angle therapy was effective. One of them was an intermittent exotrope at near, with low convergence amplitudes. Wide-angle fusional treatment increased her convergence amplitudes but did not alleviate her symptoms. The other patient had a large A pattern, a large cyclophoria, intermittent exotropia at distance and at near, and low convergence amplitudes. We were unable to increase her fusional amplitudes or relieve her symptoms.

Discussion. The results presented in this report...
lack control data. They provide evidence, however, that patients who did not respond satisfactorily to conventional treatment became asymptomatic as a result of wide-angle stimulation. One might argue that the improvement in fusional performance was not due to wide-field stimulation alone but that perhaps the uniqueness of the laboratory environment provided additional motivation for the patients to perform. We think not. Our patients were mostly adults who professed no lack of motivation for conventional treatment; if anything, they were somewhat jaded by the time they were referred to us. Although they were willing to participate in yet another treatment regimen, their expectations were tempered by previous unsatisfactory results.

Although several investigators have demonstrated that stimulation of the retinal periphery elicits fusional responses, the current results demonstrate how the inclusion of peripheral retinal regions in wide-angle stimulation may be utilized to enlarge the convergence amplitudes of patients who do not respond to conventional treatment. The enlarged amplitudes that resulted from wide-angle stimulation were reflected in corresponding increases in prism convergence amplitudes. Furthermore, the increase in fusional amplitudes was not temporary, since we have been able to document its persistence for up to 2½ years. This does not mean that the increase in amplitudes lasts for only 2½ years, but rather that we only started to evaluate this method 3 months ago.

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Key words: binocular fusion, wide-field fusional stimulation, convergence insufficiency, vergence training

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