ous humor after subcutaneous administration in the 20 vs. 35 sec alkali burns. It has been shown previously1, 2 that following a 20 sec burn, subcutaneous administration of ascorbic acid (0.5 gm/kg) raised the aqueous humor level of ascorbic acid from about 6 mg/dl to a "near normal" level of 20 mg/dl even 24 hr after the last injection. It was suggested3 that raising the level of aqueous humor ascorbic acid to at least 15 mg/dl was necessary to exert a beneficial effect upon the alkali-burned rabbit cornea. In the present study, after 35 sec burns, subcutaneous administration of ascorbic acid raised the mean level of ascorbic acid in the aqueous humor (taken 24 hr after injection) to only 10 mg/dl despite adequate levels of ascorbic acid in the plasma. Such a result indicates that the 35 sec burn inflicts greater trauma to the ciliary processes, thereby reducing the transfer of exogenously administered ascorbic acid from blood to aqueous humor.

In contrast, despite the increased severity of the alkali burn, immediate topical ascorbate treatment greatly increased anterior segment levels of ascorbic acid and significantly reduced the incidence of corneal ulceration and perforation. Clearly, topical administration of ascorbic acid obviates the difficulties encountered in the transfer of parenterally administered ascorbic acid across the blood-aqueous barrier.

We can conclude therefore that the systemic route of administration, as singular therapy for alkali burns of human eyes, might not be satisfactory because one cannot readily evaluate the severity of the burn in terms of its effect on the transfer of ascorbic acid from blood into the anterior segment. Thus ascorbic acid is being administered both orally and topically in an ongoing clinical trial to evaluate the effects of ascorbic acid on corneal alkali burns.

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From the Combined Program in Ophthalmology, University of Alabama in Birmingham—Eye Foundation Hospital, Birmingham, Ala., and *Department of Ophthalmology, University of Colorado Health Sciences, Denver. Supported by U.S.P.H.S. Consortium Grant EY 02018 from the National Eye Institute and by Ellen Gregg Ingalls Eye Research Institute. Submitted for publication March 31, 1980. Reprint requests: Roswell R. Pfister, M.D., 1720 8th Avenue, South, Birmingham, Ala. 35233.

Key words: alkali burns, vitamin C, cornea and corneal burns, topical administration, parenteral administration, rabbits

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Utility of the Arden grating test in glaucoma screening: high false-positive rate in normals over 50 years of age. SAMUEL SOKOL, ALICE DOMAR, AND ANNE MOSKOWITZ.

The Arden grating test was administered to 64 subjects between 6 and 82 years of age without ocular pathology, to 20 glaucoma patients, and to 21 ocular hypertensives. The results show an age effect, with significantly higher scores (lower sensitivity) in normal subjects over 50 years of age. In addition, there was no significant difference in performance between age-matched normals, glaucoma patients, and ocular hypertensives on the Arden gratings. The results show a high percentage of false-positives in older normal subjects. The Arden gratings should be used cautiously when one is testing patients over 50 years of age.

Arden and Jacobson1 reported in this Journal that a series of photographs of sinusoidal gratings could be used as a quick, simple screening test for glaucoma. According to the authors, this test makes "a very sharp distinction . . . between normal and glaucomatous eyes." Moreover, the grating test scores were considered to be independent of age. The purpose of the present study was to further evaluate the diagnostic value of the Arden plates. Our results do not support the original conclusions of Arden and Jacobson.

The test consists of seven plates: a screening
plate (plate 1) and six diagnostic plates (plates 2 to 7). At a testing distance of 50 cm the spatial frequency of the six diagnostic plates ranges from 0.4 to 6.4 cycles/degree in increments of 1 octave. The contrast of each plate changes from the top to the bottom of the plate and covers a range of approximately 1.75 log units. The observer's task is to view each plate as the tester slowly uncovers it and report when the grating bars are first seen. A score of between 1 and 20 is assigned for each plate, based on when the observer first sees the grating.

Arden recommended that the sum of the scores for the six plates, with an arbitrarily assigned score of 25 for each plate that is not seen, be used to quantify each subject's contrast sensitivity. On this basis he found that scores obtained for nearly all the glaucoma patients that he tested were higher than the highest total score (82) obtained by any one individual in a group of patients without ocular pathology.

**Methods**

**Subjects.** Three major groups of subjects were tested: normals, glaucoma patients, and ocular hypertensives. The normal subjects were further divided into three age categories: 26 children between 6 and 18 years (mean 12), 24 adults between 19 and 47 years (mean 28), and 14 adults between 56 and 82 years (mean 66). None of the children and young adults had any ocular complaints. The older adults underwent complete ophthalmic examinations and were included in the study only if there was no ocular pathology, visual fields with the Goldmann perimeter were normal, and intraocular pressures were less than 21 mm Hg on repeated testing. Eight of 21 patients were taking ocular medication, and the mean pupil diameter was 3.45 ± 1.01 mm.

The third group consisted of 21 ocular hypertensive patients between 21 and 80 years of age (mean 58). Each patient had symmetric cupping and pallor of the optic discs, normal visual fields, open angles, visual acuities of 20/40 or better, and intraocular pressures of 21 mm Hg or above on repeated testing. Eight of 21 patients were taking ocular medication, and the mean pupil diameter was 2.83 ± 0.84 mm.

The second major group was composed of 20 glaucoma patients between the age of 38 and 85 years (mean 66). The patients' field defects as measured by static and kinetic perimetry using the Goldmann Perimeter included peripheral nasal step (nine eyes), arcuate scotoma (five eyes), nasal step and arcuate scotoma (four eyes), paracentral scotoma (seven eyes), and one-quadrant loss (five eyes). The grating scores obtained from fellow eyes of patients with uniocular field defects were not included in the analysis of the data. All the glaucoma patients had visual acuities of 20/40 or better; 19 of 20 patients were taking medication for their glaucoma. The mean pupil diameter of this group was 2.16 ± 0.61 mm.

Table 1. Summary of one-way ANOVA and paired t test analysis for each Arden plate according to age

<table>
<thead>
<tr>
<th>Plate</th>
<th>Group mean score</th>
<th>F</th>
<th>df</th>
<th>P</th>
<th>Significance (t test)</th>
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<tr>
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<td>2</td>
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<tr>
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<tr>
<td>7</td>
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<td>11.89</td>
<td>18.63</td>
<td>24.61</td>
<td>2/53</td>
</tr>
</tbody>
</table>

1 = children; 2 = young adults; 3 = older adults.
Fig. 1. Histogram showing the proportion of age matched normals, ocular hypertensives (OH), and glaucoma patients who saw or did not see plates 6 and 7 with both eyes. Not included in the histogram are data from three normals and two glaucoma patients who saw plate 6 with only one eye and from two ocular hypertensives who saw plate 7 with only one eye.

Table II. Summary of one-way ANOVA and paired t test analysis for each Arden plate according to pathology

<table>
<thead>
<tr>
<th>Plate</th>
<th>Group mean score</th>
<th>F</th>
<th>df</th>
<th>P</th>
<th>Significance (t test)</th>
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</tr>
</tbody>
</table>

1 = glaucoma; 2 = ocular hypertension; 3 = older adults.
*1 vs. 3 (NS); 2 vs. 3 (NS); 1 vs. 2 (p < 0.05).

edge, gradually uncovering more and more of the plate. The subject was instructed to look at the middle of the plate, following the edge of the cardboard with his eye as it was moved, and to report when the grating first became visible. The tester recorded the subject's score, as indicated by a numbered scale at the sides of each test plate. Both eyes of each subject were tested, with the right eye being tested first; all subjects wore correction if needed.

Analysis of data. There are two possible outcomes in a subject's performance on a grating plate. Either the subject sees the grating and is given a score of between 1 and 20, or the subject does not see the grating. (Arden used an arbitrary score of 25 for any grating plate that was not seen). In the present study, for plates that were seen with each eye separately, the mean score of the right and left eye was calculated.² These scores were used as a data base for a one-way analysis of variance (ANOVA): first, according to age (children, young adult normals, and older adult normals) and second, according to ocular status when matched for age (older adult normals, glaucoma patients, and ocular hypertensives). We did not use Arden's method of assigning a score of 25 to plates that were not seen, since this would tend to violate the assumptions underlying the use of an analysis of variance; for example, equality of variance could be affected, and equal intervals of measurement would be unlikely. Instead, the incidence of seeing or not seeing the separate plates was analyzed with chi-square procedures.

Results

Normal subjects. All the children and young adults were able to see all the plates with each eye. However, in the group of 14 normal older adults, four subjects failed to see plates 6 and 7, and six subjects failed to see plate 7. The results of a one-way ANOVA of the three groups of normals...
who saw the plates are summarized in Table I. Preliminary calculations showed that the sample variances were homogeneous (Barlett test) and the data from each of the three groups were normally distributed. The F ratios were significant for all plates. Further analysis using t tests showed no significant differences between the children and young adults on plates 2 to 7. On the other hand, the scores for the older adults on each plate were significantly higher than those of either the children or young adults.

Age-matched glaucoma patients, ocular hypertensives, and normals. The results of ANOVA of the data from the age-matched normals and patients who saw the plates are summarized in Table II. The F ratios for five of the six plates showed no significant differences between the three groups of age-matched subjects. Only plate 4 revealed a significant F ratio; paired t tests showed no difference between the normals and ocular hypertensives and a significant difference between glaucoma and ocular hypertensives.

As found in the group of older normal subjects, some glaucoma patients and ocular hypertensives failed to see plates 6 and 7. Fig. 1 is a histogram showing the percentage of older normals, ocular hypertensives, and glaucoma patients who saw or did not see plates 6 and 7 with either eye. Chi-square analysis of the data showed no significant differences among the three groups: $X^2 = 1.88$, df = 2 for plate 6 and $X^2 = 1.01$, df = 2 for plate 7.

Discussion. Our findings confirm recent reports that contrast sensitivity changes with age.3, 4 Using the Arden grating test, Skalka4 found that the mean total score for subjects between 50 and 60 years of age was 19 points higher (sensitivity lower) than the mean total score for a group of subjects between 10 and 20 years of age. The mean difference in total score between our younger and older groups was 17 points. Skalka does not provide any information with regard to how many, if any, of the older subjects failed to see any of the plates, particularly plates 6 and 7. Derefeldt et al.3 presented sinusoidal gratings on an oscilloscope and found a significant decrease in contrast sensitivity in the middle- and high-spatial-frequency regions in subjects older than 60.

More importantly, our results demonstrate that a large number of false-positives occur in older subjects on the Arden grating test. For this reason the Arden grating test may be insensitive, at least in older patients, to the presence of glaucoma. For example, if we had used the Arden procedure of assigning a score of 25 for "not seen," we would have obtained a high percentage of false-positives in normal subjects: 37% on plate 6 and 71% on plate 7.

It is important to note that the average pupil diameter of the glaucoma patients tested was significantly smaller (p < 0.001) than the average pupil diameter of either the older normals or ocular hypertensives. We do not believe this difference had any bearing on the outcome of our study. One would expect that smaller pupils would both reduce retinal illuminance and increase diffraction effects, which would in turn lead to higher scores (lower contrast sensitivity). The fact that we found no differences in contrast sensitivity among the age-matched normals, ocular hypertensives, and glaucoma patients argues against any pupil effects.

Our results do not necessarily lessen the usefulness of the Arden plates in patients under 50 years of age who are being screened for optic nerve pathology,5, 6 nor do they indicate that contrast sensitivity is unaffected in glaucoma. Atkin et al.7 have shown that after correction for changes due to age, contrast sensitivity is still significantly reduced in glaucoma patients over 50 years of age. However, their stimulus differed from Arden's. The field size was smaller (4 degrees vs. 30 degrees), and they used two types of stimuli, a diffuse field and sinusoidal gratings, which were temporally modulated.

In conclusion, we would recommend that the Arden grating test be used cautiously and judiciously in patients over 50 years of age.

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From the Department of Ophthalmology, Tufts University School of Medicine and New England Medical Center, Boston, Mass. Supported by grant NEI-00926 from the National Eye Institute to S. S. These results were presented at the meeting of the Association for Research in Vision and Ophthalmology, 1980 (Invest Ophthalmol Vis Sci 19[ARVO Suppl]:84, 1980). Submitted for publication March 31, 1980. Reprint requests: S. Sokol, Ph.D., Department of Ophthalmology, Tufts–New England Medical Center, 171 Harrison Ave., Boston, Mass. 02111.

Key words: Arden grating test, glaucoma, contrast sensitivity, ocular hypertension, sinusoidal gratings.
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