albipunctata was found to have very slow recovery of sensitivity in the dark, and the ERG b-wave was recorded with the use of flashes of blue light of different intensity for almost 3 hr. Single-flash responses were measured, and amplitude vs. intensity functions, with single flashes constructed at various times after the end of the light adaptation. With a b-wave criterion amplitude of 20 μV, the dark adaptation curve of Fig. 3 was developed. Apart from the fact that in this condition the b-wave accurately reflects psychophysical dark adaptometry, the result is of interest in showing the stability of recording possible with the foil electrode. If the amplitude of the response had changed with small motions of the foil, the result shown in the figure could not have been obtained.

Local ERGs. Because the foil does not interfere with the optics of the eye, it is possible, with appropriate stimulus conditions, to obtain local ERGs. Fig. 4 shows records from mother and propositus daughter (8 years of age) with unilateral Best’s disease. In the left eye, the mother had a large scar, with vision 20/200, in the right eye, the cyst was in the process of breaking down, with vision reduced to 20/50. The focal ERG was elicited with a 6° red target. It was absent in the eye with the scar and reduced in the eye where the macula was undergoing degenerative changes. The daughter had an intact cyst in the left eye; the local ERG of that eye was slightly reduced but not significantly different from the right eye which showed less macular change. Note that the ERG, conventionally obtained, is normal in Best’s disease.

Fig. 5 shows the ERGs obtained by pattern-reversing checkerboards of various configurations. The patterns were generated on a TV set and were similar to the ones used in the visual evoked response (VER) for testing visual cortical function. It can be seen that when the screen was divided into two halves, the ERG was easily elicited, even though the total flux entering the eye remained constant when the pattern reversed. A pattern of 46 min squares elicited the same response (Fig. 5 B), but small (6 min) squares were ineffective (Fig. 5, C). High contrast (about 90%) is required to obtain such responses. Note that in Fig. 5, D and E, the response decrement was associated with removal of the central portion of the stimulus as well as a decrease in the total retinal area stimulated. It seems likely from the result that the central 4° of retina gives proportionately larger ERGs than do comparable areas of peripheral retina (see Armington), but no quantitative experiments were performed to confirm this point.

Our thanks are due to the numerous clinicians at Moorfields Eye Hospital who sent us patients; to our colleagues, who acted as experimental subjects; and to the technical support at the Institute of Ophthalmology and the Department of Ophthalmology, NYU Medical Center. This work was done during the tenure of a Visiting Professorship at NYU by G. B. Arden. We thank Dr. L. Angeletti of New York Eye and Ear Infirmary for referring the family with Best’s disease, Mr. J. Low of the Institute of Ophthalmology, London, for help in measuring the electrical characteristics of the foil electrode, and Dr. B. Wiass of the Electronics Department, University College, London, for supplying the ion-bonded material.

From the Electrodiagnostic Clinic, Moorfields Eye Hospital, London, England, and *Department of Ophthalmology, NYU Medical Center, New York, N. Y. This study was supported in part by grants 02179 and 01842 from the National Eye Institute, a Retinitis Pigmentosa Grant, and an unrestricted grant to the Department of Ophthalmology, NYU Medical Center, from the Research to Prevent Blindness, Inc. Submitted for publication Oct. 25, 1978. Reprint requests: G. B. Arden, Institute of Ophthalmology, Judd Street, London W. C. 1, England.

REFERENCES

Vision threshold profiles in X-linked retinitis pigmentosa. ROBERT W. MASSOF AND DANIEL FINKELSTEIN.

Absolute thresholds for blue-green and red stimuli were measured along the horizontal and vertical meridians in two patients with X-linked retinitis pigmentosa. From these data, we deduced that cones mediate detection of both stimuli in the central 10°, there is a ring scotoma in the mid-periphery, and in the far periphery rods mediate...
Primary retinitis pigmentosa (RP) is a clinically defined syndrome characterized by night blindness, contracted visual fields or ringlike scotomas, narrowed retinal arterioles, mid- to peripheral intraretinal bone spiculelike pigmentation, and good visual acuity until late in the course of the disease. All classic modes of inheritance are represented. Although the different genetic classes seem to have identical clinical (morphologic) appearances, they differ in the time course of disease progression. X-linked RP is regarded as the most severe and rapidly progressing form.

Autosomal dominant and autosomal recessive RP present more variable ages of onset than X-linked RP. For dominant RP, the average age of onset is 25 ± 17 years; for recessive RP, the average age of onset is 20 ± 15 years. This degree of variability could reflect the heterogeneity of disease mechanisms within each of these two genetic groups. We now have evidence from psychophysical studies that there may be multiple forms of dominant RP and of recessive RP. X-linked RP, in contrast, has an average onset age of 7 ± 2 years. Such a tight distribution suggests that X-linked RP may represent a homogeneous group, perhaps characterized by a single disease mechanism.

Szamier et al. recently presented an ultrastructural description of the retina in a 24-year-old man with X-linked RP. They observed that (1) central foveal cones had intact (albeit severely distorted) outer segments, (2) rods were absent in the center and mid-periphery, (3) cones had shortened inner segments and no outer segments from the parafovea to the mid-periphery, and (4) in the far periphery cones and rods both had normal inner segments and slightly shortened outer segments. This histopathologic description provides us with a unique opportunity to compare conclusions drawn from perimetric psychophysical measures of rod and cone function to those drawn from electron microscopic observations. Therefore we report here results and interpretations of perimetric vision threshold measures in two patients with X-linked RP.

Case descriptions. Two patients from different pedigrees of RP served as subjects in the present study. For both patients, an X-linked pattern of inheritance extended over three generations. Visual acuity was determined, visual fields were measured by a Goldmann perimeter with the V/4 and II/4 targets, color vision was evaluated with the Farnsworth-Munsell 100 hue test, audiologic examinations were conducted, and the electroretinogram (ERG) to white light ganzfeld stimulation was recorded. Informed consent was obtained from both patients.

Patient 1. The patient is a 16-year-old white male who complained of night blindness from early childhood. Visual acuity is 20/25 O.U. There are moderate pigment dusting and liquefaction of the vitreous, with a clear lens. On fundus examination, there are narrowed retinal arterioles and typical mid- to peripheral intraretinal bone spicule pigmentation. Visual fields for the II/4 target are contracted to about 15°, accompanied by far peripheral islands. With the V/4 target, visual fields are nearly full, with a narrow ring scotoma in the mid-periphery. Color vision testing demonstrated a strong blue-yellow defect. Audiologic testing indicated that hearing is normal. The ERG was nonrecordable.

Patient 2. This patient is a 28-year-old white male who complained of night blindness beginning at approximately 8 years of age. Visual acuity is 20/30 O.D. and 20/50 O.S. There are pigment dusting and liquefaction of the vitreous, and the lens is clear. On fundus examination there are narrowed retinal arterioles with sparse but typical bone spicule pigmentation. Visual fields are contracted to 10°, with a small peripheral island, for the II/4 target. With the V/4 target, fields are contracted to 30° nasally and superiorly and are full with a partial ring scotoma inferiorly and temporally. Color vision testing demonstrates a strong blue-yellow defect. Audiologic testing indicated that hearing is normal. The ERG was nonrecordable.

Methods. The rationale and experimental methods are detailed in an earlier paper. Briefly, following 45 min of dark adaptation, absolute thresholds were measured at the fovea and at 2.5°, 5°, 10°, 15°, and from 20° through 80° in 10° steps along the nasal, temporal, superior, and inferior meridians, with the use of the Tübinger perimeter. Thresholds were measured for both blue-green (λ_max = 500nm; maximum luminance = 23 asb) and red stimuli (λ_max = 650nm; maximum luminance = 29 asb). The stimuli subtended a 2° visual angle and were flashed for a duration of 500 msec. Absolute thresholds are defined as the mean of three to five repetitions of an ascending method of limits (beginning below threshold). Normal values...
Fig. 1. Absolute thresholds, measured along the horizontal meridian, are plotted for patients 1 (••) and 2 (○○) for the blue-green (lower panel) and red (middle panel) stimuli. The mean normal values, obtained in an earlier study,\(^2\) are plotted for comparison (x—–x). The data in the upper panel are the differences between the log threshold intensities for the two stimuli. A value near zero reflects cone-determined spectral sensitivity, and a value near 2 reflects rod-determined spectral sensitivity. Both patients have cone-determined values in the central 10° and rod-determined values in the far periphery.

For these measures were reported previously.\(^2\)

Results. Fig. 1 illustrates threshold data obtained along the horizontal meridian, from 60° nasal to 80° temporal. Data are plotted as log sensitivity, defined as the inverse of absolute threshold intensity. Sensitivity profiles obtained with the blue-green light are plotted in the lower panel, sensitivity profiles obtained with the red light are plotted in the middle panel, and the differences between the log threshold intensities for the red light and the log threshold intensities for the blue-green light are plotted in the upper panel. It can be seen in the lower and middle panels that both patients generated nearly identical sensitivity profiles. As shown in the lower panel, at fixation (0°) sensitivities were about 2.5 log units below the normal mean. At 10° nasal and temporal, the values were 4.0 to 4.5 log units below the normal mean. No threshold values could be measured for either patient from 10° to
40° nasal or from 20° to 80° temporal; this region corresponds to the ring scotoma. At 80° temporal for both patients, the sensitivity values were 2.5 log units below the normal mean. The data in the middle panel present a similar picture; sensitivities at fixation were reduced by 1 log unit. Again, there was a precipitous drop of sensitivity at 10°, with a ring scotoma from 10° to the far periphery.

The upper panel illustrates the log threshold ratios of the two stimuli along the horizontal meridian. As described previously, if rods are responsible for the detection of both lights, the threshold ratio will have a value of approximately 2 log units; if cones are responsible for the detection of both lights, the log ratio will have a value close to zero. These differing ratios are determined by the differing shapes of the rod and cone spectral sensitivity functions. In the upper panel of Fig. 1, the log ratios in the central 10° were close to the cone-determined value, and in the far periphery the log ratios were close to the rod-determined value.

Discussion. As demonstrated in the upper panel of Fig. 1, the log ratios for the central 10° are near 0; consequently, we may conclude that only cones detected both lights and that rods are making no contribution to detection. In the far periphery the log ratios are near 2; these data indicate that the rods detected both lights and therefore the rod sensitivity, relative to the cone sensitivity, must be nearly normal. (Because there is a 2.5 log unit sensitivity depression in this retinal region for the blue-green light (lower panel, Fig. 1), we can conclude that the far peripheral rods and cones are not normal but that both probably are reduced in sensitivity by the same factor, thus preserving the normal sensitivity relation.)

The above data indicate that (1) because of the threshold ratios, there probably are no functioning rods within the central 10°; (2) because the foveal cones are reduced in sensitivity by 1 log unit (middle panel, Fig. 1) and both patients have a strong blue-yellow color vision defect, the foveal cones are abnormal; (3) because of the mid-peripheral ring scotoma, there probably are no functioning mid-peripheral rods or cones; and (4) because absolute sensitivities are reduced in the far periphery, because rod-determined threshold ratios are obtained, and because the photopically measured far peripheral field is intact, there must be functioning, albeit abnormal, rods and cones both. These conclusions are in point-by-point agreement with the conclusions of the electron microscopic study by Szamier et al. It is not possible to draw conclusions from our psychophysical studies regarding outer segment length or integrity or other specific morphologic features.

The agreement between psychophysical data and electron microscopic data for X-linked RP additionally supports conclusions regarding other types of RP reported earlier. We previously described two other subcategories of RP based on this psychophysical methodology, which may be characterized broadly as a diffuse rod sensitivity loss for one group and localized rod-cone sensitivity losses for a second group. In this study, the mutual corroboration of psychophysical and histopathologic data for X-linked RP heightens our confidence in the predictive value of similar psychophysical tests for other forms of RP.

From the Wilmer Ophthalmological Institute, The Johns Hopkins University School of Medicine, Baltimore, Md. Supported by research grants from the National Institutes of Health (EY-01791) and the National Retinitis Pigmentosa Foundation. Submitted for publication Nov. 22, 1978. Reprint requests: Robert W. Massof, Wilmer Institute, Johns Hopkins Hospital, Baltimore, Md. 21205.

Key words: retinitis pigmentosa, dark adaptation, inherited retinal dystrophies, absolute thresholds

REFERENCES


Spatial periodicities of periodic complex cells in the visual cortex cluster at one-half octave intervals. DANIEL A. POLLEN AND STEVEN E. FELDON.

Within individual penetrations in the visual cortex, spatial periodicities of periodic complex cells differ by either one-half or one octave. When data are pooled from neurons subserving the central visual area in many cats, the results indicate that spatial periodicities cluster at one-half octave intervals over a 2½-octave range (0.95 to 5.4