SWS (Blue) Cone Hypersensitivity in a Newly Identified Retinal Degeneration

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Photoreceptor-mediated mechanisms were studied in patients with a recently identified retinopathy typified by night blindness, cystoid maculopathy, and atypical electroretinograms (ERGs). Dark-adapted spectral sensitivity functions were only partly explained as composites of rod and cone curves shifted to lower sensitivities; there was unusually high sensitivity from 400-460 nm. A rod mechanism, reduced in sensitivity by at least 3 log units, was detectable with dark adapтомetry. No measurable rhodopsin was found with fundus reflectometry. Light-adapted spectral sensitivities were subnormal for wavelengths greater than 500 nm but supernormal from 420-460 nm. On a yellow adapting field, the supernormal spectrum approximated that of the short-wavelength-sensitive (SWS) cone system. With spectral ERGs, two mechanisms were demonstrated. Dark- and light-adapted ERGs to green, orange-yellow, and red stimuli had similar waveforms and coincident intensity-response functions on a photopic intensity axis. ERGs to blue and blue-green stimuli were similar, and intensity-response functions coincided on a SWS cone intensity axis. Patients varied in the degree to which rod and midspectral cone function were decreased and SWS cone function was increased. Invest Ophthalmol Vis Sci 31:827-838, 1990

A retinal degenerative disease characterized by night blindness, cystoid maculopathy, and atypical electroretinograms (ERGs) with similar waveforms under scotopic and photopic conditions has been identified recently. Patients with this syndrome have night blindness from early in life, varying degrees of visual acuity loss, and kinetic visual fields that can be full or show defects centrally or in the near midperiphery. Fundus pathology includes cystoid changes in the foveal region and small yellow lesions and pigmentary disturbances near the vascular arcades. With clinical ERG techniques, there is: no rod-mediated response to dim flashes of blue light in the dark-adapted state; an abnormally reduced cone flicker signal; mismatched responses to photopically balanced single flash stimuli with a larger signal to blue-green than to orange-yellow light; and responses to single white light flashes that have similar waveforms whether elicited in the dark-adapted state or on a white background light sufficient to suppress the rod system.3

Although the clinical features of this syndrome have been well described,1-3 the pathophysiology of the retinal dysfunction has not been fully elucidated. In the current study, we used spectral sensitivity measurements, dark adaptometry, static perimetry, spectral ERGs, and fundus reflectometry to examine patients with different degrees of severity of this retinopathy. The results show very reduced but detectable rod function, decreased sensitivity of middle-wavelength-sensitive (MWS) and long-wavelength-sensitive (LWS) cones, and surprisingly, a hypersensitivity of the short-wavelength-sensitive (SWS) cone system. Evidence is provided that the atypical ERG waveform in this retinopathy is mediated predominantly by SWS cones.

Materials and Methods

Subjects

Three patients (patient 1, a 12-yr-old girl; patient 2, a 29-yr-old man; and patient 3, a 40-yr-old woman) from three different families (with no other known affected members), and 26 normal subjects (16 female and 10 male; ages 13-59 yr) participated in this study. Subjects gave their informed consent after full explanation of the procedures was given. All patients had small yellow lesions near the vascular arcades; patients 2 and 3 had cystoid changes in the foveal...
region. Visual acuities in the right eye (the eye used for psychophysical testing) of patients 1, 2, and 3 were 20/25, 20/60, and 20/50 respectively, and color vision testing (Farnsworth D-15) was normal. Goldmann kinetic perimetry (with V-4e and I-4e test targets) in patient 1 was normal; in patient 2, there were relative scotomas centrally and in the near midperiphery; and in patient 3, there was some superior field limitation to the V-4e target and a nearly complete annular scotoma to I-4e in the midperiphery.

With conventional full-field clinical ERG techniques, all patients showed: no detectable signal to dim blue flashes of light in the dark-adapted (>40 min) state; waveforms to single flashes of bright white light that were similar whether elicited in the dark-adapted or light-adapted (34 cd/m² white background) states; an abnormally reduced cone flicker (30 Hz) ERG; and unequal signals in response to photopically balanced stimuli (amplitude to blue-green light greater than that to orange-yellow).

Psychophysical Studies

A modified automated perimeter was used to perform static perimetry, dark adaptometry and measurements of spectral sensitivity in the right eye of all three patients. Instrumentation, technique, analysis methods, and normal results have been published previously. Static thresholds were measured at 75 loci across the visual field in the dark-adapted state using 500- and 650-nm stimuli and in the light-adapted state with a 440-nm stimulus (all target diameters, 103'; stimulus presentation time, 200 ms) on the white background light (10 cd/m²) of the automated perimeter. Dark-adapted sensitivity was also measured with the 500-nm stimulus at 25 test loci in a square area 20° on a side (5° grid) centered at 40° nasally and 15° inferiorly in the visual field of patient 2. These results were compared with those of normal subjects (n = 7, ages 19–59 yr) and then related to the visual pigment measurements made in this retinal region with imaging fundus reflectometry (see below).

Dark adaptometry was performed with 420-nm and 500-nm stimuli (target diameter, 103') at loci with “mixed-mediation” (ie, rods detecting 500 nm and cones detecting 650 nm) by two-color dark-adapted perimetry. Prebleach baselines were established after the patient had been dark-adapted for at least 2 hr. After a full-field bleach, sensitivity was measured for the two stimuli until the baseline levels were attained.

Spectral sensitivity was measured under three conditions: 1) in the dark-adapted (>2 hr) state; 2) in the presence of the white background light of the automated perimeter (10 cd/m²); and 3) in the presence of a yellow adapting field (two Lee filters, no. 179, over fluorescent light sources situated at the edges of the hemisphere; 123 cd/m²). Figure 1 shows the spectral characteristics of the two background lights used in this testing. The 15 monochromatic test stimuli (interference filters, 7.0–11.5 nm half bandwidth; Ealing Electro-optics, Natick, MA) ranged from 400–680 nm in 20-nm steps. A United Detector Technology 40-X photometer and 1100B spectrometer were used.

![Fig. 1. Spectral characteristics of the three background lights used in this study. Diamonds, the white background light used for light-adapted ERG recordings; plus signs, the white background light of the automated perimeter; squares, the yellow adapting field inserted into the perimeter.](image-url)
to determine the relative spectral output of the stimulus through the interference filters and of the background lights. Between three and six sensitivity measurements were made for each of the 15 test wavelengths, and the mean sensitivity was used for plotting spectral sensitivity functions.

**Spectral Electroretinography**

Spectral ERGs were performed in patients 2 and 3 using a technique based upon published methods. The instrumentation and methods we use to record and analyze full-field ERGs have been described. ERGs were elicited with a series of intensities of blue, blue-green, green, orange-yellow, and red light flashes (Wratten 98, 44, 61, 16, and 29 filters, respectively) in the dark-adapted state (>1.5 hr; stimulus frequency, 0.5 Hz) and in the light-adapted state (34 cd/m² white background of the Nicollet GS-2000 Ganzfeld stimulator, following at least 15 min light adaptation; stimulus frequency, 1.0 Hz). For each colored filter, there were six stimulus intensities, spanning 1 log unit at about 0.2-log-unit intervals; the maximum luminance of the unattenuated white flash was 6.4 cd-s m⁻². ERGs were also elicited in the light-adapted state to blue and orange-yellow light flashes flickering at 29, 35, and 39 Hz. The spectral characteristics of the light-adapting background are shown in Figure 1.

Intensity axes on which colored filters were weighted for various photoreceptive mechanisms were calculated from:

$$\sum_{\lambda=380}^{700} X(\lambda) F(\lambda) W(\lambda)$$

where

- $X(\lambda)$ = the spectrum of the white flash;
- $F(\lambda)$ = the spectral transmission of the colored filter;
- $W(\lambda)$ = the weighting function of the photoreceptive mechanism; and
- the summation was in 10 nm steps.

For photopically weighting, $W(\lambda) = V(\lambda)$, the CIE photopic spectral luminous efficiency function; for scotopically weighting $W(\lambda) = V'(\lambda)$, the CIE scotopic luminous efficiency function; and for SWS cone weighting, $W(\lambda) = \pi-3(\lambda)$, Stiles's pi-3 field sensitivity function. The product $X(\lambda) F(\lambda) W(\lambda)$ was measured in the ERG ganzfeld and was calculated from published data with similar results.

**Imaging Fundus Reflectometry**

Images obtained with a high-sensitivity television (TV) imaging fundus reflectometer (IFR) were used to estimate the levels of visual pigment present across a circular area of retina of angular subtense 25° centered at 36° temporally and 15° superiorly in the retina of patient 2. Details of the IFR, which is based upon a Zeiss 30° fundus camera to which a TV system has been optically and mechanically coupled, have been given elsewhere. Experimental methods and details of data analysis also followed published procedures. The relative reflectances of fundal images acquired at eight different wavelengths when the retina was fully light-adapted were compared with those obtained when the eye had been allowed to dark-adapt. The density changes (the differences of the logarithms of the reflectances for the two conditions) give an approximate measure of the level of visual pigment regenerated during dark adaptation.

Light adaptation was carried out with a white light delivered by Maxwellian optics and covering an area of retina concentric with but larger than the test area. The light had an intensity of 6.0 log scotopic trolands. The duration of illumination used initially was 1 min: in the normal eye such an exposure is expected to remove more than 95% of the visual pigment. Recordings were made of the retinal images obtained immediately after this exposure and at intervals for the following 30 min in darkness. In view of the possibility that the subject possessed a visual pigment of unusually low photosensitivity, the test procedure was repeated after a further exposure to the white adapting light, the duration of which was increased to 3 min.

**Results**

**Psychophysical Studies**

Figure 2 shows spectral sensitivity measurements in the dark-adapted state at 36° in the inferior field for normal subjects and the three patients. Although the data from normals correspond well to the CIE scotopic spectral sensitivity function, those of the patients do not. A CIE scotopic sensitivity function with its peak set about 3–3.5 log units below normal tends to fit the wavelengths between 480 nm and 560 nm in all three patients. The patient data at longer wavelengths can be fit by a portion of a published peripheral cone function. For wavelengths less than 480 nm, however, there is higher sensitivity than expected from either of the functions. The sensitivities for patient 3 at this inferior field locus are generally lower than those for patients 1 and 2. Functions at 20° in the inferior field could be measured in patients 1 and 2 and were similar to those shown here, but patient 3 had no detectable sensitivity at this locus.

To clarify whether the fully dark-adapted sensitivities measured at 420 nm and 500 nm were those of rods or cones, dark adaptometry was performed with
Fig. 2. Spectral sensitivity measurements, dark-adapted, in: normal subjects, (n = 5; ages 19–29 yr; area between solid lines represents range of data); patient 1, P1; patient 2, P2; and patient 3, P3. Squares represent patient data. Solid curves in P1–P3 are CIE scotopic sensitivity curves shifted vertically and equated to the patient data at 500 nm. Dashed curves represent a peripheral cone function equated to the patient data at 600 nm.

Fig. 3. Dark adaptometry with 420 nm (squares) and 500 nm (plus signs) stimuli in: a 29-yr-old normal subject (N) at 20° inferior field; patient 2 (P2), also at 20° inferior; and patient 3 (P3) at 36° inferior and 12° temporal.

Fig. 4. Spectral sensitivity measurements at two eccentricities in the inferior field performed in the presence of a white background light (Figs. 4A, B) and a yellow adapting field (Figs. 4C, D). With the white background, spectral sensitivity in the normal subjects has a peak at 440 nm and a second broad maximum centered near 560 nm; sensitivity at 20° (Fig. 4A) is generally higher than at 36° (Fig. 4B). These curves are like those in published studies and are interpreted in terms of LWS, MWS, and SWS cone systems. The patient data differ from those of the normal subjects by having higher sensitivity at the shorter wavelengths and lower sensitivity for wavelengths greater than 520 nm at both test loci. There are also differences between the data of the patients. At 20° inferiorly, there was no measurable sensitivity for patient 3; sensitivities at wavelengths less than 480 nm in patient 2, although slightly higher than normal, are lower than those of patient 1. At 36° inferiorly, the results for patients 1 and 2 are similar, but patient 3 shows sensitivities lower than those of the other patients. It is also of note that the shape of the patients' light-adapted spectral sensitivity functions differs from that measured in the dark-adapted state (Fig. 2). In the light-adapted function, sensitivity at 500 nm is decreased relative to lower and higher wavelengths; this not only provides further evidence of a rod mechanism but also implies that the rods are suppressed by the background light.
With the yellow adapting field, spectral sensitivity in the normal subjects peaks at 440 nm; between 500 nm and 600 nm, there is measurable, although very reduced, sensitivity. The normal function at 20° inferiorly (Fig. 4C) has generally higher sensitivity than that at 36° (Fig. 4D). These findings resemble those from earlier studies and represent selective adaptation of LWS and MWS cones. At 20°, sensitivity at 440 nm is higher than the mean normal by about 0.8 log units in patient 1 and by about 0.3 log units in patient 2, but sensitivity beyond 520 nm is not detectable; patient 3 had no measurable sensitivities at this locus. At 36°, patients 1 and 2 have sensitivity at 440 nm nearly 1 log unit higher than the mean of the normals, whereas patient 3 is about 0.5 log units higher; again, sensitivity is unmeasurable beyond 520 nm. The spectral sensitivity functions with the yellow adapting field in the patients are very similar to published functions for the SWS cone system.

Figure 5 shows gray-scale maps of dark-adapted sensitivity to 500 nm and to 650 nm and light-adapted sensitivity to 440 nm across the visual field of the patients and normal subjects. The normal mean map for the 500-nm stimulus (Fig. 5, left column, N), representing rod sensitivity, is relatively flat, decreasing slightly at increasing eccentricities. In the 3 patients, sensitivity differences between 500 and 650 nm indicated that there were no rod-mediated loci, but only mixed-mediated or cone-mediated loci. All of the test loci had abnormally reduced sensitivity to 500 nm (ie, >2 SD below the mean at each locus), and the maps indicate that the loss was relatively diffuse and severe across the visual field. Patients 2 and 3 show more profound losses than the younger pa-
Fig. 5. Gray-scale maps of dark-adapted sensitivity to 500 nm (left) and 650 nm (center) and light-adapted sensitivity to 440 nm (right), in the right eyes of patient 1 (P1), patient 2 (P2), and patient 3 (P3). The normal results (N) represent the mean data from 16 subjects (ages 13–59 yr) tested with the 500-nm stimulus, dark-adapted; 4 subjects (ages 22–41 yr) tested with the 650-nm stimulus during the cone plateau of dark adaptation; and 6 subjects (ages 19–29 yr) with 440 nm, light-adapted. The gray scales used to represent the results all have 16 levels of gray (key at lower right). Maximum sensitivity, shown as white, is 54 dB for 500 nm, 34 dB for 650 nm, and 20 dB for 440 nm; black indicates no detection of the stimulus.

Patient 1 and also show scotomatous areas (ie, “0 dB” sensitivity, illustrated as black). Mean extrafoveal rod sensitivity loss for patient 1 is 34.0 dB (SD = 3.4); for patient 2, 41.7 dB (SD = 4.2); and for patient 3, 45.8 dB (SD = 4.6). In the patient data, many of the loci in the central field were cone-mediated, and therefore the mean rod sensitivity losses may be underestimates.

The normal mean map for 650 nm (Fig. 5, central column) was measured at the cone plateau (4–8 min after the bleach), thereby representing longer wavelength cone sensitivity across the visual field. The decline in sensitivity from the central to the far peripheral field is consistent with published data. In the patients, since there were no rod-mediated loci, dark-adapted sensitivity to 650 nm represents longer wavelength cone sensitivity. Patient 1 shows a relatively mild cone sensitivity loss (25% of loci were >2 SD below the mean), but patient 2 has more loss (63% of loci abnormally reduced), especially superiorly and in the temporal periphery. Patient 3 shows the most sensitivity loss (89% of loci abnormally reduced) with scotomatous regions superiorly, temporally, and nasally.
The regional retinal variation of the increased sensitivity at shorter wavelengths in the patients was investigated by performing perimetry with a 440-nm stimulus on a white background light (Fig. 5, right column). In normal subjects, sensitivity decreases with increasing eccentricity, a pattern which is consistent with previously published work.19 23 Patients 1 and 2 do not show the relatively steep decrease in sensitivity with eccentricity that is present in the normal, but instead show a more flat distribution of sensitivity that decreases only in the far periphery. For patient 1, 25% of loci were within 2 SD of the mean normal, and 75% of the loci had sensitivities that were at least 2 SD higher than normal. For patient 2, the foveal locus was subnormal; 33% of the loci were normal; and the remaining 65% were higher than normal. Patient 3 shows sensitivity losses in the same regions of the visual field (mainly superior, temporal, and nasal) as were evident with 650 nm, dark-adapted. Sixteen percent of the loci were >2 SD below the normal mean; 77% were normal; and 7% were higher than normal. Although there is an apparent increase in severity of dysfunction with age in these three patients, a direct relationship between age and clinical measures of severity was not evident in a larger series of patients.3

Spectral Electroretinography

ERGs were recorded in the light- and dark-adapted states using different colored stimuli (Fig. 6), and the results were analyzed to determine if the signals from the patients represented one or more than one photoreceptive mechanism (Fig. 7). Figure 6 (upper) shows the light-adapted ERGs in a representative normal subject and in patients 2 and 3. In the normal subject, the largest response is obtained with the orange-yellow stimulus, with the next largest from blue-green and green, and then red, and finally blue light. In contrast, patients 2 and 3 show the largest amplitude responses to the blue and the blue-green stimuli; there are smaller responses to orange-yellow and green and a barely measurable response to red. It is also of note that the patients' ERGs to the blue and blue-green stimuli differ dramatically from those of the normal by having a broader waveform and slower implicit time. Although less dramatic, the patients' responses to the other colors are also not normal in waveform appearance.

Figure 6 (lower) illustrates that in the normal subject the dark-adapted ERGs to blue, blue-green, green, and yellow stimuli are relatively equal in amplitude; the response to red light is smaller and shows the typical early cone and later rod components.3 The ERGs from patients 2 and 3 are lower in amplitude than those of the normal; responses to blue and blue-green light flashes have the largest amplitudes, with the other colors showing lower amplitude signals. The patients' dark-adapted ERGs resemble their light-adapted recordings in waveform shape; the amplitudes in the dark tend to be larger, especially for the middle- and long-wavelength (green, orange-yellow, and red) stimuli.

The principle of univariance25 predicts that if responses to two different spectral stimuli arise from a single photoreceptive mechanism, then: 1) the intensity-response functions for the two stimuli should coincide when plotted on an intensity axis that weights the stimuli for the mechanism under consideration; and 2) responses of equal amplitude to the two different stimuli should have similar waveforms. By use of this principle, the spectral ERGs of the patients were divided into two groups. Figure 7 shows results from patient 2; the results for patient 3 were similar. In the light-adapted (Fig. 7A) and dark-adapted (Fig. 7B) states, the middle- and long-wavelength stimuli produced responses with similar waveforms that had coincident intensity–response functions on a photopically (MWS + LWS cone) weighted intensity axis. The short-wavelength stimuli (blue and blue-green) produced responses with similar waveforms and coincident intensity–response functions on an intensity axis weighted for SWS cones (Fig. 7C, D). Although the same grouping applied in both light- and dark-adapted conditions, dark-adapted ERGs may have had a small rod component, because responses to blue-green are slightly more sensitive relative to blue than in the light-adapted ERGs (compare Fig. 7D to Fig. 7C). Figure 7C also shows the light-adapted response function to blue light in the normal subject (probably representing SWS and midspectral cone systems).3 The much larger signals in the patient again suggest hypersensitivity of the SWS cone system.

Reported differences in critical flicker fusion frequency of the SWS cone system compared with that of MWS and LWS cones26–29 prompted us to compare ERGs elicited with blue and orange-yellow lights in the light-adapted state at 29, 35, and 39 Hz in patient 2. Stimulus intensities that elicited light-adapted responses of similar amplitude to the two colors at a frequency of 1 Hz were chosen to elicit responses at the higher frequencies. At 29 Hz, there was a definite response to both colors, but at 35 and 39 Hz there was only a response to the orange-yellow stimulus. Equal amplitude responses to 35 Hz flicker could be obtained with the aforementioned orange-yellow stimulus and a higher-intensity blue stimulus (by 0.4 log units); the two responses, however, differed in timing. With this higher intensity blue stimulus, there were still no detectable responses at 39 Hz.
Imaging Fundus Reflectometry

No measurable visual pigment was detected within the measurement area during the IFR testing of patient 2: all double density changes observed at 7 wavelengths ranging from 460–600 nm were within 1 SD of zero. This was the case both when the retinal illuminance of the bleaching-adaptation exposure was 7.8 log scotopic troland-sec, and when it was raised to 8.3 log scotopic troland-sec. The mean sensitivity loss with the 500 nm stimulus within the area tested with IFR was about 30 dB. The lack of measurable visual pigment and this degree of rod sensitivity loss are consistent with the relationship expected if decreased quantal absorption were the sole cause of the rod dysfunction.9

Discussion

In contrast to other retinal diseases which can show decreased SWS function,30,31 the retinopathy de-
scribed herein appears to be unique in manifesting increased function of the SWS visual pathway. Evidence of SWS cone hypersensitivity was provided by results of both psychophysical and electrophysiologic studies. With measures of dark- and light-adapted spectral sensitivity, the effect was present; the finding was confirmed by isolating the SWS mechanism with chromatic adaptation. These psychophysical tests also indicated that the midspectral cone system was abnormally low in sensitivity, and that rod function was so severely impaired as to be barely measurable. Electrophysiologic correlates to these findings were provided by applying the principle of univariance to spectral ERG data. The patients' dark- and light-adapted ERGs were shown to represent mainly a supernormal SWS cone mechanism and a subnormal midspectral cone mechanism; what may be a small rod system component was detectable in the dark-adapted recordings.

Whether the retinal locus for the increased SWS cone function and that for the decreased midspectral cone function are at the receptor level, or whether they involve postreceptoral mechanisms, is not known. The IFR results, however, serve to localize
the rod dysfunction to the receptor. Given the low sensitivity of the rod system, at least two possible outcomes might have been expected from the IFR testing. If this disorder were like that in congenital stationary night blindness, normal levels of rhodopsin would have been present. The finding of no measurable rhodopsin suggests that the operating range is set by the reduced ability of the rods to absorb (or to photolyse after absorption of) incident quanta. A prolonged time course of rod adaptation such as was demonstrated in these patients has been reported also in vitamin A deficiency and in retinitis pigmentosa. A serum vitamin A level in patient 3 was normal.

The findings in the current study provide a means to interpret the symptoms of patients with this retinopathy and to interpret the results of their visual function tests performed with clinical techniques. The 3–4 log units of rod sensitivity loss measured perimetrically (and the unmeasurable rhodopsin levels) are in accord with the complaints of night blindness and the nondetectable rod ERG b-wave to dim blue flashes in the dark-adapted state. The midspectral cone sensitivity losses across much or all of the field are consistent with the abnormally reduced cone flicker ERG. A full Goldmann kinetic visual field in some of the patients (eg, patient 1), despite severely impaired rod function and abnormal midspectral cone sensitivity, is understandable, given that the SWS system is functioning at supernormal levels across most of the field. When field defects are present by Goldmann perimeter (eg, patients 2 and 3), they are in regions of dysfunction of all the photoreceptor systems: the midspectral cone and rod systems are subnormal and the SWS system is subnormal or normal rather than supernormal in sensitivity. Apparently, enough MWS and LWS function remains to perform the Farnsworth D-15 test correctly. Undoubtedly, more refined tests of color vision would reveal differences from normal. The decreased visual acuity could simply be the result of a “dropping-out” of the MWS and LWS cones, but further study is required to clarify the basis of the central retinal dysfunction and its relation to the cystoid macular changes.

The atypical ERG waveform reported previously as “rod-like” under dark- and light-adapted conditions must represent predominantly a supernormal SWS cone system ERG with a subnormal midspectral cone component. Although much larger than SWS cone ERGs isolated in normal subjects with chromatic adaptation or silent substitution, the ERG with the SWS cone mechanism in the patients of the current study has the same broad waveform shape, implicit time in the range of 45–65 msec, and a relatively low critical flicker fusion frequency. Unlike the published normal SWS cone ERGs, there is an a-wave at higher stimulus intensities and a relatively steep b-wave amplitude versus log intensity function. Study of this waveform under conditions known to elicit specific phenomena from SWS cone ERGs (eg, transient tritanopia, off-response behavior) would be of interest for future work.

The combination of retinal function abnormalities in this disorder is unlike that determined with similar techniques in either typical retinitis pigmentosa or the cone–rod dystrophies. The results of retinal function tests in three atypical retinopathies, however, do share features with those described herein, although interpretations of the results differ. Gouras et al performed spectral ERGs in patients with a “unique cone–rod degeneration” and explained the results (some of which resembled those in the current study) as an altered electric responsiveness of rods and cones and a defect in rod saturation. Unpublished psychophysical data were said to show insensitive rods but a normal SWS cone system. The lack of psychophysical evidence for a supernormal SWS mechanism may have resulted from testing a retinal region with substantial dysfunction. Keunen et al reported two siblings with a “congenital stationary night blindness” that showed no measurable rhodopsin and identical photopic and scotopic ERG parameters. There also were abnormal results with foveal cone densitometry but no fundus abnormalities; these findings raise the possibility that central cone dysfunction might precede the cystoid maculopathy. In a 14-yr-old patient described as having a “rod–cone dystrophy” by Fishman and Peachey, clinical findings were like those described for this retinopathy; ERGs evoked with blue and orange stimuli light-adapted were interpreted as originating from the rod system and a defect in rod adaptation was proposed.

To test the hypothesis that insensitive and poorly saturating rods were the basis of the ERG responses, we plotted all of our light-adapted responses on a scotopically weighted axis (Fig. 8). Intensity–response functions for most of the colors did not coincide, but the overlap at certain intensities of the functions to blue-green and orange-yellow stimuli may explain why Fishman and Peachey, who used only these two colored stimuli, concluded that their recordings were from the rod system. Figure 8 (waveform inset) shows, however, that amplitude-matched responses to blue-green and orange-yellow stimuli are quite different in timing, and therefore arose from different mechanisms. Clearly, a rod mechanism does
not govern the light-adapted ERG responses in our patients.

The three patients in this study differed in degree of severity of the retinal dysfunction. The fundal changes near the vascular arcades and the cystoid maculopathy certainly suggest that the disease process has a degenerative component, at least in these retinal regions. Longitudinal studies of retinal function are needed to determine if the differences among patients represent slow progression of a retinal degeneration, variable expression, or both.

**Key words:** nightblindness, electroretinography, retinal degeneration, short-wavelength-sensitive cones, spectral sensitivity

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**References**


