Identification of Proteins in Retinas and IPM From Eyes With Retinitis Pigmentosa

Susan Y. Schmidt,* Cynthia A. Heth,* Ross B. Edwards,* Junelle T. Brandt,* Alice J. Adler,† Allen Spiegel,‡ Hitoshi Shichi,§ and Eliot L. Berson*

Opsin, the α-subunit of transducin, S-antigen, interphotoreceptor retinoid-binding protein (IRBP) and cathepsin D were assessed in autopsy eyes from patients with retinitis pigmentosa (RP) and normal autopsy eyes. Immunochemical methods were used to determine the presence of these proteins on Western blots of retinal homogenates from five RP donors and on blots of interphotoreceptor matrix (IPM) preparations from six other RP eyes. The amounts of immunoreactive opsin, S-antigen, α-transducin, and IRBP appeared below normal in retinas from RP eyes. All six IPM samples from patients with advanced RP had reduced amounts of S-antigen and no detectable IRBP or transducin. Cathepsin D (an RPE protein) was present in IPM of RP eyes in amounts comparable to that in IPMs from normal eyes. Small amounts of cathepsin D were also detected in retinas from both normal and RP eyes. These studies show that proteins specific to the photoreceptor-pigment epithelium complex in normal eyes can be detected in autopsy eyes from patients with RP and suggest that the observed reductions in photoreceptor-specific proteins occur as a consequence of photoreceptor loss. Invest Ophthalmol Vis Sci 29:1585-1593, 1988

Retinitis pigmentosa (RP) comprises a group of hereditary degenerative diseases characterized by photoreceptor cell degeneration and loss of vision. Histopathological studies of autopsy eyes with advanced RP1-7 and electrophysiological studies of the early stages8 have provided evidence that the abnormality resides within the photoreceptor-pigment epithelium complex. This report focuses on biochemical studies of 11 autopsy eyes with RP (designated RP-1 through RP-11) all of which had extensive loss of photoreceptor cells. Retinas were available for study in five of these eyes (RP-1 through RP-5) while the interphotoreceptor matrix (IPM) was analyzed in the remaining six RP eyes (RP-6 through RP-11).

Reports on the ultrastructure of RP-1 retina,3 RP-4 retina,6 and other RP eyes in our2,4 and other laboratories13,7 have defined the differential involvement of rods and cones and regional differences in photoreceptor loss. For example, in sex-linked3 (RP-1) and autosomal recessive RP6 (RP-4) the only surviving photoreceptor cells in the fovea were cones; only occasional photoreceptor cells were observed in the midperiphery in the zone of bone spicule pigmentation, and nearly normal (RP-1) or reduced (RP-3 and 4) numbers of rods and cones were present in the peripheral areas of the retina. Photoreceptor cells in these RP eyes had either no outer segments or outer segment length was greatly reduced; remaining cone inner segments were swollen (particularly those in the fovea) and in some instances contained unusually large autophagic vacuoles. In view of the regional differences in photoreceptor loss in eyes with RP, efforts were made to subdivide some of the retinas into central and peripheral areas and compare findings within the same eyes.

Immunochemical methods were used to evaluate retinas and IPMs from eyes with RP for the presence of known photoreceptor-specific proteins including opsin, S-antigen and α-transducin. The presence of interphotoreceptor retinoid-binding protein (IRBP), as well as cathepsin D were evaluated in retina and IPM from donor eyes with RP since both IRBP (origi-
Table 1. Data on retinas and IPMs from 11 autopsy eyes with retinitis pigmentosa

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>Patient data</th>
<th>Retinas and IPMs</th>
<th>Immunochemical analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Specimen no.</td>
<td>Patient data</td>
</tr>
<tr>
<td>Retina</td>
<td></td>
<td>Normal for comparison</td>
<td>Male, 24 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-1</td>
<td>Sex-linked</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Central</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Peripheral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-2</td>
<td>Female, 77 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-3</td>
<td>Female, 55 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-4</td>
<td>Male, 68 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-5</td>
<td>Female, 93 yrs.</td>
</tr>
<tr>
<td>IPM</td>
<td></td>
<td>Normal for comparison</td>
<td>Male, 57 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-6</td>
<td>Isolate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-7</td>
<td>Male, 57 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-8</td>
<td>Female, 71 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-9</td>
<td>Female, 50 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-10</td>
<td>Male, 87 yrs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP-11</td>
<td>Female, 74 yrs.</td>
</tr>
</tbody>
</table>

Summary of analyses performed on each retina or IPM preparation from eyes with RP. In the normal retina or IPM mean values for the density and size of each immunoreactive protein was rated as 4 except for cathepsin D which was present only in trace (tr) amounts in normal retinas and opsin which was not detected in IPM. The density of each immunochemical reaction in retinas and IPMs from RP eyes was graded in relation to the mean normal intensity of each specific immunoreactive protein. The grading was based on visual assessment and cannot be considered quantitative. An adjustment was made for the protein applied to each lane so that comparisons reflect comparable amounts of protein in normal and RP samples. Dashed lines (--) designate where no analyses were done and 0 refers to a nondetectable immunochemical reaction.

dating from photoreceptors and possibly involved in transport of retinoids and cathepsin D (a proteolytic enzyme from the pigment epithelium) may have relevance to abnormalities in the photoreceptor-pigment epithelium complex.

Materials and Methods

Autopsy Eyes

Eleven autopsy eyes from patients with retinitis pigmentosa (RP) were obtained for these studies either through the New England Eye Bank or through the National Retinitis Pigmentosa Foundation. Patient data and a list of the immunochemical analyses for each RP eye are provided in Table 1. Retinas were isolated from five different eyes with RP (RP-1 through RP-5); four of these (RP-1 through RP-4) were prepared within 4 hr after death while RP-5 was prepared 17 hr after death. Central and peripheral regions of the retina were dissected from RP-1 and RP-3 eyes. The RP eyes used for the IPM studies (RP-6 through RP-11) were received between 12-30 hr after death.

Histological examination of fellow eyes of all but RP-9 showed that except for RP-2 and 7, most RP eyes retained some photoreceptor cells. Detailed electron microscopic studies of retinas from fellow eyes of RP-1, 3 and 4 showed a single layer of cones in the fovea, occasional photoreceptors in the midperiphery, and some remaining rods and cones with shortened outer segments in the more peripheral regions of the fundus. Photoreceptor cells were...
greatly reduced in number in fellow eyes of RP-5, 6, 8, 10, and 11. Photoreceptor outer segments were observed in RP-6 and 10, but because of the long postmortem intervals and tissue autolysis it was not clear whether or not outer segments were preserved in RP-5, 8 and 11.

Twenty-two normal human autopsy eyes (18–87 years old) served as controls for evaluating results from retinas and IPM preparations from RP eyes. These eyes were obtained through the New England Eye Bank or the National Diabetes Research Interchange. Retinas were isolated from eight of these eyes received 3–4 hr after death and IPM was prepared from 14 of these normal eyes received between 12–30 hr after death. Results from IPMs of normal and RP eyes were also compared with those from an eye with choroidal sclerosis (CS), a retinal degenerative disease involving the choroid and pigment epithelium; the fellow eye from the patient showed the presence of well-preserved photoreceptor cells in the macular and far peripheral areas of the retina.

Retinas were dissected rapidly in dim light in ice-cold 0.9% saline and frozen in liquid nitrogen. In some experiments to compare central and peripheral areas of the retina, following dissection the macular-perimacular area was separated from the remaining retina using a 6 mm diameter trephine centered on the fovea. Retinas were stored at −80°C. For isolation of IPM, the eyecups and retinas were rinsed with gentle agitation using three changes of 0.9% saline for a total of 15 min. The IPM preparations were centrifuged at 50,000 g for 30 min. The supernatant was concentrated (Amicon, Danvers, MA) and stored at −80°C.

**SDS-PAGE and Immunochemical Analyses**

Retina homogenates or IPM preparation were suspended in sample buffer as previously described. The proteins were solubilized with SDS at room temperature or 37°C for 30 min and were analyzed by SDS-PAGE on 10% gels. The concentration of protein was measured according to Lowry et al, and known amount of protein was loaded on each lane (see Figure legends for details). The protein pattern was visualized following staining with silver.

For the immunochemical analyses, the proteins on gels were transferred electrophoretically to amino-phenylthioether (APT)-derivatized paper. The blots were incubated with primary antisera, then with secondary antibodies directed against the Fc region of the primary immunoglobulins. The antibody complex was localized on the blots by using the appropriate species of horseradish peroxidase anti-peroxidase (PAP) as the tertiary antisera. Because of the limited amounts of material from retinas and IPMs from RP eyes, the same blots were sequentially reacted with different antisera.

The following polyclonal antibodies were used for immunochemical identification of proteins; rabbit anti-bovine IRBP, rabbit anti-bovine S-antigen, rabbit anti-bovine α-transducin, and rabbit anti-bovine opsin from our laboratories, and also goat anti-human cathepsin D (gift of Elizabeth Neufeld). The antibody to α-transducin has been shown to selectively bind to α-transducin in rod photoreceptor cells. Purified preparations of human IRBP (132 kD), bovine S-antigen (48 kD), α-transducin (37 kD), opsin (35 kD), and human cathepsin D (31 kD) were used as standards in the identification of proteins, based on their molecular weight and specificity of immunochemical staining. The presence of albumin in IPMs was evaluated using a commercially available rabbit anti-human albumin antibody (Cappel, West Chester, PA). Pilot studies using Western blots of normal retinas or IPMs indicated that each of the antibodies, except for S-antigen (which cross-reacted with a protein of 20 kD), reacted with a single polypeptide. The immunochemical reaction observed with each of the primary antibodies was specific; no specific reaction occurred in control experiments when the primary antibody was omitted or when it was replaced by nonimmune serum. Increased immunochemical staining was observed for a given protein as the amount of total protein applied to the gel was increased over a 20-fold range (10 µg–200 µg total protein per lane). The observed increases in the size of immunoreactive spots in normal samples served to establish a grading system, with 4+ representing an average amount of immunostaining for a given protein in 100 µg total retinal or IPM protein and 1+ representing that seen with 10–25 µg total protein. This grading system, although not rigorously quantitative, provides a useful basis for comparing immunoreactive spots in retinas and IPMs of normal and RP eyes.

While testing for the specificity of each immunochemical reaction a nonspecific immunoreactive band ~95 kD (designated as A₁ in Results) was identified on blots of retina and IPM preparations, regardless of the antisera tested. This 95 kD protein was identified to be a serum component which may be present in small amounts in retinal blood vessels and in IPM, or its presence could be due to contamination with serum during the postmortem interval or during the preparation of these tissues. Band A₁ was also seen when the primary antiserum was omitted or when it was replaced by nonimmune rabbit serum. The detection of artifact band A₁ required the presence of the secondary antisera and no staining was seen on blots incubated with tertiary antibody alone.
Fig. 1. Silver stained slab gels of proteins in retinal homogenates (a) and IPM preparations (b). Normal eyes are designated with N while retinas and IPMs from RP patients are designated with the RP number assigned to each RP eye (Table 1). C and P refer to central and peripheral regions of the retina in cases where such dissections were done. The purified proteins, IRBP (132 kD), S-antigen (48 kD; S-Ag), and opsin (35 kD) were run as markers for retina (a); cathepsin D (31 kD; Cath D) was run as a marker for IPM (b). Reduced amounts of opsin are present in retinas from RP eyes. IRBP is a prominent band in normal IPM preparations but is not detectable in those from RP eyes. Total protein applied to each lane was 25 μg for retinas and 37.5 μg for IPMs.

Results

Protein patterns in normal and RP retinas appear similar on SDS gels (Fig. 1a). No differences were observed between retinal proteins from central or peripheral regions of the fundus in normal retinas or in the RP-3 retina. Protein patterns were also similar for RP retinas dissected and frozen within 1 hour postmortem [RP-1 and 3 (Fig. 1a) as well as RP-4, not shown] or after 3 hr postmortem (RP-2); a lengthy postmortem period, however, was associated with protein degradation and/or aggregation (RP-5). The most notable difference in protein patterns between normal and RP retinas was the reduced amount of staining in the region of opsin (35 kD) in RP retinas. Bands in the molecular weight range corresponding to those of serum albumin (68 kD), S-antigen (48 kD) and cathepsin D (31 kD) were observed in all retinal homogenates.

The staining patterns of proteins in IPM samples from normal and RP eyes are similar to each other (Fig. 1b). However, there is a reduction in high molecular weight (>100 kD) proteins in RP eyes compared with the normal. IRBP (132 kD), a prominent band in normal IPM, is missing from the IPM in all RP eyes but is detectable in the IPM of the CS eye. The IPM preparations show staining in the region of serum albumin (68 kD), S-antigen (48 kD) and cathepsin D (31 kD) as well as many other bands. Variation in postmortem intervals between 4–30 hr did not seem to affect the protein patterns of IPM in normal or RP eyes.

Immunohistochemical localization of rod-specific α-transducin (Fig. 2a), IRBP and S-antigen (Fig. 2b), and opsin and cathepsin D (Fig. 2c) on blots of retinal proteins indicates that these proteins were present in all five RP retinas except for opsin and α-transducin, which were not detectable in the retina from RP-2, and IRBP, which was not detectable in RP-2 and 5 retinas. The immunohistochemical staining was reduced indicating reduced amounts of these photoreceptor-specific proteins in retinas from RP eyes compared with the normal (Fig. 2, Table 1). S-antigen was present in all five retinas from RP eyes while IRBP was detectable in three of the five RP retinas tested (Table 1). Both proteins were detectable in central and peripheral regions of RP-1 (not shown) and 3 (Fig. 2) retinas despite extensive photoreceptor cell loss. Cathepsin D was present in trace amounts in normal retinas and appeared slightly higher in retinas of eyes with RP. Cathepsin D seemed particularly enriched in retinas from RP-1 and 3 eyes (Fig. 2c, Table 1). The apparent molecular weight of the immunoreactive proteins was similar in all retinas from normal and RP eyes analyzed within 4 hr after death. RP-5 retina, analyzed 17 hr after death, showed a slight increase in the molecular weight of opsin.

Differences can be noted between central (macular
Fig. 2. Immunochemical localization of proteins on Western blots of retinal homogenates; the blot was first reacted with the antisera to α-transducin (a), then sequentially with antisera to IRBP and S-antigen (b). Blot (c) illustrates the localization of opsin and cathepsin D on other blots of retinal proteins. Standard lanes show α-transducin (a), IRBP and S-antigen (b). NP and NC designate normal peripheral and central samples, respectively. Total protein loaded per lane was 100 µg for normal retinas and 150 µg for retinas from eyes with RP. Artifact band A₁ is indicated on a and b.

Area) and peripheral regions in RP-1 and 3 retinas: α-transducin and opsin immunostaining seems reduced in the central compared with the peripheral regions (Fig. 2a, c). Central vs. peripheral differences are also noted for α-transducin but not for opsin in some normal human retinas. The reduced amounts of these photoreceptor-specific proteins in central vs. peripheral regions in the RP eyes correlates with the
histology showing reduced numbers of photoreceptors and greatly reduced or nonexistent outer segments in the central region of the retina compared with more peripheral regions. Cathepsin D, a protein that is not specific to the photoreceptor cells, was present in comparable amounts in central and peripheral regions of RP-1 and RP-3. S-antigen immunostaining was similar in central and peripheral regions in RP-3 (Fig. 2b) and RP-1 retinas (Table 1).

Blots of IPM from RP eyes contained no detectable immunoreactive IRBP (Fig. 3a) in contrast with normal IPM. Immunoreactive S-antigen was reduced in IPM from RP eyes compared with the normal. An additional immunoreactive band (20 kD; lowest band, Fig. 3b) appeared following immunochemical staining for S-antigen in preparations of IPM; a particularly strong reaction is seen in IPM of RP-7 and 8, a weak reaction in IPM of RP-9 and 11. Similar variations in the density of the 20 kD immunoreactive band is also seen in normal IPM preparations. This 20 kD band may represent a different protein with an antigenic determinant recognized by the antibody or may be a breakdown product of S-antigen which is present in the IPM but not in the retina (Fig. 3b). The absence of opsin (35 kD) suggests there was little retinal membrane contamination in IPM preparations. The α-subunit of transducin, present in normal IPMs, is not detectable in the IPM preparations from RP eyes while a-transducin (not shown) is present in the IPM but not in the retina (Fig. 3b). The absence of opsin (35 kD) suggests there was little retinal membrane contamination in IPM preparations. The α-subunit of transducin, present in normal IPMs, is not detectable in the IPM preparations from RP eyes (Fig. 3c). Cathepsin D, which shows a wide variation in the normal, is present in IPM preparations from RP eyes in amounts comparable to those in normal eyes (Fig. 3c). Analysis of the IPM from the CS eye indicates the presence of reduced amounts of IRBP and S-antigen (Figs. 3a and b), while opsin (Fig. 3b) and α-transducin (not shown) are not detectable.

Table 1 summarizes the individual results of the immunochemical analyses on each eye. Normal retinas contained all five proteins and, except for opsin, all other proteins were present in IRM from normal eyes. Retinas from RP eyes contained reduced amounts of immunoreactive IRBP, S-antigen, opsin, and α-transducin compared to normal retinas. S-antigen immunoreactivity was greatly reduced in IPM preparations from RP eyes while α-transducin and IRBP were not detectable. These results are consistent with the morphological observation that the number of remaining photoreceptor cells was greatly reduced in all RP eyes used in this study.

Discussion

The findings in this study indicate that proteins specific to the photoreceptor-pigment epithelium complex, including opsin, IRBP, α-transducin, S-antigen and cathepsin D, can be detected in autopsy eyes of patients with retinitis pigmentosa. Some of these proteins (opsin, transducin and S-antigen) are known to be present in photoreceptor cells and to play a role in the visual transduction mechanism; others, such as IRBP (synthesized in photoreceptors and secreted into the IPM) and cathepsin D (a proteolytic enzyme synthesized in the pigment epithelium) may play roles in the IPM in the transport of vitamin A and in the degradation of outer segment phagosomes in the pigment epithelium, respectively. The presence of these photoreceptor-specific proteins in retinas from RP eyes with preserved photoreceptor cells suggests that the degeneration of photoreceptor cells was not caused by the complete absence of any of these proteins.

Reduced immunochemical reactions in RP retinas for the photoreceptor-specific proteins opsin, transducin, S-antigen and IRBP paralleled the extensive reduction in photoreceptor numbers as noted in fellow eyes. For example, the distribution of opsin and α-transducin paralleled the distribution of photoreceptors in RP-1 and 3 retinas, since the reactions were more intense in peripheral regions of the retina where the photoreceptor cells were better preserved than in the macular regions where only a single row of photoreceptor cells remained. The observations indicate that the apparent reductions in opsin and α-transducin in these and other RP eyes may be directly related to the loss of photoreceptors. These findings argue against a gross deficiency in any of these proteins in photoreceptor cells of eyes with RP. In addition, S-antigen remained detectable in an apparently photoreceptorless retina (RP-2) at late stages of RP. S-antigen was also detectable in IPM of some RP eyes in which neither IRBP nor α-transducin was detectable. The persistence of S-antigen in an apparently photoreceptorless retina, and the unchanged molecular weights of all proteins in RP retinas also argue against excessive amounts of hydrolytic enzyme activity and protein degradation in photoreceptor cells of these RP eyes.

Correlation of visual function prior to death and postmortem ultrastructural analyses of photoreceptor cells in RP-1, 3 and 4 eyes suggest that the remaining photoreceptor cells were functioning as some vision was reported by these patients prior to death despite the tremendous reductions of photoreceptor cell numbers and near complete absence of outer segments in the macular regions of these eyes. This agrees with our observation that photoreceptor cells in these RP eyes had some of the components necessary for the light-activated cascade of cyclic GMP hydrolysis. Evidence for visual transduction has also been reported in rd1 mice (retinal degeneration, slow) in which light-dependent reductions in cyclic GMP
Fig. 3. Immunochemical localization of proteins on blots of IPM from normal and RP eyes. IRBP, S-antigen and albumin (66 kD) were sequentially localized on the same blot (a, b). Blot (c) demonstrates the localization of cathepsin D and that of α-transducin following reaction with the two different antisera. Purified proteins—human IRBP (132 kD), S-antigen (48 kD), α-transducin (37 kD), cathepsin D (31 kD), opsin (35 kD) and albumin (66 kD)—were run as standards. Immunoreactive IRBP (seen in normal IPMs and the marker lane) was not detectable in IPMs from RP eyes. S-antigen and albumin are present in all IPM preparations, while opsin is not detected in IPM from either normal or RP eyes. A positive reaction with the opsin antiserum was observed only for the opsin standard (b). Total protein applied to each lane was 100 μg for both normal and RP IPMs in (a) and (b), and 80 μg for normal and 120 μg for RP IPMs in (c). Artifact band A₁ is designated on (a) and (b).
were observed in the absence of outer segments.\textsuperscript{26} Opsin has been detected in inner segment plasma membrane of RCS rats and \textit{rd} mice after the outer segments have disappeared, at late stages of hereditary retinal degenerations.\textsuperscript{27,28} These observations in some animal models suggest that outer segment-specific proteins may become associated with the inner segment as the degeneration progresses, and raise the possibility that a similar process may occur in RP.

It is of interest that IRBP was not detectable in the IPM of RP eyes, and yet could be detected within the retinas from four different RP eyes, each of which had surviving photoreceptor cells. Since previous studies have shown that IRBP is synthesized by photoreceptor cells,\textsuperscript{9,10} the presence of IRBP in retinas from RP eyes suggests that the remaining photoreceptors were capable of IRBP synthesis. Failure to detect IRBP in the IPM samples from RP eyes at late stages of photoreceptor degeneration may be due to a low IRBP concentration, as a consequence of loss of photoreceptor cells. Reduced numbers of photoreceptor cells may also explain the failure to detect \(\alpha\)-transducin and the low levels of S-antigen compared with normal levels of albumin and cathepsin D which are not of photoreceptor origin. Previous studies have shown that while IRBP is an intrinsic component of the IPM, photoreceptor-specific proteins, such as \(\alpha\)-transducin and S-antigen may become artifactualy associated with the IPM due to leakage from the photoreceptor cells during the postmortem interval and/or during the isolation of the IPM.\textsuperscript{29} As in the present study, small amounts of IRBP were reported to be present in retinas from RP eyes, particularly in peripheral areas.\textsuperscript{30,31} In a previous report on a section of RP-4 retina-choroid complex, no IRBP was detected on Coomassie stained gels,\textsuperscript{6} whereas in the present study IRBP was detected within another section of retina from the same eye. These differences may be explained by differences in the sensitivity of the two methods (staining vs. immunocytochemical reaction) or may be due to regional differences in the severity of photoreceptor cell loss.

Cathepsin D, which is present at very high levels in the pigment epithelium, was found to be a component of the IPM and retina (confirming previous enzymatic studies\textsuperscript{22}), in both normal and RP eyes. In contrast to the decreased immunoreactivity of photoreceptor-specific proteins in RP eyes, cathepsin D was present in comparable amounts in retinas and IPMs from normal and RP eyes. The evidence suggests that cathepsin D in IPM preparations originates from the pigment epithelium; cultured normal pigment epithelium has been shown to secrete cathepsin D.\textsuperscript{33} Furthermore, a protein of similar molecular weight has been shown to be secreted by cultured PE from normal\textsuperscript{34} and RP eyes (R. B. Edwards, unpublished results).

The possible biochemical causes of photoreceptor cell degeneration in human retinal degenerations remain to be defined. Although it is clear that the abnormalities reside within the photoreceptor-pigment epithelium complex, the exact pathogenic mechanisms remain elusive. The present immunocytochemical studies provide evidence that at least some components of the cGMP cascade are present in RP eyes; however, it is not yet known whether or not these proteins have normal structural characteristics, or if they are functionally intact. Future studies involving in situ hybridization of mRNAs in RP eyes with cDNA probes and immunocytochemical localization of these proteins should help answer questions about gene expression and the distribution of these proteins in the remaining photoreceptor cells in RP eyes.

Key words: retinitis pigmentosa (RP), interphotoreceptor matrix retinoid binding protein (IRBP), opsin, \(\alpha\)-transducin, S-antigen

Acknowledgments

We thank Joanne Miller for excellent technical assistance and Kathleen Tauson for excellent typing of the manuscript.

References


