ELSEVIER

Cone Electroretinograms in Response to Color Stimuli After Successful Retinal Detachment Surgery

Shuichi Yamamoto, Masanori Hayashi and Shinobu Takeuchi

Department of Ophthalmology, Toho University Sakura Hospital, Sakura, Japan

Abstract: Cone electroretinograms (ERGs) in response to different color flashes were examined using a Ganzfeld stimulus in 19 eyes after successful retinal detachment surgery. In the operated eyes, the short wavelength sensitive (S-) cone b-wave was reduced more than the mixed long (L-) and middle (M-) wavelength sensitive cone b-waves. The ratio of the S-cone ERG b-wave amplitude between operated eyes and fellow eyes was significantly lower than the L- and M-cone ERG b-waves ($P < .01$). These ERG results indicated that the S-cone system is more impaired than the L- and M-cone systems after retinal detachment surgery. **Jpn J Ophthalmol 1998;42:314–317** © 1998 Japanese Ophthalmological Society

Key Words: Cone electroretinogram, retinal detachment, short wavelength sensitive cone.

Introduction

Rhegmatogenous retinal detachment can be treated successfully by scleral buckling surgery, and the rates of retinal reattachment are satisfactory. However, a discrepancy exists between anatomical repair and visual function.[1] After successful retinal detachment surgery, patients are known to have a blue-yellow color vision defect.[2–4] A residual defect in hue discrimination was observed 2 years after surgery in patients whose visual acuity had returned to normal levels.[2] Recovery from the blue-yellow defect, as evaluated with the pseudoisochromatic test, which is sensitive for evaluating acquired color vision deficiency, was similar to that of visual acuity. The deficiency improved within 2 months to the preoperative level, with a residual defect.[4] Recently, a histopathological study, using carbonic anhydrase and an antibody to an isoform of arrestin (S antigen), revealed total loss of the short wavelength sensitive (S-) cones, whereas the long (L-) and middle wavelength sensitive (M-) cones were comparatively resistant to damage.[5] In this report we describe cone electroretinograms (ERGs) in response to different color flashes with a Ganzfeld stimulus in patients who had undergone successful retinal detachment surgery.

Subjects and Methods

Nineteen patients with unilateral rhegmatogenous retinal detachment who had successful outcomes after a single surgical procedure without epimacular proliferation and/or cystoid macular edema were studied. Their ages ranged from 18 to 64 years (M = 40.5). Patients with a history of ocular trauma or other retinal diseases were excluded from this study. All patients had undergone conventional surgical techniques of scleral buckling with cryoretinopexy and drainage of subretinal fluid. The macula was involved in 11 eyes, and the retina was totally detached in 1 eye. The duration of preoperative retinal detachment, which was estimated as the time from the onset of subjective symptoms to the day of surgery, ranged from 2 days to 24 weeks. Both the preoperative visual acuity and postoperative visual acuity ranged from counting fingers to 20/20. The refractive error of the operated eye ranged from −6.5 D to +1.25 D, and the difference between the operated eye and the fellow eye was less than 1.5 D in all patients. No difference was observed in media opacity between the two eyes of any patient at the time of the ERG examination. Informed consent was obtained from all subjects after the methods, purpose, and possible consequences of the study were explained.

Received: September 12, 1997

Address correspondence and reprint requests to: Shuichi YAMAMOTO, MD, Department of Ophthalmology, Toho University Sakura Hospital, 564-1 Shimoshizu, Sakura, Chiba 285, Japan

0021-5155/98/$19.00
PII S0021-5155(98)00014-8

The method for ERG recordings has been described previously.[6–8] In brief, the patient's pupils were fully dilated with tropicamide eyedrops, and the ERG was recorded simultaneously from both eyes with bipolar Burian-Allen contact lens electrodes. A Ganzfeld stimulator provided full field flash stimuli and a white background illumination (50 cd/m^2). Spectral stimuli were produced by Kodak Wratten color filters (Eastman Kodak, Rochester, NY, USA) 98 (450 nm), 48 (471 nm), 61 (534 nm), 21 (593 nm), and 29 (633 nm) on the same white background illumination. At 450 nm stimuli, we routinely examined responses with the strongest flash intensity and then dimmed the other longer wavelength stimuli with neutral density filters to produce approximately equal L- and M-cone b-waves, because all longer wavelength stimuli had more effective energy for the L- and M-cones. The stimulus frequency was 5 Hz, and responses were averaged 500 times using a Neuropack 2 averager (Nihon Kohden, Tokyo).

Statistical analyses were performed by means of nonparametric tests, such as Wilcoxon signed-rank test for paired comparison and Mann-Whitney *U* test for unpaired comparison, because the obtained data did not show a Gaussian distribution.

Results

Figure 1 illustrates cone ERGs in response to different chromatic stimuli in the presence of white background illumination from an operated eye and a normal fellow eye in a 38-year-old patient who underwent surgery for retinal detachment involving the macula, 2 months before the ERG study. The postoperative visual acuity was 20/40 in the operated eye. In normal eyes, the S-cone ERG elicited by short wavelength (450 and 471 nm) stimuli appears as a separate b-wave riding on an earlier mixed L- and M-cone b-wave. Middle- and long-wavelength (534, 593, and 633 nm) stimuli produce only L- and M-cone b-waves. We measured the S-cone b-wave from its appearance, after the peak of the L- and M-cone b-waves, to its own peak for the 450 nm stimulus. In the operated eyes, the S-cone b-wave and the negative wave after the S-cone b-wave, which is another characteristic response to short wavelength stimuli,[6] were more reduced than were the L- and M-cone b-waves.

Table 1 summarizes amplitudes of the S-cone ERG b-wave to 450 nm and 471 nm stimuli and those of the L- and M-cone b-wave to 450 nm, 471 nm, 534 nm, 593 nm, and 633 nm stimulus in operated eyes and in normal fellow eyes. The normal

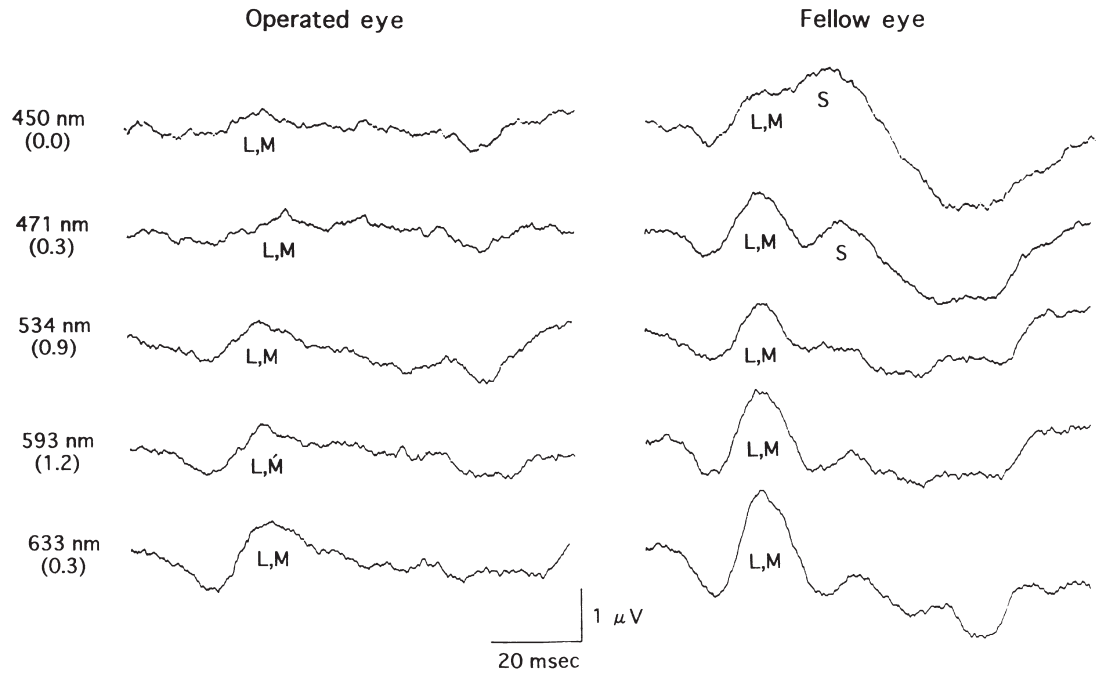

Figure 1. Cone electroretinograms (ERGs) in response to different chromatic stimuli in the presence of white background illumination from operated eye (left) and normal fellow eye (right) in a 38-year-old patient who underwent surgery for retinal detachment 2 months before ERG study. Number on left signifies nominal wavelength of maximum transmission of each filter. Numbers in parentheses indicate neutral density filter used to adjust flash energy to produce approximately equal L- and M-cone b-waves. L,M signifies L- and M-cone ERG b-waves and S signifies S-cone b-waves.

Jpn J Ophthalmol
Vol 42: 314–317, 1998

Table 1. S-Cone and L- and M-Cone Electroretinogram (ERG) b-Wave

	Amplitude (μV)		Ratio of Amplitude (Operated Eye/Fellow Eye)
	Operated Eye	Fellow Eye	
S-cone ERG			
450 nm	0.37 (0–1.68)	1.17 (0.43–2.33)	0.36 (0–0.86)
471 nm	0.29 (0–1.33)	0.75 (0.12–2.00)	0.49 (0–1.49)
L- and M-cone ERG			
450 nm	0.73 (0.37–1.29)	1.02 (0.37–2.02)	0.67 (0.23–1.22)*
471 nm	0.83 (0.25–1.57)	1.22 (0.41–2.67)	0.61 (0.16–1.97)*
534 nm	0.71 (0.29–1.83)	1.19 (0.41–2.17)	0.71 (0.33–1.76)*,***
593 nm	1.02 (0.53–2.46)	1.60 (0.50–2.88)	0.63 (0.40–1.18)*,***
633nm	1.27 (0.89–2.42)	2.08 (0.39–4.83)	0.66 (0.36–1.21)*,***
Cone ERG to white	40.8 (20.0–75.8)	68.8 (30.8–165.0)	0.60 (0.29–1.12)**

Values represent median (minimum–maximum).
*$P < .01$ and **$P < .05$ compared with S-cone ERG to 450 nm, and ***$P < .05$ with S-cone ERG to 471 nm (Wilcoxon signed-rank test).

range for the S-cone ERG amplitude was 0.54–2.64 μV in our laboratory. The amplitude to every stimulus was significantly lower in operated eyes than in fellow eyes ($P < .001$). The ratio of the S-cone ERG b-wave amplitude between operated eyes and fellow eyes was significantly lower than that of the L- and M-cone ERG b-waves ($P < .01$).

The ratios of the b-wave amplitudes were compared between cases in which the macula had been involved and those without macular involvement (Table 2). The ratios were reduced in eyes with detached macula to every wavelength stimulus; however, no statistical significance was observed.

Discussion

Several electrophysiological studies have demonstrated a gradual recovery of ERG responses after retinal detachment surgery,[9,10] with no difference reported in ERG recovery in the three-cone mechanisms. To our knowledge, our preliminary study demonstrated for the first time the relative vulnerability of the S-cone ERG in eyes after retinal detachment surgery. Although the amplitudes of b-waves originating from the three types of cones were reduced in operated eyes, as compared with normal fellow eyes 3 months after successful surgery, the reduction in the S-cone ERG b-wave was significantly greater than that in the L- and M-cone ERG b-waves.

There have been many psychophysical studies reporting acquired color vision loss along a blue-yellow axis in patients with retinal detachment,[11] and in those after successful retinal detachment surgery.[2–4] Immunohistochemically, Nork et al[5] examined retinas from enucleated eyes with traumatic retinal detachment and found a complete dropout of the S-cones, homogeneous loss of about half the rods, and mild reduction of the L- and M-cones, even in retinas that

Table 2. Ratios of S-Cone and L- and M-Cone ERG b-Wave Amplitude

	Ratio of Amplitude (Operated Eye/Fellow Eye)		
	Macula-On	Macula-Off	*P* Value
S-cone ERG			
450 nm	0.51 (0.17–0.86)	0.35 (0–0.80)	.54
471 nm	0.64 (0–1.00)	0.46 (0–1.49)	.12
L- and M-cone ERG			
450 nm	0.66 (0.46–1.22)	0.70 (0.23–1.10)	.59
471 nm	0.81 (0.50–1.05)	0.50 (0.16–1.97)	.05
534 nm	0.87 (0.49–1.06)	0.58 (0.33–1.76)	.14
593 nm	0.64 (0.40–1.18)	0.62 (0.42–1.00)	.41
633 nm	0.70 (0.36–1.21)	0.65 (0.42–0.90)	.68
Cone ERG to white	40.8 (20.0–75.8)	68.8 (30.8–165.0)	.15

Values represent median (minimum–maximum).
All analyses were done using Mann-Whitney *U* Test.

had suffered retinal detachment only 2 1/2 days before enucleation. The S-cone system has been known to be vulnerable in retinal diseases.[7,11–14] Patients with retinitis pigmentosa showed greater loss in the S-cone ERG than in the L- and M-cone ERG.[13] The amplitude of the S-cone ERG b-wave was also selectively reduced in diabetic patients, with or without background retinopathy.[7] The S-cone pathway has been thought to be more vulnerable to hypoxia than the L- and M-cone system[15]; thus detachment from the retinal pigment epithelium may cause such selective damage to the S-cones. Scleral buckling reportedly reduced ocular blood flow, probably because of increased choroidal vascular resistance.[16] This may also have led to hypoxia in the outer retina, resulting in the selective impairment of the S-cone system. A limited response range of the S-cone pathway was reported to be another reason for its vulnerability in retinal disease.[17] On response functions for the L- and S-cone pathways, an equivalent change in log R_{max} affected the threshold of the S-cone pathways far more than that of the L-cone pathways.

Nork et al,[5] however, reported a total dropout of S-cones in their patients; the blue-yellow defects recovered gradually after the surgery.[1,4] It will be interesting to prospectively observe the S-cone ERG recovery in patients with rhegmatogenous retinal detachment.

References

1. Gundry MF, Davis EWG. Recovery of visual acuity after retinal detachment surgery. Am J Ophthalmol 1974;77:310–4.
2. Foulds WS, Reid H, Chisholm IA. Factors influencing visual recovery after retinal detachment surgery. Mod Probl Ophthalmol 1974;12:49–57.
3. Chisholm IA, McClure E, Foulds WS. Functional recovery of the retina after retinal detachment. Trans Ophthalmol Soc UK 1975;95:167–72.
4. Ueda M, Adachi-Usami E. Assessment of central visual function after successful retinal detachment surgery by pattern visual evoked cortical potentials. Br J Ophthalmol 1992;76:482–5.
5. Nork TM, Millecchia LL, Strickland BD, Linberg JV, Chao G. Selective loss of blue cones and rods in human retinal detachment. Arch Ophthalmol 1995;113:1066–73.
6. Gouras P, MacKay CJ, Yamamoto S. The human S-cone electroretinogram and its variation among subjects with and without L- and M-cone function. Invest Ophthalmol Vis Sci 1993;34:2437–42.
7. Yamamoto S, Kamiyama M, Nitta K, Yamada T, Hayasaka S. Selective reduction of the S cone electroretinogram in diabetes. Br J Ophthalmol 1996;80:973–5.
8. Yamamoto S, Nitta K, Kamiyama M. Cone electroretinogram to chromatic stimuli in myopic eyes. Vis Res 1997;37:2157–9.
9. Blach RK, Behrman J. The electrical activity of the eye in retinal detachment. Trans Ophthalmol Soc UK 1967;87:263–6.
10. Akiyama K. ERG recovery after retinal detachment surgery. Nippon Ganka Gakkai Zasshi (Acta Soc Ophthalmol Jpn) 1974;78:766–72.
11. Yokoyama M. Blue sensation in eye disease. Rinsho Ganka (Jpn J Clin Ophthalmol) 1979;33:111–25.
12. Greenstein VC, Hood DC, Ritch R, Steinberger D, Carr RE. S (blue) cone pathway vulnerability in retinitis pigmentosa, diabetes and glaucoma. Invest Ophthalmol Vis Sci 1989;30:1732–7.
13. Swanson WH, Birch DG, Anderson JL. S-cone function in patients with retinitis pigmentosa. Invest Ophthalmol Vis Sci 1993;34:3045–55.
14. Yamamoto S, Kataoka Y, Kamiyama M, Hayasaka S. Nondetectable S-cone electroretinogram in a patient with crystalline retinopathy. Doc Ophthalmol 1995;90:221–7.
15. Smith VC, Ernest JT, Pokorny J. Effect of hypoxia on FM 100-hue test performance. Mod Probl Ophthalmol 1976;17:248–56.
16. Yoshida A, Hirokawa H, Ishiko S, Ogasawara H. Ocular circulatory changes following scleral buckling procedures. Br J Ophthalmol 1992;76:529–31.
17. Hood DC, Benimoff NI, Greenstein VC. The response range of the blue-cone pathways: a source of vulnerability to disease. Invest Ophthalmol Vis Sci 1984;25:864–7.