Isolation of Focal Rod Electroretinograms From the Dark-Adapted Human Eye

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**Purpose.** To isolate focal rod electroretinograms (ERGs) from the dark-adapted human eye.

**Methods.** In two normal volunteers, dark-adapted focal rod ERGs were recorded from the peripheral retina in response to 30° diameter blue flashes of varying retinal illuminance and from different retinal regions in response to 10° diameter bright blue flashes. Dark-adapted focal rod ERGs also were recorded from a patient with the multiple evanescent white dot syndrome (MEWDS) and an enlarged blind spot in response to 30° diameter blue flashes presented within and outside the scotoma. The slower and larger stray light rod component elicited by these flashes was removed by subtracting the matching rod response to a dimmer, full-field flash, or was ignored when it did not overlap the faster and smaller focal rod component.

**Results.** The focal rod ERG had a waveform and sensitivity similar to those of the full-field rod ERG, was approximately proportional in amplitude to the density of rods directly illuminated, and was nondetectable within the retinal area corresponding to the enlarged blind spot of the patient with MEWDS.

**Conclusions.** Focal rod ERG a- and b-waves, in response to stimuli as small as 10°, can be recorded from different regions of the dark-adapted human retina to evaluate localized rod function. Invest Ophthalmol Vis Sci. 1996;37:930-934.
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ground adaptation or preconditioning. This method allows comparison with routinely obtained dark-adapted, full-field rod ERGs. Sufficiently bright flashes may be used to generate a-waves and b-waves for assessment of outer and inner retinal function.

METHODS

The subjects, two male volunteers (36 and 43 years of age) with normal results of ocular examination and one female patient (21 years of age) with the multiple evanescent white dot syndrome (MEWDS), gave their informed consent to participate in this study, which adhered to the tenets of the Declaration of Helsinki with methods approved by the Investigational Review Boards of the Massachusetts Eye and Ear Infirmary and Harvard Medical School. After 45 minutes of dark adaptation, ERGs were monitored from the dilated eye with a bipolar contact lens electrode, amplified, digitized, and summed as previously described. Focal flashes were presented by having the subject view the aperture of a Ganzfeld dome at a distance of 1 foot. Flash diameter and retinal location were varied by placing a mask with a central hole over the aperture and by having the subject fixate a red light-emitting diode mounted in the rear surface of the dome for testing the center of the retina or another red light-emitting diode at different angular distances from the center of the aperture for testing the peripheral retina. Full-field flashes were presented by having the subject place his or her chin on the chin rest of the dome and fixate the red light-emitting diode mounted in its rear surface. The colors of the focal and full-field flashes were blue (\(\lambda_{\text{max}} = 440\) nm, 90 nm half bandwidth) or red (\(\lambda_{50\% \text{ cut-off}} = 605\) nm).

To isolate focal responses, we presumed that the stray light component to a focal flash is equivalent to the full-field response to a dimmer flash, even though the distribution of stray light may be nonuniform particularly near the stimulus (unpublished observations, 1995 and ref. 13). If this were true, then the matching full-field response could be subtracted from the mixed response to the focal flash to derive or “isolate” the focal component. We tested this idea in a preliminary way in our normal volunteers by determining whether a rod ERG to nonuniform illumination could be matched by a rod ERG to uniform illumination. Colored papers of differing reflectance to blue light were cut into annuli and placed against the inner surface of a Ganzfeld dome so that the central 30° around the fixation point in the rear of the dome was uncovered and the papers, each subtending ~25°, had reflectances of ~20%, ~13%, and ~5%, respectively, with increasing eccentricity. This resulted in a graded distribution of light spanning 1.3 log units with a space-average retinal illuminance of 0.6 log scot td-sec.

The resultant ERG waveform (Fig. 1, upper trace) could be matched closely by a rod ERG elicited by a flash of the same mean retinal illuminance generated by the Ganzfeld dome with the colored papers removed (Fig. 1, lower trace). This raised the possibility that the rod ERGs from different retinal regions elicited by graded stray light can summate as a response indistinguishable from that to a uniform light of the same mean retinal illuminance.

RESULTS

Focal Rod Electroretinogram to a 30° Diameter Flash

The response to a peripheral 30° diameter blue flash from our normal volunteers (Fig. 2, a) consisted of a faster, smaller “focal” component and a slower, larger “stray light” component. The response to a dimmer, full-field blue flash (Fig. 2, b) consisted of a negative deflection (a-wave) followed by a positive deflection (b-wave) that closely matched the stray light b-wave of the first response (Fig. 2, a). This response to a dimmer full-field flash was empirically selected from a series of responses to full-field flashes of varying retinal illuminance as the one that provided the best match to the stray light component elicited by the focal flash with respect to both amplitude and temporal characteristics. Digital subtraction of the second from the first response (a minus b) resulted in isolation of a focal response (Fig. 2, c) that was larger than the focal component of the first response (Fig. 2, a) because of subtraction of the stray light a-wave that
Focal Rod Electroretinogram to a 10° Diameter Flash

The response to a 10° diameter blue flash presented to the periphery of our normal volunteers (Fig. 4A, upper trace) consisted of a focal rod component (enlarged in inset) that was not overlapped by the stray light rod component and, therefore, could be quantified without subtracting the full-field response (Fig. 4A, lower trace) that closely matched the stray light component. The separation of the two components was greater than that to a 30° diameter stimulus because a smaller stimulus elicits an even slower and smaller stray light response.5,6 To isolate the focal rod response to a 10° diameter blue flash within the macula, it was also necessary to subtract the cone component to a photopically matched red flash of the same diameter (not illustrated), as has been done to isolate the full-field rod ERG to bright blue flashes.12,14 Focal rod ERGs to 10° diameter flashes presented to different retinal locations showed a variation in b-wave amplitude that was approximately proportional to the variation in rod density15 (Fig. 4B). The focal rod b-wave, although generated by bipolar cell activity and Müller cell potentials, appears to serve as an indirect measure of rod photoreceptor density. Similarly, we have shown that the normal focal cone b-wave amplitude profile corresponds to the normal regionalvariation in cone density.16

Detecting Peripheral Retinal Malfunction

Clinical application of this method was illustrated in the testing of our patient with MEWDS, a unilateral,
idiopathic disease with acute onset involving the retinal pigment epithelium and outer retina. This disease results in reduced full-field ERGs and frequently is associated with an enlarged blind spot as in the left eye of this patient (Fig. 5A). With full-field testing, the patient had a 40% reduction in rod and cone ERG amplitudes in the left eye relative to the unaffected right eye, suggesting a retinal abnormality. Focal cone ERG testing revealed subnormal foveal and nasal parafoveal responses in the left eye and normal foveal and nasal parafoveal responses in the right eye. Focal rod ERG testing of the left eye revealed a nondetectable response to 30° diameter flashes in the temporal field (nasal retina) within the scotoma and a normal response to 30° flashes in the nasal field (temporal retina) (Fig. 5B).

**DISCUSSION**

We have described a clinically applicable procedure to isolate focal rod ERGs from the dark-adapted human eye. Focal rod responses can be elicited with bright flashes to generate amplitudes with measurable a-waves and b-waves from areas as small as 10°. This method does not require surround illumination, which may desensitize retina not only outside, but also within, the tested area. The focal nature of the response was shown by the parallel relationship between ERG amplitude and rod photoreceptor density.

Our demonstration that the stray light response from a focal flash can be duplicated by the full-field response from a dimmer flash was anticipated by the
work of earlier investigators,\(^5\)\(^{-7}\) who lacked digital data acquisition and manipulation with which to verify this conclusion. When we presented an uneven full-field flash of light, we found that the resultant ERG could be matched by an ERG elicited by a homogeneous full-field flash of the same mean retinal illuminance. The retina may respond to the space-average illuminance also for stray light gradients.

There may be circumstances in which this method should be applied with special care. For example, if a patient has a regional abnormality of vision associated with a delayed, as well as reduced, focal rod ERG, it might be necessary to determine the full-field response that matches the stray light response based solely on the peak and descending portion of the stray light b-wave. After computer subtraction of the matching response to a full-field stimulus from the response to the focal stimulus, this procedure should uncover the reduced and delayed focal component.

Focal rod ERG testing allowed assessment of retinal function in an area outside the macula corresponding to a visual field defect in a patient with MEWDS. The abnormal focal rod ERG in this area indicated rod malfunction; the normal focal rod ERG outside the scotoma helped to show that the rod malfunction was regional. Our finding of abnormal focal cone and rod ERGs in this patient, as well as reports of abnormal focal cone ERGs in other patients with this condition,\(^9\) suggests that MEWDS involves both rod and cone malfunction.

The capacity to record focal rod ERGs with a-waves and b-waves should provide an added dimension for localizing the site of visual malfunction. Whereas visual field testing does not distinguish outer from inner retinal malfunction and sometimes does not distinguish a retinal from a cortical abnormality, analysis of focal rod a-waves and b-waves should help to define the location of disease. Focal rod ERG testing may prove useful for comparing rod photoreceptor function in different retinal regions of patients with retinitis pigmentosa and allied night-blinding disorders.

**Key Words**

electroretinography, focal, multiple evanescent white dot syndrome (MEWDS), retina, rod

**References**


