Recording the Contralateral PERG: Effect of Different Electrodes

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A pattern electroretinogram (PERG) can be recorded when the eye wearing the electrode is occluded and the stimulus is viewed with the other eye. We find that this phenomenon occurs when an Arden gold foil electrode is used, but not when either an ERG-Jet lens or a scleral lens electrode is used. Therefore, a corneal-type electrode should be used in PERG recording situations where the fellow eye is not occluded. Invest Ophthalmol Vis Sci 24:1514-1516, 1983

Seiple and Siegel demonstrated that a pattern electroretinogram (PERG) can be recorded from an occluded eye when the stimulus is viewed with the other eye. Their interpretation is that a distant potential arising from the unoccluded eye is picked up by the electrode. This artifact could cause interpretive problems in suspected cases of unilateral optic neuropathy. If the normal eye is used for fixation while recording from the affected eye, one cannot be certain that a recorded response is actually from the eye wearing the electrode.

We find that this phenomenon occurs with only one type of electrode. We were able to replicate the previous finding with an Arden gold foil electrode, but not with two types of corneal electrodes: a Riggs-type scleral lens electrode or an ERG-jet lens electrode.

**Materials and Methods.** Two adults with normal vision served as subjects. Prior to the study, informed consent was obtained from both subjects. A phase-alternated checkerboard (7.5 alternations/second) was displayed on a TV monitor at a distance of 75 cm. The monitor could be switched to present a non-synchronized TV program for a noise condition. The screen subtended $16 \times 12.7$ degrees of arc, and the checks were 1 degree/side. This check size was chosen because it is similar to that commonly used for studying normal subjects and patients with known pathologic conditions. The contrast between the light and dark checks was 0.84. Mean luminance was 1.90 log cd/m². Three types of ERG electrodes were used: an Arden gold foil electrode, a Riggs-type scleral lens electrode, and an ERG-jet lens electrode.* The ERG electrode was placed in the right eye and referenced to the left ear; the right ear served as ground. Grass (Quincy, MA) gold-plated earclip electrodes were used as the reference and ground leads. This is the electrode configuration originally used to demonstrate the recording of the distant potential. When the right eye viewed the screen, the left eye was covered; when the left eye viewed the screen, the right eye was covered. The signals were led to a preamplifier (Grass 7P5 A; gain = 20k, band pass set at 1 and 35 Hz). For each trial, 128 stimulus responses were averaged on a Nicolet® Med-80 microcomputer (Madison, WI). The analysis time was 250 milliseconds.

**Results.** Sample waveforms of PERGs obtained from the right eye of one subject with each of the three electrodes are illustrated in Figure 1. The left column shows PERGs recorded using the gold foil electrode with the right eye (top row) and with the left eye (second row) viewing the checkerboard display; the middle column shows PERGs recorded using the scleral lens electrode; and the right column shows PERGs recorded using the ERG-jet lens electrode. The noise condition (bottom row) was obtained with the right eye viewing a non-synchronized TV program and served as a control. The alternation rate of 7.5 alternations/second produces a waveform containing 2 cycles within the 250-millisecond sweep period. All trials were performed with monocular viewing conditions.

The PERG responses were analyzed with a cross-correlational technique described in more detail elsewhere. Briefly, this analysis was accomplished by calculating the cross-correlation between the 1,024 digital points of two ERG waveforms. The cross-correlation was performed without shifting the records as response latency was not expected to vary systematically within an electrode type. Responses from the right eye (electrode) viewing condition were cross-correlated with: (1) replications of the right eye viewing the stimulus (Within), (2) responses when the left eye (no electrode) viewed the stimulus while the right eye (with electrode) was patched (Between), and (3) responses when the right eye viewed the monitor with no checks (Noise). Each of these cross-correlations gives an $r$ value which reflects the similarity between the two PERG waveforms. The overall effect of test condition on these cross-correlation $r$ values was determined using the Kruskal-Wallis one-way analysis of variance by ranks. The difference between the various samples was found to be significant ($H = 106.73$, $df = 8$, $P < 0.001$). On this basis, pairs of conditions (electrode type across correlation type) were tested using the Mann Whitney $U$ statistic. A summary of this analysis follows for the pooled results from one

* The Burian-Allen electrode is one that is commonly used in the clinic to record flash electroretinograms. It does not seem to be suitable for PERG recording because it causes a non-correctable astigmatism. The ERG-jet electrode does not seem to cause an astigmatism, and any resultant blur is easily refracted.

0146-0404/83/1100/1514/$0.95 © Association for Research in Vision and Ophthalmology
Fig. 1. PERGs obtained with the three types of electrodes used. The electrode is always in the right eye. The top row contains PERGs from the right eye (OD) viewing the checkered pattern while the left eye was covered. The middle row contains PERGs from the left eye (OS) viewing the checkered pattern while the right eye was covered. The bottom row contains responses from the right eye (OD) viewing a noise condition (a TV program) with the left eye covered. The analysis time was 250 milliseconds for all records.

OD checks
OS checks
OD noise

Electrode in OD, referenced to left ear

subject. The main results were similar in the other subject.

Using the gold foil electrode, the Within cross-correlations (N = 13, \( r = 0.786 \)) were not significantly different from the Between cross-correlations (N = 25, \( r = 0.652, P > 0.05 \)). With the scleral lens, the Within (N = 6, \( r = 0.827 \)) and Between (N = 16, \( r = 0.470 \)) cross-correlations were significantly different (\( P < 0.01 \)). Similarly, with the ERG-jet lens electrode, the Within cross-correlations (N = 28, \( r = 0.722 \)) were also significantly higher than the Between (N = 56, \( r = 0.296 \)) cross-correlations (\( P < 0.01 \)).

For each electrode, the Within cross-correlations were significantly different than the Noise cross-correlations (\( P < 0.01 \)). However, only the gold foil Between cross-correlation was significantly different from the Noise cross-correlation (N = 18, \( r = 0.310, P < 0.01 \)). The Noise cross-correlations for both the scleral (N = 20, \( r = 0.195 \)) and ERG-jet (N = 24, \( r = 0.189 \)) lens electrodes were not different from the respective Between cross-correlations (\( P > 0.05 \)).

Although not a direct goal of the study, the results also made it possible to compare the Within cross-correlations for the gold foil, scleral, and ERG-jet lens electrodes. The comparison showed that there was no significant difference among the electrodes (H = 3.49, df = 2, \( P > 0.40 \)).

**Discussion.** In agreement with Seiple and Siegel,\(^1\) our cross-correlational analysis shows that a signal recorded from a gold foil electrode in the uncovered right eye (left eye covered) is no different than a signal recorded from a gold foil electrode in the covered right eye with the left eye uncovered. However, we were unable to replicate these findings using two other types of corneal electrodes. The critical difference seems to be whether the electrode is in contact with the cornea or the skin. Seiple and Siegel were able to record a PERG from an electrode attached to the forehead, indicating that a distant retinal potential spreads easily through the skin. This potential may not spread as easily, however, through the cornea because of an insulating layer localized near\(^13\) or at\(^14\) Bowman's membrane. The presence of this insulating layer has been shown based on measurements of the standing potential between an injured portion of the cornea with the uninjured center of the cornea,\(^13\) and from measurements of the ERG between the cornea and a probe entering the retina choroidally.\(^14\) The distant potential from the other eye would have to cross the cornea to be picked up by a contact lens electrode. This insulating layer within the cornea could attenuate this small potential enough to preclude recording it. On the other hand, the potential which is transmitted to the gold foil electrode would not have to pass this barrier, and would be recorded more easily.

Each of the three electrodes we used is equally reliable when the eye wearing the electrode is stimulated and the other eye is covered. However, in some clinical situations, such as unilateral optic neuropathy, the good eye may be used to fixate the stimulus while the affected eye is studied. If a gold foil electrode is used in these cases, a PERG from the normal eye may be recorded and mistaken for one from the affected eye. In such cases, the gold foil electrode is unsuitable. Rather, a corneal electrode, which does not record the PERG from the unaffected eye, should be used. Since the scleral lens electrode is not suitable for routine clinical use, we recommend a commercially available contact
A hallmark of early diabetic retinopathy is the selective loss of the retinal mural cells (pericytes) from vessels. Using antibodies prepared against purified human placental aldose reductase, the presence of the enzyme aldose reductase can be demonstrated immunohistochemically in the cytoplasm of retinal mural cells of trypsin-digested human retinal vessels. This enzyme, which reduces various hexose sugars to their respective sugar alcohols, has been implicated in the pathogenesis of several diabetic complications.

Diabetic retinopathy, one of the leading causes of blindness in the United States, generally is divided into non-proliferative and proliferative forms. Non-proliferative retinopathy is characterized by vascular changes in the retinal capillary bed with formation of microaneurysms, exudates, and intraretinal hemorrhages, while the formation of new vessels and fibrous tissues is seen in proliferative retinopathy. The vascular changes appear to begin with the capillaries which, as seen in Figure 1A, are made up of two types of cells—endothelial cells and mural cells. One of the hallmarks of early diabetic retinopathy is the selective loss of the retinal mural cells, leaving only portions of basement membrane (mural cell ghosts, Fig. 1B) which precedes the appearance of microaneurysms. This selective loss strongly contrasts to the relative persistence of the endothelial cells in diabetic retinas.

While the pathogenesis of diabetic retinopathy remains unknown, we have been exploring the possibility that adverse effects resulting from the aldose reductase catalyzed accumulation of sorbitol may be related to the observed degeneration of retinal mural cells. Aldose reductase (alditol:NADPH oxidoreductase E.C. 1.1.1.21), an enzyme in the sorbitol pathway, has been implicated in the pathogenesis of several diabetic complications. Under hyperglycemic conditions, this enzyme, which utilizes the cofactor NADPH to reduce hexose sugars to their respective sugar alcohols, has been shown to play a significant physiologic role in the production of sorbitol. In diabetic or galactosemic rats, the intracellular accumulation of sugar alcohols...