dus camera with Kodak black-and-white Plus-X film. All photographs are made at 2X magnification, thereby eliminating the need for secondary magnification techniques. Finally, all observations are made from the black-and-white transparencies rather than from black-and-white prints.

Optimum observation of the ocular fundus depends on the contrast that is produced when maximum illumination is combined with an optimum filter. The tungsten-filament vacuum lamps used in most older, less powerful direct ophthalmoscopes produce uneven illumination across the visible spectrum, with significantly reduced luminance in the lower end of the spectrum (400 to 550 nm) than in the higher end (Fig. 1). For this reason, light produced by these lamps appears more yellow than true white light (sunlight), and filters that absorb light in the red spectral region cause a marked reduction in total fundus illumination, making observation of critical fundus details impossible. Since the luminance of any bulb is dependent on its color temperature, raising the color temperature of the bulb will increase its total luminance, particularly across the lower end of the visible spectrum.

Color temperature, defined as the absolute temperature of a blackbody that has the same chromaticity as that of the light source under consideration, can be raised by either increasing the voltage used to power the light source or changing the nature of the light source itself. Recently, halogen (iodine) and inert gases (krypton, xenon) have been used in the tungsten-filament ophthalmoscope bulbs, replacing the previous vacuum-type bulb. The color temperatures of these bulbs are significantly higher than that of the vacuum bulb, resulting in an increased luminance across the entire visible spectrum, particularly in the lower end (Fig. 1). Increasing the power source of the ophthalmoscope to 4.5 V raises the color temperature of the gas-filled bulbs even higher, providing increased illumination and permitting optimum use of a monochromatic filter (Fig. 2). At present, we prefer a gas-filled (halogen or krypton) tungsten bulb in a direct ophthalmoscope with a 4.5 V power source; however, a different light source with an intrinsically higher color temperature, rather than a power boost, may ultimately provide optimum observation of the PRNFL in the future.

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Electroretinography with noncorneal and corneal electrodes. Julian Frederick Giltrow-Tyler, Sydney James Crews, and Neville Drasdo.

The noncorneal ERG is essential for certain patients in which corneal recording is contraindicated. A prelimi-
A report is presented investigating ERGs from three noncorneal montages and their correlation with the corneal ERG. Statistical analysis showed that an electrode at the medial canthus combined with medial viewing gave the closest correlation to the corneal ERG. Repeatability was good for all montages. The inner canthus electrode was considered preferable for noncorneal recording because it was less affected by other time-locked activity; it correlated well with the corneal ERG and can be used in conjunction with the electro-oculogram.

The electroretinogram (ERG) may be recorded from many noncorneal sites, but these are rarely used because contact lens electrodes produce large, relatively noise-free, and easily displayed responses. The noncorneal ERG is advantageous in certain patients: the old, very young, nervous, and those with inflamed or compromised anterior segments.

Electroencephalogram (EEG) type electrodes are favored for noncorneal recording because they are relatively comfortable and easy to apply and require no anesthesia.

There are little normative data concerning the noncorneal ERG and its relationship to the conventional ERG, and we believed it worthwhile to investigate three montages proposed by previous authors.

Method. Nine healthy volunteers (six men and three women) with ages 18 to 28 years (mean 21) were used in this study. None suffered from any retinal disorder, and only one was myopic (−6.00 D). Pupils were not dilated because of their natural large size in mesopic conditions. In all cases the right eye was studied and the left eye patched.

Noncorneal ERG. Three EEG silver/silver chloride stick-on cup electrodes and one earclip electrode were used, the non-corneal electrodes being sited as shown in Fig. 1. The montages chosen were based upon those recommended by previous investigators: lower lid,1 medial canthus, lower lid,2 and medial and lateral canthi.3 The line of sight was directed to place the cornea near the active electrode.

When the lower lid and inner canthus electrodes were applied, the adhesive discs were cut tangentially so that the electrodes could be positioned as close to the cornea as possible without causing irritation, as previously indicated by Berry.4 The skin's resistance was reduced to below 10 KΩ whenever possible, the epidermis being abraded with a blunt syringe needle if necessary. (It was not always possible to reduce the lower lid electrode resistance to 10 KΩ, however, less than 20 KΩ was always managed.)

The subject viewed an opalescent screen at 50 cm, subtending a visual angle of 45°. The integrated luminance of each flash was 12 nit-seconds. The screen was retroilluminated by a xenon flash. When recording montages two and three (Fig. 1), subjects were asked to turn their heads slightly to the right and view the screen across the bridge of the nose, the nose cutting off the visual field just to the left of the screen and fixation being the center of the screen. This resulted in the cornea being as close to the inner canthus electrode as possible.

When the subjects were relaxed, the responses to 32 flashes of light at 550 msec intervals were processed by a Unimac averager and recorded on a Bryans XY26000 plotter. Low pass filters (3 db down at 50 Hz) and a time constant of 0.3 sec were employed.

![Fig. 1](http://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/933309/ on 05/07/2018)
Ten sets of results were recorded from each subject for each montage to check signal reproducibility, the means of these results were used in later analysis.

Corneal ERG. A Henke’s contact lens electrode was referred to the ipsilateral ear electrode, and an electrode at the medial canthus was earthed. The ear was used as a reference because it is considered to be the least active cephalic reference site. Subjects were dark-adapted for 5 min and exposed to four single-flash stimuli at 1 min intervals. The mean of the four results was calculated.

Results. The lower lid electrode always produced a larger signal than the nasal electrode even with medial viewing, i.e., lower lid 62.77 ± 16.52 μV, nasal electrode 40.46 ± 9.20 μV, but this tended to be associated with greater interindividual variation (see below).

The relationship of noncorneal ERG to corneal ERG was considered to be of major importance, and the results are shown graphically in Fig. 2. Montage 2 had the highest noncorneal:corneal correlation (r = 0.848; p < 0.01) and the smallest y intercept for a projected noncorneal ERG value of zero. Montage 1 correlated less well but was still significant at the 0.05 level (r = 0.736). The y intercept in montage 1 was 70% higher than in montage 2, indicating that the response was possibly subjected to other external influences.

Montage 3 correlated well (r = 0.805; p < 0.01) but showed the highest y of 171 μV, some 100 μV above that for montage 2.

The noise level was recorded in all subjects with a nonstimulus control; in no case did it exceed 1% of the b-wave amplitude after averaging.

Discussion. The placing of the reference electrode at the outer canthus (montage 3) increased the coefficient of variation (V) of the response (Fig. 2). It has been shown that the ERG at the outer
canthus can be quite variable, with polarity reversal of the a-wave and no clear reversal of the b-wave. This could be accounted for by the dipole characteristics of the eye, with anterior and posterior positions having opposite polarities. With the eye in medial gaze, the outer canthus electrode might lie anterior to or posterior to the isopotential axis of the dipole field.\textsuperscript{5, 6}

The positive y intercept (Fig. 2) can possibly be explained as an interaction between the ERG and one or more of the following artifacts:

1. The myoclonic blink reflex to high-intensity light. This triphasic response has a peak latency of 70 to 80 msec and is present in many normal subjects. Its effect is reduced with lower flash intensities and higher rates of stimulation.\textsuperscript{6} Allison et al.\textsuperscript{7} recorded a similar positive peak at the outer canthus with a latency of 65 msec.

2. The blink reflex. This has a longer latency (about 130 msec) than the myoclonic reflex and only affects the later parts of the ERG. It also is described by Allison et al.,\textsuperscript{7} and the possibilities of its myogenic origin are discussed.

3. The "override artifact." The override artifact\textsuperscript{8} or an increase in conductivity can occur if the palpebral aperture is narrowed. If the narrowing is due to reflex activity time-locked to the stimulus, any spurious transients which might result would be included in the averaged signals. This effect has been noted only on vertically oriented electrodes.

These effects probably increase the potential on the lower lid and outer canthus electrodes more than on the inner canthus electrode which is sited over the medial palpebral ligament. However, this electrode is probably affected to some extent by the potential field generated by activity in adjacent structures.

A recording from a subject exhibiting two large potential changes independent of the ERG is shown in Fig. 3, a. The first artifactual peak occurs at 65 msec, 15 msec after the b-wave, and would appear to be the myoclonic reflex. The second peak occurs at about 100 msec and is probably related to the blink reflex. Fig. 3, b, is a clear trace from another subject showing no signs of contamination from these sources.

Eight subjects were checked 6 weeks later to see whether the results were repeatable. All montages showed high repeatability ($p < 0.01$), with montage 1 proving to be the most consistent ($r = 0.980$). Montage 3 was the least reproducible ($r = 0.914$), and montage 2 fell between the two ($r = 0.937$).

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**Key words:** electrotinogram, pH ERG, periorbital, noncorneal, corneal, skin comparison, validation

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