An Electrical Artifact Associated With the ERG-Jet™ Gold Foil Electrode

Peter L. Gehlbach and Richard L. Purple

Purpose. To examine a photoelectric artifact associated with the ERG-jet™ corneal contact lens electrode (Universal SA, La Chaux-de-Fons, Switzerland).

Methods. An artifact associated with the ERG-jet™, gold foil corneal contact lens electrode was reproduced in vitro and in vivo using 50 msec light flashes. In vitro responses were examined using light flashes that varied in intensity, duration, and wavelength. Ionic strength of the bathing solution and temperature dependence were also examined. In vivo responses were compared to similarly recorded signals using the Burian-Allen bipolar electrode.

Results. The artifact is not apparent with microsecond light flashes, as with the Grass PS22 Photo-stimulator connected to a Ganzfeld. Longer light flashes and increasing light intensities, however, elicit graded responses that may resemble the late PHI component of the ERG in profile and in magnitude. The artifact varies with temperature, ionic concentration of the bathing medium, and wavelength of stimulating light. The artifact also varies in magnitude and polarity from one disposable electrode to the next. Light flashes of shorter wavelengths elicit greater responses than light flashes of equal radiant energy but of longer wavelengths.

Conclusions. The artifact derives from electrode polarization occurring at the interface between the gold foil and its ionic medium. Caution is required when using light stimuli longer than 2-3 msec with this and similar types of intrinsically polarizable metal electrodes. Invest Ophthalmol Vis Sci. 1993;34:2596-2599.

Materials and Methods. The artifact was originally detected with the electrode positioned on the eye. Because the response was more easily reproduced in vitro, extended studies were carried out in a 150-ml beaker of 0.9% saline solution at room temperature. ERG-jet™ electrodes were used directly from the package with minimal handling. Twelve successive electrodes were sampled, and all produced artifacts of similar waveform, although the amplitude and polarity varied unpredictably between electrodes. Larger amplitudes were always produced when the light stimulus was aimed at the corneal side of the electrode where the exposed gold foil was in direct contact with the ionic solution. The electrode was connected via a standard Grass HIP511R preamplifier to a Grass P511G amplifier (Grass Instruments Co., Waltham, MA). Amplifier low- and high-frequency settings were 0.1 Hz and 3.0 kHz, respectively. The indifferent electrode was either a chlorided silver wire electrode or another ERG-jet™ electrode shielded from the light stimulus. The ground electrode was a chlorided silver wire electrode. Amplified signals were displayed on a Tektronix 5111 Storage Oscilloscope (Tektronix, Inc.).
Reports 2597

Beaverton, OR). Stored signals were photographed, and measurements were made from the prints.

Flash stimuli were provided by a standard optical bench containing a 100-watt tungsten-iodide light source (#6321, Oriel Co., Stratford, CT), heat, and ultraviolet filters (Melles Griot, Glencoe, NY), a 5-log unit, calibrated, 6-inch-crossed iconel wedge set (Eastman Kodak, Rochester, NY), a Uniblitz shutter (Vincent and Associates, Rochester, NY), and focusing lenses suitable to direct the light beam onto a fiberoptic cable (#77533, Oriel Co., Stratford, CT). A Tektronix J-16 Photometer measured peak white light at the ERG-jet electrode at 5.2 log (cd/m²). Wavelength dependency of the artifact was studied using metal interference filters with approximately 10-nm, half-amplitude pass bands (Ditric Optics, Hudson, ME).

Tenets of the Declaration of Helsinki were followed in the use of the human subjects reported here, informed consent was obtained, and approval was granted for their use by the University of Minnesota’s Committee on the Use of Human Subjects in Experiments.

RESULTS. Figure 1 illustrates a set of typical artifacts generated by light flashes of constant duration and increasing intensity (Fig. 1A) or by by flashes of constant intensity but increasing duration (Figs. 1B and 1C). A minimum flash duration of 2–3 msec was required to generate the artifact at maximal stimulus intensity (Fig. 1C). Our highest intensity flashes, when less than 2 ms in duration, did not elicit the response, nor did standard Ganzfeld stimulation with μsec flashes from a Grass PS 22 xenon flash tube.

The artifact was generally of negative polarity. Its greatest observed amplitude was 900 μV at the highest flash intensity, with a flash duration of 100 ms and the light directed at what would normally be the corneal surface of the electrode. On occasion, the polarity of the response was positive or even biphasic. It was our impression that this occurred when the light beam was directed at the foil–wire junction. This reversal of polarity could not be reliably reproduced, however, and we are left to describe it as unpredictable.

Figure 2A illustrates the temperature dependence of the response. There is a linear, inverse relationship

![Figure 1](https://example.com/figure1.png)

**FIGURE 1.** (A) Graded electrical response of ERG-jet™ electrode exposed to light flashes of increasing intensity, with a constant flash duration of 100 ms. Minimum flash intensity (top trace) was 3.25 log (cd/m²). Maximum flash intensity was 5.2 log (cd/m²). (B) Graded response of an ERG-jet™ to progressively longer flash duration at a constant flash intensity of 5.2 log (cd/m²). (C) Artifact’s appearance with short, high-intensity stimuli. All traces were produced by a flash of 5.2 log (cd/m²) intensity, with a 1-, 2-, 3-, and 4-ms duration (upper trace to lower, respectively).
between the log of the response in μV and temperature expressed in degrees Kelvin. Fig. 2B documents the artifactual response to two different wavelengths of light. Flashes of light at 480 nm elicit greater responses than light flashes at 560 nm of equal radiant energy. This implies that the size of the artifact is dependent on individual photon energies. In Fig. 2C, the ionic strength of the bathing solution clearly has an effect on the amplitude of the response. Saturated NaCl decreases the magnitude of the artifact compared to either a 0.9% saline solution (intermediate amplitude) or to distilled water (largest amplitude). All solutions were maintained at 22°C.

The net charge disturbance from one electrode was measured by placing it in series with a 1 MΩ resistor and using light flashes of maximal intensity. Current was $0.76 \times 10^{-9}$ amperes. Total charge transfer over 50 ms was $38 \times 10^{-12}$ coulombs.

Controls ensuring that the artifact depended upon the gold foil were carried out. The electrode was sequentially dismantled and exposed to 100-ms flashes of the highest intensity light. Removing the plastic corneal lens did not affect the artifact significantly. Removing gold foil from the lens attenuated the response, but a significant signal could be recorded as long as a small amount of gold remained attached to the wire. Removing the remaining gold foil from its wire juncture abolished the response. The bare connecting wire did not produce a measurable artifact.

Figure 3 demonstrates the effect of a small 50-μV artifact on both a normal ERG and on the ERG of a patient with severely depressed responses. Fig 3A is a recording of the isolated 50-μV artifact. In Fig. 3B the bold trace is a normal, photopic, 50-msec flash ERG, whereas the thin trace is the same ERG recorded with an ERG-jet™ electrode. The more negative a- and b-waves are documented. The effect of even this small artifact is noticeable in a severely depressed ERG (Fig. 3C). The bold trace ERG is artifact free, whereas the thin trace contains the ERG-jet™ artifact. In recordings on this order of magnitude, differences in waveform appear to be significant. Additionally, differences in latency become pronounced. Recordings with electrodes producing larger artifacts further distort the data and are not so subtle that they would be missed.

DISCUSSION. Photovoltaic artifacts continue to contaminate ERG recordings, even though slow polarization effects resulting from the use of nonchlorided, polarizable metals have been minimized by the use of AC-coupled amplifiers and bipolar recording systems. It is important to note that rapid polarization phenomenon may not be excluded by the typical [fr1/2] amplitude low-pass settings (1–3 Hz) of AC, ERG amplifiers. This problem has been variably addressed. Sandberg et al. have subtracted from their recordings a digitalized, scaled replica of an arti-
FIGURE 3. (A) 50 μV ERG-jet™ artifact. (B) Bold trace: normal photopic 50-ms flash ERG recording made with a Burian-Allen bipolar electrode. Thin trace: same recording with the ERG-jet™ electrode. (C) Bold trace: severely depressed photopic ERG from a patient with autosomal dominant retinitis pigmentosa and recorded with a Burian-Allen bipolar electrode. Thin trace: same recording with the ERG-jet™ electrode.

fact generated by the Burian-Allen contact lens electrode. Berson and Goldstein7 and Fuller et al8 have shielded the metal electrode from light and made corneal contact via a saline bridge contained in a flexible tube. Similarly, Sieving et al8 have modified the Burian-Allen electrode such that an appropriately shielded silver-silver chlorided wire electrode is attached to a wick that contacts the cornea.

The ERG-jet™ gold foil electrode incorporates an inherently polarizable gold foil into its construction. Photovoltaic phenomena are somewhat reduced by virtue of a design that minimizes the amount of light incident upon the cornea side of the electrode, that is, the gold surface in ionic solution. The approximately 1 logarithm increase in artifact amplitude seen when light is flashed directly onto the exposed gold foil in solution versus that seen when the light beam is directed at the outer convex side of the electrode illustrates the relative importance of the requirement for the polarizable surface to be in an ionic solution at the time of light exposure.

This artifact, though variable, is reproducible, and it underscores the need for caution when employing electrodes that are inherently polarizable. This is particularly true for DC recording conditions, and it is also true for AC recording conditions in which the light stimuli may be a few ms in duration, as they are when photopic b- and d-waves are separated. We emphasize again that light flashes of 2 msec or more are required to generate the artifact reported here. Standard clinical electroretinography, as conducted with Ganzfeld domes and most brief (μsec) flashes, as recommended by the International Standards Committee, should not produce this artifact.

Key Words
photovoltaic artifact, ERG, gold foil electrode, electrode polarization, photoelectric effect

Acknowledgments
We thank Alan Goldman, Professor of Physics, and Jurgen Fohlmeister, Associate Professor of Physiology, both of the University of Minnesota, for valuable discussions and tutorials regarding the physics of this artifact.

References