
Corneal electrodes useful for clinical electoretinography require topical anesthesia, interfere with vision, can abrade, and are not well accepted by most children and many adults. A low mass conductive thread, corneal (DTL) electrode is described and comparatively tested against the Burian-Allen electrode. The DTL electrode was found to have few of the limitations of the hard contact lens electrode. Furthermore, the DTL electrode signal quality was comparable to that of the Burian-Allen electrode and provided less between-patient variability.

The clinical value of electoretinography has been described by Krill and Fishman. Both writers report the use of the Burian-Allen corneal electrode, which is widely accepted in the United States and is discussed, along with several other electrode types, in a recent review by Rigg. Numerous other methods have been described in the literature. Signal variation with recording site of the noncorneal electrode, described first by Armington and Tepas, has been analyzed by Giltrow-Tyler et al. A particularly interesting and stable electrode which is usable with DC potentials was first described by Knave et al. and has figured in several publications on the low-frequency components of eye potential changes since that time. Patient comfort is improved where lid "hook" electrodes are used, but electoretinogram (ERG) amplitudes were consistently reduced relative to a corneal electrode.

Many of the problems associated with the Burian-Allen electrode have been solved in our clinic since we began using soft contact lens cushions between the cornea and the standard Burian-Allen lens. However, even this modification requires corneal anesthesia and results in an occasional corneal or conjunctival abrasion in agitated patients with exaggerated eye movements. We also find that corneal electrodes like the Burian-Allen are poorly accepted by children. This paper describes our experience with a new electrode which measures electrical potentials from the cornea and which appears to have few of the difficulties commonly associated with clinical use of contact lens electrodes.

Materials and methods. Our electrode (the DTL electrode) is based upon an extremely low mass conductive thread which makes contact between the tear film of the eye and an adjacent stranded, insulated electrical wire. The thread consists of a 2 cm length of spun nylon fibers impregnated with metallic silver by a proprietary method. The individual fibers are 12 μm in diameter, and the spun thread consists of three to six fibers. The fibers are manufactured under the trade name X-Static by Rohm & Haas Co. of Philadelphia, Pa. A practical DTL corneal electrode is pictured in Fig. 1. The loosely spun conductive fibers were woven between the spread strands of the tip of a piece of 24-gauge copper electronic "hook-up" wire with vinyl insulation. After the conductive thread was woven into the strands, the joint was covered with a conductive epoxy and subsequently insulated with a fast drying epoxy. DC resistance of the DTL electrode thread is approximately 100 ohms/cm. At 1 to 2 cm from the thread-wire junction, a plastic support button was attached with epoxy to the vinyl insulation of the hookup wire. The remaining hookup wire was terminated in a connector which allowed the electrode to be attached to our usual ERG junction box, in place of a Burian-Allen electrode. We find that the DTL electrode may be autoclaved or gas-sterilized without resistance change. Marked resistance changes do occur if the electrode is cleaned in alcohol.

For recording potentials, the DTL electrode support button is attached with adhesive to the skin near the outer canthus. The dry conductive thread is of such low mass that it floats in the air currents and must be "captured" before it can be placed upon the cornea. (We use a small plastic or
Fig. 1. DTL electrode, connecting wire tip, and conductive thread. The thread shown consists of six conductive fibers.

Table I. Average b-wave amplitudes (microvolts) from ERGs recorded simultaneously from the DTL and BA electrodes for two subjects (W. W. D. and G. L. T.)

<table>
<thead>
<tr>
<th>Condition (ft-lambert)</th>
<th>G. L. T.</th>
<th>W. W. D.</th>
<th>G. L. T.</th>
<th>W. W. D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.1, flash; 15, background</td>
<td>73.70</td>
<td>68.05</td>
<td>92.58</td>
<td>56.73</td>
</tr>
<tr>
<td>9.2, flash; 15, background</td>
<td>(6.3)*</td>
<td>(15.6)</td>
<td>(8.6)</td>
<td>(6.6)</td>
</tr>
<tr>
<td>2.9, flash; 15, background</td>
<td>36.25</td>
<td>34.18</td>
<td>40.13</td>
<td>26.95</td>
</tr>
<tr>
<td>2.9, flash; 4, background</td>
<td>15.23</td>
<td>22.05</td>
<td>12.10</td>
<td>14.35</td>
</tr>
</tbody>
</table>

*Values in parentheses are ± 1 S.D. calculated from individual b-wave measures.
† Individual b-waves were too small for accurate measurement.

wire rod which is shaped like a shepherd’s staff.

The crooked area is moistened with an artificial tear solution, with or without methyl cellulose. When this is touched to the DTL electrode fiber, the fiber remains attached by surface tension. With the assistance of an optical loupe, the fiber may be stretched above the cornea of the open eye. As the shepherd’s staff is moved toward the nose, the wetted electrode disengages and drops onto the surface of the cornea. We find that it cannot be seen or felt by the patient. The fiber then floats upon the surface film of the eye and is only disturbed a little by blinking. When tearing is also present, it may be washed out of the eye. Occasionally the DTL electrode thread finds its way into the conjunctival sac beneath the lower eyelid. This does not usually happen unless a thread of fewer than three fibers is used. It still records large potentials when in the sac and remains undetected by the patient. To record potentials after the DTL electrode fibers are in position on the cornea, a standard silver–silver chloride electrode is attached adjacent to the button at the outer canthus, and attachments for both electrodes are provided to the preamplifier. The ground site is attached by a silver–silver chloride button electrode paste at the center of the forehead.

ERGs were recorded as previously described by Dawson et al.* Two subjects with clinically normal vision were studied at two levels of background illumination. For the brighter background level (15 ft-lamberts), three flash intensities were used (29.1, 9.2, and 2.9 ft-lamberts), whereas for the less intense background (4 ft-lamberts), only one flash intensity (2.9 ft-lamberts) was used. The electrical responses were recorded on FM tape with an overall passband of 0.1 to 1.0 kHz (–3 db points). A separate FM channel was used to record potentials from a standard Burian-Allen electrode.
Fig. 2. ERG signals from DTL and Burian-Allen (BA) electrodes recorded simultaneously. Data are from two subjects (upper and lower). We present results for two background levels (A and B, 15-ft lamberts; C, 4 ft-lamberts) and two stimulus intensities (A, 29.1 ft-lamberts; B and C, 2.9). The center ERG record of each set is the mean, above and below are ±1 S.D. Calibrations for time and amplitude of all records are shown in lower Fig. 2. Examination of Fig. 2 shows that the only clear difference in these sets of simultaneously recorded ERGs was the presence of a somewhat larger late potential (negative peak at about 175 msec) for the DTL electrode. These appeared to be blink artifacts which were associated primarily with movement of the upper lid. They were more pronounced in some subjects than others. Giltrow-Tyler et al. reported similar artifacts in ERGs recorded from electrodes positioned on the skin adjacent to the eye. However, their ERG signals were several times smaller in magnitude than those recorded with the DTL electrode.

Table I summarizes the amplitude results for simultaneous records of ERG b-waves recorded from the DTL and Burian-Allen electrodes. B-waves were measured from the most negative portion of the a-wave to the most positive portion of the b-wave. There was not consistent amplitude variation due to electrode type. The between-subjects variation for the DTL results was reduced.

Discussion. The now-standard corneal contact lens ERG electrodes have numerous limitations. Among these are failure to fit most patients well, production of optical aberrations, conjunctival or corneal irritation, a tendency to abrade the cornea or conjunctiva, and poor patient acceptance (particularly with children). Our recent clinical use of the DTL electrode suggests that it has few of these problems. Furthermore, it is relatively inexpen-
sive, is disposable, and may be readily sterilized. Stodtmeister and Wilmanns have recently explained that a degree of variability in ERG response may be a consequence of coating agent variation between laboratories and patients. Numerous foreign fluids such as artificial tears, methyl cellulose, and anesthetics are required when corneal contact lens electrodes are used. The DTL electrode requires no additional fluids, therefore at least partially circumventing this problem. Consistency of the conductive medium may account for the reduced between-subject variability which we find in recordings from the DTL electrode (Table I). We will supply investigators with small samples of the conductive thread used in the DTL electrode in exchange for information on recording performance and patient acceptance.


Key words: human electroretinography, contact lens electrodes, photopic, b-wave amplitude, b-wave variability

REFERENCES


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