Chair-side Reference: Electrophysiology

Electrophysiological tests may be considered in cases of: unexplained vision loss, symptoms and/or family history suggestive of an inherited eye disease, and use of potentially retinotoxic medication. These tests are not primary tests but are performed on indication based on the results from an initial assessment typically consisting of imaging and functional tests.

<table>
<thead>
<tr>
<th>Electro-oculography (EOG) – assessment of retinal pigment epithelium function</th>
<th>Clinical applications</th>
<th>Abnormal results and associated conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technique</strong></td>
<td><strong>Clinical applications</strong></td>
<td><strong>Abnormal results and associated conditions</strong></td>
</tr>
<tr>
<td><strong>An eye movement generated voltage recorded by placing electrodes either side of the eyes.</strong></td>
<td><strong>Mainly useful for subretinal diseases:</strong> Arden ratios:</td>
<td><strong>Typical patterns of loss</strong></td>
</tr>
<tr>
<td><strong>Created by the corneofundal potential (aka standing potential: the cornea is 6-10 µV positive relative to the RPE.)</strong></td>
<td>&gt;2.0 generally normal</td>
<td><strong>Mainly used for Best disease however other conditions that involve the RPE will also show abnormal responses.</strong></td>
</tr>
<tr>
<td><strong>The corneofundal potential:</strong></td>
<td>1.5 - 2.0 borderline</td>
<td></td>
</tr>
<tr>
<td>1. Mainly derived from the RPE.</td>
<td>&lt;1.5 generally abnormally low</td>
<td></td>
</tr>
<tr>
<td>2. Changes in response to background levels of retinal illumination</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Results are collected under scotopic and photopic conditions.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Usually expressed as light/dark or Arden ratio.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A ratio of the maximum (peak) amplitude in the light (LP) to the minimum (trench) amplitude in the dark (DT)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An EOG in a healthy individual showing an obvious light peak (Arden ratio of 2.58)

**Full-field electroretinography (ERG) – assessment of the function of photoreceptors and cells in the inner nuclear layer of the global retina**

**Records the massed electrical response of the retina to a flash of light.**

- **The waveform of a typical full-field ERG has:**
  - Initial negative a-wave: Photoreceptors (receptor potential)
  - Positive b-wave: ON-bipolar cells
  - Oscillatory potentials (smaller waves): Amacrine cell activity

- **There are two broad categories of full-field ERG:**
  - Light-adapted (photopic) ERG
    - Flash and 30Hz Flicker
  - Dark-adapted (scotopic) ERG
  - 3 flash brightness levels and oscillatory potentials

**Widely used for the differential diagnosis of conditions including:**

- Inherited retinal disease
- Retinal vascular disease
- Opaque media or trauma
- Unexplained visual loss
- Infant assessment
- Albinism
- Toxic and nutritional eye disease

**Typical patterns of loss**

**Retinitis pigmentosa (RP):** Scotopic ERG is more reduced compared to photopic ERG with both worsening with time.

**Cone dystrophy:** Photopic ERG is reduced.

**Cone-rod dystrophy:** Photopic ERG is more reduced than scotopic ERG.

**Choroideremia:** Scotopic ERG is more reduced compared to photopic ERG in the early stages with both worsening with time.
**Visually evoked potentials (VEP)**—assessment of the integrity of the visual pathway from the eye to the occipital cortex

- Generated by the occipital visual cortex in response to stimulation of the retina by either light flashes or pattern stimuli using different check sizes
- If abnormal, cause can be located anywhere between the retina and the cortex.
- Typical waveform of the pattern-reversal VEP consists of N75, P100, and N135 peaks (correspond to milliseconds)
- Analysis primarily looks at the peak time and amplitude of P100

**Pattern ERG may be useful in:**
- Retinal vascular disease
- Unexplained visual loss
- Toxic and nutritional eye disease
- Stargardt disease
- Cone dystrophies
- Macular dystrophies
- Hydroxychloroquine (Plaquenil) retinopathy
- Glaucoma
- Optic neuropathies
- Primary ganglion cell diseases (e.g., Leber Hereditary Optic Neuropathy [LHON] and Kjer-type dominant optic atrophy [DOA])

It is also used when pattern VEP is abnormal to determine the location of the abnormality (ie central retinal or optic nerve)

- A normal pattern VEP
- Peak of P100 should occur at or near 100 ms
- Mainly used to confirm the diagnosis of optic neuropathy and other demyelinating disease
- Other uses include but not limited to:
  - Unexplained visual loss
  - Toxic and nutritional eye disease
  - Suspected intracranial lesion

**Typical patterns of loss**
- Stargardt disease
  - P50 reduction
- Optic nerve demyelination
  - mainly N95 involvement
- Acute optic neuritis
  - Reduced P50 which usually recovers within a few weeks
- Ischaemic optic neuropathy
  - more frequently P50 involvement
- Lebers Hereditary Optic Neuropathy
  - Normal P50 but very poor N95 (at acute presentation)
- Kjer-type dominant optic atrophy
  - N95 reduction

**Typical patterns of loss**
- Reduction in waveforms correspond to the retinal locations of the pathology
- 1. Cone and Cone-Rod dystrophies - reduced or undetectable
- 2. Hydroxychloroquine (Plaquenil) retinopathy - decreased parafoveal waveform amplitudes
- 3. Stargardt disease - depressed foveal peak
- 4. Best disease - often abnormal with amplitudes correlating to visual acuity

**Pattern ERG in Stargardt disease**
- Reduced P50 and N95 amplitudes.

**Pattern ERG in Acute Optic Neuritis**
- Normal P50 but very reduced or undetectable N95

**Pattern ERG in Optic Nerve Demyelination**
- Reduced P50 which usually recovers within a few weeks

**Pattern ERG in Ischaemic Optic Neuropathy**
- P50 reduction

**Pattern ERG in Leber Hereditary Optic Neuropathy**
- Normal P50 but very poor N95 (at acute presentation)

**Pattern ERG in Kjer-type dominant optic atrophy**
- N95 reduction

**Visual evoked potentials (VEP)**—assessment of the ganglion cell and central retinal function

- A local retinal response evoked by a contrast-reversing pattern (black and white checkerboard)
- Arises largely in the ganglion cells
- Two major components:
  - P50: related to ganglion cell and partially pre-ganglionic activity
  - N95: related to ganglion cell function (numbers correspond to milliseconds)

- Electroretinography (mfERG)
  - Multifocal ERG stimulus with 61 hexagonal elements (adapted from Hood et al 2012)
  - Provides a topographical assessment of retinal function by testing local retinal function
    - Typically 61 or 103 locations (40-50°)
  - Recorded from the cone system by stimulating the retina with an array of hexagons
  - Largely influenced by bipolar cells with some contribution from photoreceptors and inner retinal cells
  - Each individual waveform is not an individual ERG waveform but a mathematical extraction from a single continuous ERG recording.

- A normal pattern ERG
- A normal multifocal ERG
- A normal pattern-reversal VEP

**Electrode locations (adapted from Odom et al 2010)**

**Electrode locations**
Chair-side Reference: Electrophysiology

This chair-side reference was designed to assist optometrists in private practice when interpreting results from electrophysiological tests covered by the ISCEV Standard. It provides general information only and does not include non-standard electrophysiological tests.

Disclaimer: Although every care has been taken to ensure that this document is free from any error or inaccuracy, CF EH does not make any representation or warranty regarding the currency, accuracy or completeness of these Guidelines.

Abbreviations

- EOG: Electro-oculography
- RPE: Retinal pigment epithelium
- PR: Photoreceptors
- BC: Bipolar cells
- AC: Amacrine cells
- GC: Ganglion cells
- ERG: Electroretinography
- ISCEV: International Society for Clinical Electrophysiology of Vision
- VEP: Visually evoked potentials

Acknowledgements

The schematic retinal presentation figure is adapted from Figure 1 in Whatham AR and Nguyen V et al. The value of clinical electrophysiology in the assessment of the eye and visual system in the era of advanced imaging. Clinical and Experimental Optometry 2014;97:99-115

References

4. Holder GE. Pattern Electroretinography (PERG) and an integrated approach to visual pathway diagnosis. Progress in Retinal and Eye Research 2001 Vol. 20, No. 4, 531-561