Electroretinogram is the electrical potential generated by the retina to a flash of light.

The first ERG recording was in frog eyes by the famous physicist Professor Frithiof Holmgren in 1870 and the birth of human ERG was in 1877 by the physicist Dewar.

The response obtained from the retina to a flash of light is a gross potential and is contributed by the various component cells of the retina. This information can be more defined and can be attributed to the functions of the individual retinal cells by altering the stimulus parameters and the patient's adaptive states.

Major indication for an ERG recording is to assess the retinal functional status where a definitive conclusion is impossible by clinical evaluation alone, example – inherited retinal dystrophies, retinal vascular disorders, unexplained visual loss, opaque media, trauma etc.

Main contributors of ERG in retina are the radially oriented neurons (photoreceptors, bipolar cells) and glial cells (muller cells, retinal pigment epithelial cells). The irregularly and laterally arranged cells (horizontal cells, amacrine cells) are minor contributors.

Chemical changes in and around the retinal cells responsible for ERG.

Flash ERG is a mass response of the neural and nonneural elements of the retina. The initial action of the light is a phototransduction cascade, a set of biochemical changes initialized by the photoreceptors, rods being the major contributors due to their abundance. The photoreceptors then signal to the bipolar cells, the rods and short wavelength cones to the ON bipolar cells and the medium and long wavelength cones to both the ON (depolarizing) and OFF (hyperpolarizing) bipolar cells. Spatial buffering of (K+) by the radially oriented muller and retinal pigment epithelial cells are also contributors to the ERG recordings.

Instrument

Parts of the instrument.

(Pictures given below are of the Tomey Technology and vision EP-1000 PC)

Illumination – Includes the background illumination and the stimulus.

The background illumination is provided by a ganzfield bowl (Figure 1) which provides uniform illumination of 17-34 candelas per meter squared and has three to five light emitting diodes which helps in accurate fixation.

Stimulus - The standard stimulus is one which produces stimulus strength of 1.5-3 cd/m2 at the surface of the ganzfeld bowl. Stimulus strength can be attenuated over a range of at least 3 log units without altering the wave length.

Electrodes

Mainly 3 electrodes are used

1. Active electrode can be

a) Corneal contact lens which is centrally transparent with a large optic opening. Disadvantage being frequent repositioning, discomfort to the patient and expensive.

b) Non-contact lens electrode which is in contact with the lower cornea or bulbar conjunctiva. These include gold foil, DTL – fibre; (commonly used, silver particles- fig 2), H-K loop and the LVP Zari electrodes which was invented at LVPEI and uses zari embroidery thread. ( DT electrodes are shown in Figure 2)

2. Reference electrode

Placed at the outer canthus for unipolar electrodes(Figure 3).
Ground electrode can be placed on the forehead or ear lobe (Figure 3)

All ERG skin electrodes need very good contact, hence scrubbing of the site with an abrasive and use of appropriate conductive pastes or gels (Figure 4) is recommended.

The impedance of the skin electrodes is manufacturer specific and generally the surface electrode impedances should be equal and <5K (Figure 5).

**Patient preparation**

Pupils are maximally dilated and their size recorded. Dark adaptation for at least 20 minutes is required and the electrodes can be placed under dim red illumination at the end of this period. The patient’s chin is placed comfortably on a chin rest in the ganzfield bowl (Figure 6) and is asked to focus at fixation targets (Figure 6).

The connections from the electrodes are guided to a junction box from which it goes to the signal amplifier and the monitor (Figure 7).

Calibration of the instrument - Regular calibration of the instrument is essential and normative data should be maintained for each lab by recording from a group of normal individuals.

International society for clinical electrophysiology and vision (ISCEV) standards - since the values obtained in ERG are stimulus and patient adaptive state dependent the ISCEV developed standards so that clinical comparison is possible between the laboratories. Details of the ISCEV are available at www.iscev.org. Based on the clinical need anything beyond standard can be utilized.

**Major waves of the ERG**

- **a wave** - First negative wave following a stimulus. Major source is the photoreceptor with post-receptoral contributions. Rod driven in the scotopic condition and cone driven in photopic state (Figure 8).

- **b wave** - The positive b wave (Figure 9) is the major component of the diffuse flash ERG. Origin from the rod bipolar cells and cone ON and OFF bipolar cells. Contributions from the Muller cells has also been postulated.

**Other waves of the ERG recording**

- **D wave** - Positive deflection at light offset that is a characteristic of the photopic ERG. The main contributor is the OFF bipolar cells.
- **C wave** - Cornea positive wave that follows the B wave. It has 2 major contributors the neural retina and retinal pigment epithelium.
**E wave** - Delayed field potential that is produced at light offset. Present only in the dark adapted retina and is essentially the scotopic version of d wave.

**Proximal negative response (PNR)** - Light evoked field potential evoked in the inner retina

**M wave** - Like the PNR it is a light evoked potential from the proximal retina

Recording of the signals - based on the ISCEV standards 5 recordings are basic for standard ERG

**Rod response** - This is the first signal to be recorded after the dark adaptation. A dim white flash of 2.5 log units below the white standard flash (25db flash) is used. There should be at least an interval of 2 seconds between the flashes to maintain the dark adapted state.

Rod response consists of a broad based b wave (Figure 10). A wave in the rod response is not very evident unless the stimulus strength is increased. The interstimulus interval should be increased in such cases to maintain the dark adapted state.

**Maximal Response**

The standard flash under dark adapted state is used here with a minimum of 10 seconds between the flashes. This is a combined response of rod and cone functions. Here a wave and b wave are evident and consists of a sharp negative a wave followed by a large rapidly rising b wave which returns to the baseline slowly (Figure 11). Though it is a combined response it mainly depicts the rod function.

**Oscillatory potential**

The same standard flash is used here after resetting the bandpass filter so the low frequency is limited to 75-100Hz and high frequency to 300Hz or above. Flashes are given at 15 seconds interval and only the second or subsequent responses are recorded. It is seen as repetitive waves along the ascending limb of b wave (Figure 12). Main contributors are the amacrine cells.

**Cone response**

The patient is light adapted for 10 minutes by switching on the background light of the ganzfield which can saturate the rod response. Standard white flash is used with no attenuation with an interval of not less than 0.5 seconds. It gives the cone function and consists of a small less sharp a wave followed by a sharply rising b wave which rapidly returns to the baseline (Figure 13).

**30 HZ flicker**

A repetitive standard flash at 30 flashes per second is given under the same photopic condition and is mainly a cone function indicator. The measurement of amplitude here is from the trough to peak of each response (Figure 14).
Interpretation of the results obtained

The implicit time and the amplitude of the waves are the main values recorded. Implicit time is from the start of the stimulus to peak of the wave. Amplitude for a wave is from the base to trough and b wave is from trough of a wave to peak of b wave. Two repetitive waveforms are needed to demonstrate reproducibility.

For all practical purposes, the variables most often measured are the b wave amplitude of the rod response, a and b wave amplitude and peak time of the standard flash response, a and b wave amplitude and peak time of photopic response, and the peak time and amplitude of flicker response.

Normative data developed at the electrophysiology lab of Little Flower Hospital for standard flash ERG

<table>
<thead>
<tr>
<th></th>
<th>Amplitude (µV)</th>
<th>Latency (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rod response</td>
<td>150-250</td>
<td>65-80</td>
</tr>
<tr>
<td>Maximal response</td>
<td>270-500</td>
<td>35-40</td>
</tr>
<tr>
<td>Cone response</td>
<td>120-180</td>
<td>12-30</td>
</tr>
</tbody>
</table>

Major clinical indications

The major clinical indications for standard ERG are inherited retinal disorders, vascular diseases of the eye, opaque media, unexplained visual loss, toxic and nutritional eye disease, retrobulbar neuritis in the remission stage, albinism (to rule out other mimic diseases).

The ERG feature of few of these conditions are given below

Rod cone dystrophy

Here significant reduction in the a and b wave amplitude of the rod response is evident.

Retinitis pigmentosa

This is a rod-cone dystrophy and in the advanced form both rods and cones are equally affected.

Cone dystrophy

Here the cone functions are more deranged than the rod functions.
Juvenile X linked retinoschisis also give a negative ERG and its distinguishing feature from congenital stationary night blindness are the abnormal fundus findings and absence of night blindness.
In this case with central retinal vein occlusion of the right eye significant reduction in the b wave amplitude and oscillatory potential is seen in the right eye. Significant reduction in the b/a ratio is usually evident in CRVO.

Clinical correlation is extremely essential before providing any definitive impression of the condition.

**Specialised forms of ERG**

Pattern ERG- this is a retinal biopotential evoked when temporally modulated patterned stimulus of constant luminance (checker board, gratings) is viewed. This form of ERG mainly signifies the functions of the inner retina and macula and need to be done with undilated pupils.

**Multifocal ERG**

This measure the spatial distribution of the central retinal cone function. Here functional field mapping of 40-50 deg of central retina is done. Good indicator of macular functions.

Conclusion- Basic standard flash ERG is an excellent tool to assess retinal functions and provides answer to a variety of clinical situations were a definitive diagnosis is difficult.

**References**