The Electroretinogram (ERG)

The Electroretinogram (ERG) is an electrical response of the eye. The global or full-field ERG is a test used worldwide to assess the status of the retina in eye diseases in human patients and in laboratory animals used as models of retinal disease. Researchers and clinicians who are interested in objective assessment of retinal function need to become familiar with the ERG waves. With proper analysis, the functional integrity of different retinal structures can be dissected out and we are able to understand information processing mechanisms and/or the sites of retinal disorders. The ERG originates from extracellular currents that are generated in response to a light stimulus.

Purpose

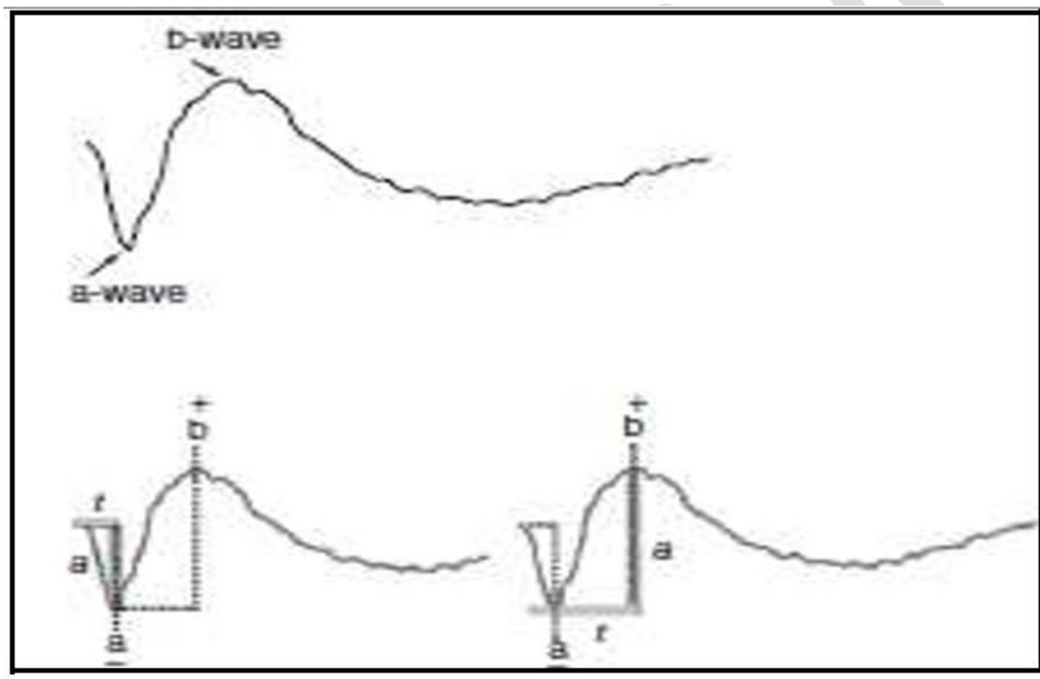
Electroretinography (ERG) is a diagnostic instrument intended for measuring the electrical activity generated by the cells in the retina. The retina is a part of the eye that is responsible for detecting light and images, similar to the film in a camera. After detecting an image, the retina transmits resulting electrical signals to the brain, where the picture is finally registered. ERG measures the electrical activity of the retina, thereby giving an accurate assessment of function of the retina. The ERG can provide important diagnostic information on a variety of retinal disorders and is useful in evaluating both inherited (hereditary) and acquired disorders of the retina. The ERG also helps to distinguish retinal degeneration and dystrophies.

Principle

The retina is composed of rod and cone cells in the photoreceptive layer of tissue at the back of the inner eye. **There are around 120 million rods in the human eye and 6–7 million cones. The cones are responsible for the eye's colour sensitivity. The rods are more sensitive to light than the cones, but they are not less sensitive to colour**. When theretina is stimulated with light, electrical currents are generated in the cells of retina and flow through, around, and outside of the eye resulting in an electric field. ERG signal is actually a measurement of the difference in potential between any two locations in this three-dimensional electric field. ERG signal depends upon the function of the retina, stimulus parameters, and properties of other structures of the eye.

ERG Waveform

During ERG recording, the patient's eyes are exposed to standardized stimuli and the resulting electrical signal is recorded showing the time–signal amplitude (voltage) graph. The electrical response is a result of a retinal potential generated by light-induced changes in the flux of transretinal ions, primarily sodium and potassium. **The amplitude of the ERG signal is very small and typically in the microvolts or nanovolts range**. The ERG is essentially an integrated display of electrical potentials contributed by different cell types within the retina and the stimulus conditions. In practice, ERG is recorded by stimulating the eye with a bright light source such as a flash produced by light emitting diodes (LEDs) or a strobe lamp. The flash of light results in generating a biphasic waveform as shown in Figure below, which can be recorded at the cornea. The two prominent components of the waveform are the a- and b-waves. The a-wave is the first large negative component, followed by the b-wave, which is corneal positive and usually larger in amplitude.



Amplitude and implicit time measurements of the ERG waveform.

The two important characteristics of the ERG waveform as illustrated in Figure above are

(i) a-wave amplitude is measured from the baseline to the negative trough of the a-wave and

(ii) (ii) b-wave amplitude is measured from the trough of the a-wave to the following peak of the b-wave and (b) the time measured from flash onset to the trough of the a-wave and the time from flash onset to the peak of the b-wave.

The length of ERG signal is typically 200 ms, with the first 80 ms as the most essential time segment as it contains most of the ERG components. This suggests that the ERG signal is relatively a short signal and provides a significant challenge to the analysis of the signal. The a-wave is an indicator of the general condition of the photoreceptors in the outer retina, while the b-wave reflects the condition of the inner layers of the retina.

ERG Electrodes

The choice of electrode is one of the important factors that must be considered when recording the electroretinogram. Several types of electrodes have been developed and tried over the years to measure the tiny voltage signals associated with ERG. Figure below shows the most commonly used ERG electrodes. Broadly, **there are two types of electrodes:**

(i) with contact lens electrodes

(ii) or non-contact lens electrodes that are in contact with either the cornea or the bulbar conjunctiva.

Most often, the small ERG signals are obtained using electrodes embedded in a corneal contact lens and placed on the surface of the cornea. This allows to measure a summation of retinal electrical activity at the corneal surface. These electrodes are centrally transparent with a large optical opening and may include a speculum to hold the lids apart. Contact lens electrodes give larger signal amplitudes. However, they are expensive and often uncomfortable to wear. Contact lens electrodes can be unipolar like the Jet electrode and some of the Burian-Allen electrodes or bipolar like other Burian- Allen electrodes. The non-contact lens-type varieties include gold foil, H-K loop, the DTL-fibre, and the LVP-Zari electrodes.

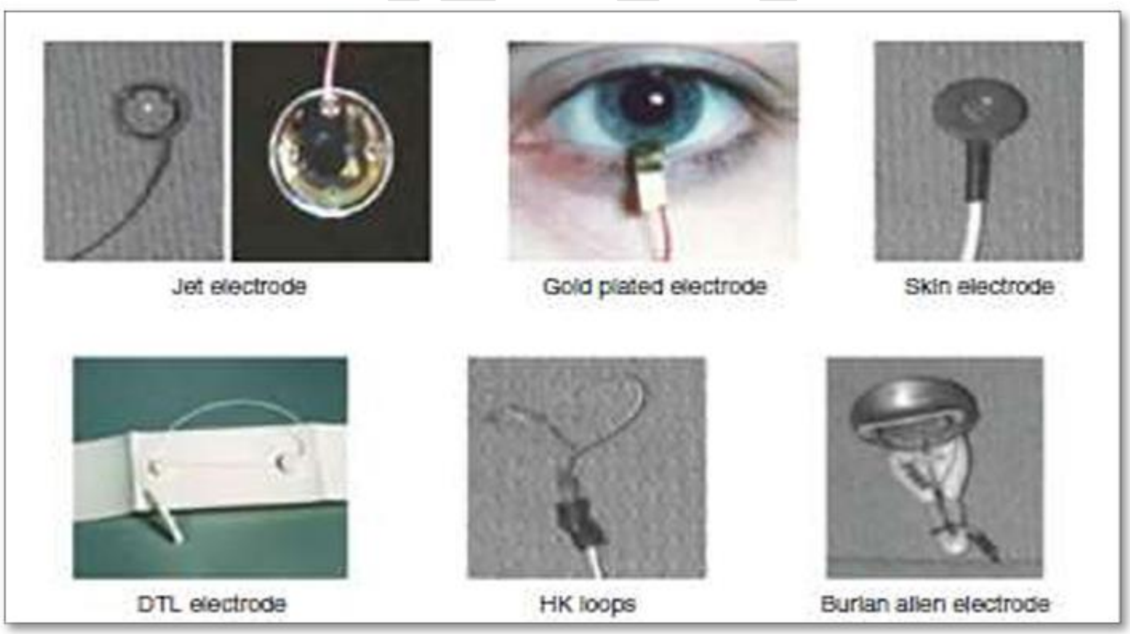
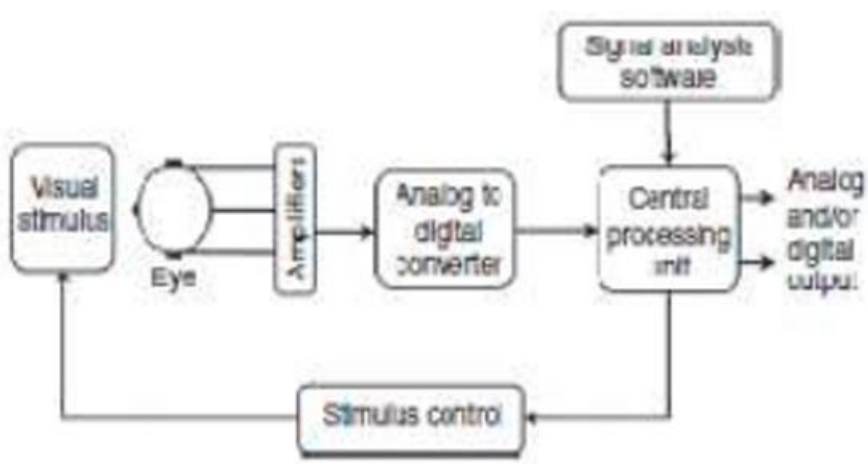


Figure 13 Various types of electrodes used in ERG recording.

Email (saad.mutashar.abbas@uomus.edu.iq)

System Description

The ERG recording system is similar to other types of bioelectric events recorders such as electrocardiogram (ECG) or electroencephalogram (EEG). Figure 138.4 shows a block diagram of the signal acquisition and processing system. The electrical signal generated by the retinal cells is picked up by the electrodes and given to a preamplifier followed by another for amplification and filtration of noise. The patient is electrically isolated to ensure safety from leakage currents, if any. A bandpass filter is used to remove undesired frequencies and bandwidth of the amplifiers is usually kept in the range of 0.3 300 Hz. This frequency range is adequate to record oscillatory potentials and to meet other specialized requirements. The amplified analog ERG signal then goes to an analog-to-digital converter for digitization followed by its processing in the microprocessor. The sampling rate for digitization should be at least 1000 Hz or more. The analog output from the microprocessor goes to the display/recorder unit for displaying the ERG response in time domain. It can also store data for further analysis, capture multiple ERG signals, and average them in order to remove noise. The software provided in the system is usually capable of averaging multiple responses to increase signalto- noise ratio. An important part of the hardware is the stimulating equipment. Many light-stimulating systems or photostimulators have been developed in order to obtain stimulation of the retina. For ERG recording, two types of illumination arrangements are required.



Block diagram of signal acquisition system in ERG.

Email (saad.mutashar.abbas@uomus.edu.iq)

Specifications

1- Light source: Red, green, blue, and white LEDs
2- Frequency range:
3- DC coupled
4- CMMR: >100 dB
5- Noise:
6- Sampling rate: 2 kHz
7- Flicker frequency: 28.3 Hz
8- Power source: Liâ

Applications

The main application of ERG is for the diagnosis of various retinal diseases. It is used by ophthalmologists and optometrists specifically to determine progressive retinal atrophy, a genetic condition that causes slow, gradual but nonâ€ vision loss. The ERG is also used extensively in eye research, as it provides information about the function of the retina that is not otherwise available.

Email (saad.mutashar.abbas@uomus.edu.iq)