ELECTRODIAGNOSTIC TESTING OF THE VISUAL SYSTEM

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THIS CHAPTER WILL INCLUDE A REVIEW OF:

- Electrooculogram (EOG)
- Electroretinogram (ERG)
- Visually evoked response (VER)

INTRODUCTION

The visual system uses electrical impulses to transmit data from the photoreceptors to other neurons, and eventually to the brain. Therefore one way to study and assess the visual system is to measure its electrical activity. The VER and ERG tests measure gross electrical potentials of the visual system; that is, they measure the electrical response of major parts of the visual system. Electrodiagnostic tests provide important information about the visual system and can help diagnose certain diseases, especially those affecting the retina or optic nerve. The three main types of electrodiagnostic tests are:

- EOG (Electrooculogram)
- ERG (Electroretinogram)
- VER (visually evoked response) or VEP (visual evoked potential)

Each tests a different electrical phenomenon and is used for diagnosing different conditions.

ELECTROOCULOGRAM (EOG)

The neurons and muscles of the eye normally store small electrical charges within their cells and it is possible to measure the net electrical charge of the eye. Normally the eye has a slightly more positive electrical charge at the front of the eye and a more negative charge at the back, as shown in Schwartz, 2004 Fig. 16-1. The EOG measures the difference in electrical charge between the front and back of the eye. The difference between the front and back of the eye is approximately 6 mV, but will vary depending on the eye's state of adaptation and in the presence of certain diseases.

ELECTROOCULOGRAM (EOG) (CONT.)

The EOG testing procedure is illustrated in Schwartz, 2004 Figs. 16-1 and 16-2.

- Electrodes placed on the skin near the inner and outer canthi
- Subject looks right and left while the change in electrical potential is recorded
- The EOG value is the difference in the electrical charge between the front (+) and back (−) of the eye

You begin by letting the patient dark adapt for about 10 minutes while recording. The room lights are then turned on and the recording continues as the patient light adapts. The voltage difference between the front and back of the eye varies depending on light or dark adaptation and the health of the eye.

Schwartz, 2004 Fig. 16-3 shows a recording from an EOG.

- The electrical charge reaches a minimum **(dark trough)** after about 8 minutes in the dark. This may indicate activity of the RPE
- It reaches a maximum **(light rise)** after about 15 minutes in the light. This may indicate activity of the photoreceptors
- From this compute the **Arden ratio**:

$$\text{(Arden Ratio)} = \frac{\text{(Light rise)}}{\text{(Dark trough)}} \times 100$$

Abnormal EOG < 165%

The EOG is not used much anymore but has largely been supplanted by the ERG. Some retinal diseases, however, can be diagnosed by the EOG but not the ERG. Examples are Stargardt's disease (fundus flavimaculatus), butterfly-shaped dystrophy and Best's disease (viteliform dystrophy).

ELECTRORETINOGRAM (ERG)

The ERG measures the response of the entire exposed retina (primarily outer layers) to light. The measured voltage is only about 1 mV, which is smaller than the potential measured by the EOG. There are several types of ERG procedures.

- The standard full field ERG floods the entire retina with a single flash
- The flicker ERG exposes the retina to a flickering light
- The focal ERG exposes a limited area of the retina
- The multifocal ERG tests a large number of discrete locations in the retina using a honeycomb-like target in which certain facets in the array are flickered on and off (Schwartz, 2004 Fig. 16-7). This tests many small areas of the retina separately, and little ERGs are recorded for each retinal location. This can be used to diagnose the health of one part of the retina
- The pattern ERG (PERG) projects a small checkerboard pattern onto the retina. The PERG uses a counterphase flickering checkerboard or grating pattern as shown in Schwartz, 2004 Fig. 16-8. It differs from the standard and flicker ERGs in that it records the retinal response, not to simple illumination, but to changes in contrast. Whereas the standard ERG appears to originate from electrical activity in the outer retina, the PERG seems to come from the inner retinal layers. There is also a focal pattern ERG test, which limits testing to a smaller area of the retina

ELECTRORETINOGRAM (ERG) (CONT.)

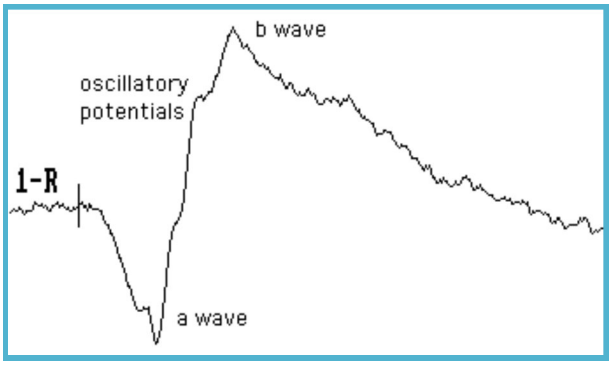

Figure 27-1: *Standard ERG trace*

Figure 27-1, above, shows a typical readout from a standard ERG test. Also see Schwartz Fig. 16-4. The wave shows the recorded electrical response to a single bright flash of light, with time along the x-axis. Major features are the negative a-wave, followed by the positive b-wave and other components that are not shown. Separate a- and b-waves are generated by the photopic and scotopic systems. The negative a-wave is associated with the photoreceptors. The b-wave comes from the Müller glial cells and the photoreceptors. Oscillatory potentials refer to small bumps on the ascending side of the b wave and may be tested to diagnose retinal hypoxia, such as might occur in diabetic retinopathy.

The ERG response to a flickering light is a repeating series of waves, which are composed off repeating patterns of the waveform shown in Figure 27-1.

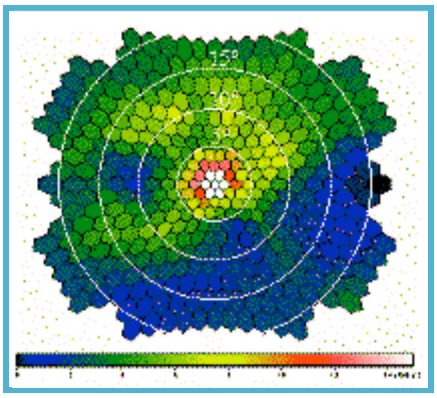

Figure 27-2: *Colour map of a multifocal ERG*

Depending on stimulus conditions (dark/light adaptation, stimulus colour (Fig. 27-2), luminance, duration, etc.), the ERG can be configured to target either the scotopic system, photopic system or both. In diagnosing diseases, you compare the magnitudes of the a- and b-waves, their time courses and response pattern to a normal response.

The **International Society for Clinical Electrophysiology of Vision (ISCEV)** has established a standard protocol for ERG testing that greatly simplifies the procedure. It goes through the following steps, using a flash or flicker of white light:

Dark adaptation prior to testing

- Step 1: Single flash with a luminance of 0.01 cd/m^2 (25 dB). This tests the dark-adapted rod response
- Step 2: Single flash with a luminance of 1.5-3.0 cd/m^2 (0 dB). This measures a combined rod and cone response
- Step 3: Repeat a single flash at 1.5-3.0 cd/m^2 (0 dB). The computer isolates the oscillatory potentials
- Light adapt for three minutes to saturate the rods
- Step 4: Single flash at 1.5-3.0 cd/m^2. This measures a cone-only response
- Step 5: 30-Hz flickering light with a luminance of 1.5-3.0 cd/m^2 (0 dB)

The standard ERG is most useful for detecting diseases of the **peripheral retina**, such as retinitis pigmentosa. Since the fovea occupies a very small area of the retina, it contributes little to the ERG. Therefore, you would not use the ERG to diagnose macular diseases.

VISUALLY EVOKED RESPONSE (VER)

This test is also known as the visually evoked potential (VEP), or visually evoked cortical potential (VECP). It records the very small change in voltage (~ 5μV) at the visual cortex (occipital lobe) in response to a light stimulus. Since the visual cortex near the occipital pole is dominated by foveal input, this is primarily a test for diseases that affect **central vision**. Any condition that affects the neural signal between the fovea and visual cortex can affect the VER. That is, anything that causes poor (central) visual acuity will cause a diminished VER response. The VER can be used for the following:

- Optic nerve disease. For example, if the retina appears normal on ophthalmoscopy but the patient has reduced vision, it may be caused by optic neuritis. For example, VER can help diagnose multiple sclerosis (MS), which can cause optic neuritis
- To objectively test visual acuity or contrast sensitivity in non-responsive patients. The VER is sometimes used **to test infant vision**, though it may over-estimate visual acuity. This is accomplished by recording the VER while the infant watches an alternating checkerboard pattern. The size of the squares can be adjusted to test different levels of visual acuity
- Diagnosis of malingering or hysteria. Some patients say, or think they see very poorly, but if you suspect malingering you can verify the visual acuity objectively with the VER. However, it's difficult to measure visual acuity better than 20/40 with the VER

Any disease that affects the neural input between the fovea and visual cortex can affect the VER. Note that diagnosis by the VER is non-specific—the VER alone cannot diagnose the site of the anomaly between the fovea and visual cortex. Anything that affects retinal image quality (such as a uncorrected refractive error, or cataract) can also reduce the VER response. Amblyopia also diminishes the VER.

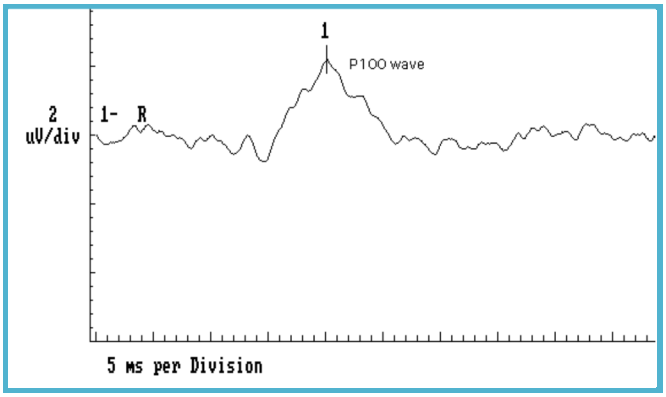

Figure 27-3: *VER printout*

Data from a flash VER test is recorded as a waveform similar to that shown in Figure 27-3. The y-axis indicates voltage of the response and the x-axis represents time after the flash. The most important feature is the peak, known as the P100 wave. It normally occurs at about 100 ±10 milliseconds. This time duration is referred to as the **implicit time**. An abnormal VER would show a smaller-than-normal P100 amplitude and longer-than-normal implicit time. Before diagnosing the results, you should have calibrated the instrument and established norms for that particular machine.

Table 27-1: *Summary of electrodiagnostic tests*

TEST	WHAT MEASURED?	EXAMPLE USES	COMMENT
EOG	Electrical charge of the whole eye	Stargardt's, Best's diseases	Arden ratio
ERG (standard)	Entire retina, outer layer's electrical response to visual stimulus	RP, night blindness, rod vs cone anomaly	Flash or flicker, multifocal pattern
VER	Visual cortex response to foveal input	ARMD, optic neuritis, amblyopia, infant vision, malingering	Also called VEP, VECP flash or flicker (steady state) with pattern; non-specific

Borish, 2006: Chapter 16 also covers Electrodiagnostic testing.

SELECTED READING/REFERENCES

- Schwartz SH. **Visual Perception - A Clinical Orientation, 3rd Edition**. Appleton & Lange, Stamford, Connecticut, 2004
- Benjamin WJ (ed). **Borish's Clinical Refraction, 2nd Edition**. Butterworth-Heinemann, Philadelphia, 2006