Basics Electrophysiology of the Retina

Ophthalmic Ultrasound Examination

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Overview of Presentation

What can we do with electrophysiological recordings?
Usefulness?
Indications?
Overview of Presentation

Basic cellular mechanisms for generation and changes of electrical potentials
Basic mechanisms of electrical field generation in the tissue
Recording protocols
Different Types of recording procedures
Clinical recording setups
Important !!!

Electroretinography (ERG) alone does not give you necessarily a diagnosis
Clinical examination and patient’s history are as important!!!
Literature

Electrophysiologic Testing Ophthalmology Monographs (AAO manuals) (Eds. Fishman, Birch, Holder, Brigell)

Adler’s Physiology of the Eye (Ed. W.M. Hart)

Electrodiagnostic Testing of the Visual System (Ronald E. Carr, Irwin M. Siegel)

The Eye Basic Science in Practice (Eds. Forrester, Dick, McMenamin, Lee)

Principals and Practice of Clinical Electrophysiology of Vision (John R. Heckenlively, Geoffrey B. Arden)
Why Do We need an ERG?

- VF constrictions w/o morphological correlate
- Bad VA without obvious reason
- Apparently insufficient visual function in infants and toddlers
- Obvious clinical hints for retinal degenerations
How Are the Recordings Performed

Ganzfeld Bowl
Corneal Electrodes
Reference Electrode
Ground Electrode
Amplifier

Courtesy by Michael Bach, Freiburg I.B.
UniversitätsSpital Zürich
What Does the ERG Tell Us?

Distinguish between the function of the two photoreceptor types: 
**rods** and **cones**

Information about **ganglion cell layer**

Information about **glial cells**

Information about the physiological properties of the **retina as a tissue**
Normal ERG Recordings

Scotopic

Photopic
Photoreceptors hyperpolarize
Ganglion cells depolarize
Glial cells depolarize
RPE cells depolarize
Depolarization creates local K⁺ gradients in the extracellular space → radial electrical potentials
General Principles for ERG Generation

Recorded are extracellular electrical fields (like an ECG)
In general the field potentials recorded are created by spatially difference currents within a tissue
All cells in the retina can create extracellular fields
The generated fields are small and can only be detected if the electrical fields of single cells sum up to a “tissue field potential”
Large amplitudes are generated by long and big cells (bigger potential differences from one cell end to the other) that are radially oriented in the retina
Meridionally oriented cells do not create big enough summation potentials to be recorded
Nomenclature of Full Field ERG

a-wave
b-wave
c-wave
d-wave
P I comp.
P II comp
P III comp

FIG 2–4. Analysis of the E-ERG (cat) at two intensities: upper, 14 mL; lower, 0.14 mL. The a-wave has been broadened slightly out of proportion to demonstrate its derivation more clearly. (From Grant R. J Physiol 1934; 81:1–28. Used by permission.)
Generation of a-, b- and c-wave

ERG consists of summation of three processes → P I, P II, P III, (named for disappearance under ether anesthesia, Riggs)
These three processes sum up to give the shape of the ERG curves that are recorded
Origin of the ERG Peaks

**a-wave:**
First negative deflection in the full field recording → represents photoreceptor activation

**b-wave:**
First positive deflection in the full field recording → represents the depolarization of the Müller cells

**c-wave:**
Slow second positive deflection in the full field recording → mainly produced by the pigment epithelium (apical polarization induced by reduction in $K^{+}_o$ in the subretinal space)
ERG wave generation

a-wave generation:
Corneal negative wave composed of more or less exclusively composed by fast P III, i.e. the photoreceptor potential
ERG wave generation

b-wave generation:
Corneal positive wave composed of:
P I, corneal negative receptor potential and later RPE field potential
P II, Müller cell induced corneal positive potential
Oscillatory Potentials

Consists of several rapid, low amplitude potentials, sometimes called wavelets, superimposed on the b-wave
Usually the average number of waves is about seven (species dependent)
Origin probably in the amacrine cells
Differently sensitive to pharmacological agents (early OP’s depressed by GABA antagonists, dopamine agonists, β-alanin and substance P, late OP’s by glycine antagonists and ethanol)
Retinal Rod and Cone Density

Figure 1-1. Retinal topographic construction showing population densities of cones (red tones) and rods (blue tones) superimposed on the fundus.

FIG 5–19.
Graph showing the cone and rod photoreceptor density along the horizontal meridian of the human retina. (From Østerberg G: *Acta Ophthalmol Suppl* 1935; 8:1–103. Used by permission.)
Recording Protocol

In order to differentiate the different cell types from each other the following protocol has been proposed by the ISCEV (International Society for Clinical Electrophysiology in Vision)

Scotopic responses (dark adapted)
- A response developed by the rods in the dark adapted eye (dim flash)
- A maximal response in the dark adapted eye (strong flash, rods and cones!!)
- Oscillatory potentials (strong flash)

Photopic responses (light adapted)
- A response developed by the cones
- Responses obtained to a rapidly repeated stimulus (flicker)
ERG Measurements  Amplitudes

-24 db scotopic

b - wave

normal

b - wave

0 db scotopic

a - wave

0 db photopic

b - wave

normal

b - wave

0 db photopic 30Hz flicker

a - wave

normal

b - wave
ERG Measurements  Implicit times

No timing  No timing
Retinitis pigmentosa cone-rod dystrophy
RP different forms or stages

Normal

RP sine pigmento

Advanced
Cone dystrophies

Normal  mild  intermediate  severe
Electrooculogram EOG

Uses the potential difference between the anterior and the posterior pole of the eye to record the potential changes that are created if the patient looks back and forth between two fixation points that are 30° apart.

The potential difference is mainly created by the RPE and is increased during light adaptation.

This change in Potential is expressed as “Arden Ratio” (Light peak / Dark trough) that should be larger than 1.8.

Values below 1.65 are usually considered pathological.

Very specific for diagnosing juvenile form of Vitelliforme macular dystrophy (Best’s disease).
Electrooculogram EOG

Figure 2.2: Fixation lights and ocular excursions used during recording of EOG potentials.

Figure 2.1: Frontal view of electrode placement for recording EOG responses. Four recording electrodes are positioned at medial and lateral canthi; ground electrode is placed on forehead.
Electrooculogram EOG

Figure 10–3. Lower tracings are the electrical responses produced by fixed saccadic movement sampled in the dark and during a period of intense light adaptation. The black circles represent the average amplitude (given in mm of polygraph pen excursion) of several saccades performed under the three conditions of retinal adaptation. The greatest EOG amplitude achieved in the light (light peak) is divided by the lowest amplitude in the dark (dark trough) and the calculated ratio is expressed as a percent.
Multifocal ERG
Multifocal ERG

A Typical Multifocal Recording Setup

- 103 scaled elements
- achromatic flicker by binary m-sequence

Monitor Screen

Burlan-Allen
Bipolar
Contact Lens
Electrode

Amplifier
1kHz gain, 10-380 Hz

Computer
Fast A transform

103 focal
ERG kernels

Response
Densities

foveal peak
optic nerve head
Multifokales ERG
mf ERG - Origin of Signal Components

Damage at or before the bipolar cells will substantially decrease the amplitude of the signal.

Inner retinal damage to amacrine and/or ganglion cells does not affect mfERG amplitude, although it may have a small effect on its waveform.

*FIGURE 4.* The retinal origin of the multifocal electroretinogram signal. (Modified from ref. 25.)
mf ERG - Ganglion Cell Contribution

The mfERG responses are not affected by retinal ganglion cell loss in ischemic optic neuropathy.
Conclusion mfERG

Very complex technique
Easy to record
In order to understand the results in a given disease it is of great importance to understand the pathology of adaptational processes of this specific disease within the retina itself
A ERG laboratory needs very good normative values and recordings as comparable as possible in order to be able to interpret the results
mf ERG – Stargardt’s disease
Chloroquineretinopathy
Fundus Images
Chloroquineretinopathy
IR Images
Chloroquineretinopathy
AF Images
Chloroquineretinopathy

Visual Fields
Chloroquine retinopathy
Electrooculogramm
(normal Arden Ratio)
Ganzfeld ERG

(normal Cone- and Rod function)
Chloroquineretinopathy
Multifocal ERG
(reduced amplitudes in centre)
General Conclusions

ERG recordings are essential for ophthalmological workup of unclear disorders
Have to be considered always together with the clinical picture
BASIC SCIENCE COURSE NEUCHATEL
2017

Ophthalmic Ultrasound Examination

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Overview

Technical Basics
Examination technique
Based on:
Ophthalmic Ultrasound A Practical Guide
Hatem R. Atta
Why Ultrasound?

Imaging in case of opaque media

- Mature cataract
- Corneal scarring
- Inflamation anterior segment
- Vitreous hemorrhage

Diagnosing and differentiating intraocular tumors

Biometry
Basics

A-scan (Amplitude)
- Provides a one dimensional access to tissue

B-scan (Brightness)
- Provides a cross sectional image of tissue (many a-scans are merged for cross sectional image)
Basics A-Scan

Understanding of factors that determine the appearance of tissue signals during A-scan examination is essential in order to provide the examiner with the required knowledge to perform the examination.

A-scan provides one dimensional display of returning echoes as vertical spikes of various heights and distances.
Normal A-scan of the eye

I: Initial spike
A: Anterior lens, iris spike
P: Posterior lens spike
V: Vireous
R: Retinal spike
O: Orbital spikes
Perpendicularly of scan
Gain

Effect of gain on appearance of A-scan signals
Signals are wider and higher if gain is increased
Standardized A-scan

Standardization features:

Sound amplification: 36 dB range, s-shaped amplification curve

Probe design: 8 MHz pencil size probe, parallel sound emission, beam width varies from 0.5 to 5mm

Tissue model: tissue phantom provided by manufacturer, allows calibration to desired tissue sensitivity
Setting of T-sensitivity

Standard T=0

T +6

T -6
Examination Procedure

Basic examination is performed in 8 directions distributed over 12 clock hours.

Labelling of sections is determined by projection of the beam and not the probe location.
A-scan Examination

A

B

C

D

Limbus
Equator
Piriform

A
B
C
D

E
A-scan and Vitreous Body

T +6 allows visualization of vitreous body with opacities
A-scan and Chorioretinal Layer

T-24 allows visualization of chorioretinal layer in two spikes (R = retina, S = sclera)
A-scan an Fundus Periphery
A-scan an Fundus Periphery
B-Scan Basics

Two dimensional image
Therefore orientation of the probe is important
Probe is marked
Marker indicates top of image on screen
Coupling jelly is necessary (classic ultrasound coupling jelly, methocel, lubricifying eye jelly)
Scan Orientation

Axial scans

Longitudinal scans

Transversal scans
Axial Scan
Transversal Scan
Longitudinal Scan
Everything transparent??
Thank you for your attention!!
Bon appetit

Thanks to
Mrs Angela Schaefer (ERG recordings)
Dr. Daniel Barthelmes (ERG Analysis, graphics)
Prof. Günter Niemeyer