CORRELATING ERG NORMATIVE DATA: A TRIP TO VENUS

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INTRODUCTION: The ERG or electroretinogram falls under the broader category of electrodiagnostics representing one of the four field potentials involved in vision. Scientists over the past 100 years have been able to demonstate that a flash of light elicits a distinctive electrical response. In 1849, Dubois-Reymond discovered the presence of a resting potential between the front and back of the eye. In 1865, Holgren noted that this resting potential changed with respect to the amout of light entering the eye. Dewar recorded this resting potential or ERG for the first time in a human in 1877. Actual clinical applications of the ERG did not arise until 1941 when Riggs showed that a stable electrical connection with the cornea can be made with a silver disc electrode mounted in a scleral contact lens. Granit was the first to really analyze the ERG and received a noble prize in medicine for his work. By using ether to anesthetize cats, Granit was able to isolate the individual components of the ERG wave and identify where each response originated. The first wave that was isolated was the PI or c wave, the second was PII which consisted of the b and d waves, and the last was PIII or the a wave. The a wave which was isolated last corresponded to the beginning of the ERG wave and represents the hyperpolarization of the photoreceptors. The b wave represents the bipolar cell response and the c wave measures the activity of the RPE. The d wave, which was isolated in the PII process, represents the interaction between the cone photoreceptors and the inner nuclear layer. K.T. Brown broke Granit's PII wave down into two parts, the b wave and a d.c. component which does not change in magnitude over time. Along with the cone late receptor potential it forms the d wave. It is generated in the inner nuclear layer but by different elements then those that compose the b wave. The ERG is then a summation of each individual wave. Just prior to the intiation of the a wave a small wavelet called the Early Receptor Potemtial(ERP) can be seen. The ERP corresponds to the conversion of rhodopsin to lumirhodopsin. The c and d waves are not always present in the ERG form so they are not used clinically. Other minor wave forms in the ERG include the x wave and oscillatory potentials. The x wave can sometimes be elicited by using an intense red light stimulus and occurs as a separate, smaller peak just prior to the b wave. Oscillatory potentials can be seen as small oscillations on the b wave which arise when very high stimulus luminances are used. These oscillations are absent when retinal circulation is compromised as in the case of diabetic retinopathy. The time from stimulus onset to the end of the d wave takes, on average, about 2.5 seconds.[2]

The ERG represents a waveform of electrical activity which is derived from the voltage difference between two electrodes. This resting potential, which is about six millivolts in humans, is produced by all the structures that lie between the two electrodes. The recording electrode is placed on the cornea via a contact lens and the reference electrode is placed somewhere on the face which allows it to be

electrically continuous with the back of the eye. The structures then lying between the two eletrodes are all of the structures which lie between the front and the back of the eye(ie. retina, vitreous, lens, ciliary body, iris, aqueous, E.O.M.'s, and facial muscles), however it is assumed that the retina is the only one of these structures that will change in response to light stimulation. There are bimodal eletrodes that have both the recording and reference placed inside the contact lens. This type of electrode gives an approximation of the electrical potential at the back of the eye, is easier to use and in most cases just as accurate. This electrode should be switched when the reliability of the data is in question and there appears no other explanation. In order to record the ERG response, the electrodes are connected to an amplifier that increases the signal one million times. This amplification process also greatly increases the electrical "noise" that is inherent in any ERG apparatus. To overcome this problem the computer systems are designed to eliminate random electrical signals and only record those responses that are time dependent on stimulus onset(ie.the ERG wave). Since the different layers of the retina may respond at different times to a light stimulus, the actual measurement at the cornea is the algebraic summation of all the electrical activities of the retina. This has clinical relevance in that the knowledge of such elements constitute the different waves can be useful in diagnosing certain retinal pathologies.[3,2]

The ERG can show variations in form(ie. b wave amplitude and implicit time) depending on whether the rod system, the cone system or both are responding. The rod only response, which can be elicited by using dim, low frequency light under dark adapted conditions, has a long latency and implicit time and high b wave amplitudes. The cone only response, which can be elicited by using a bright, high frequency light(ie.>30Hz), has short latency and implicit time and has a relatively low b wave amplitude. This can be explained by the high convergence ratio of rods to bipolar(muellers cells) especially in the periphery and the low one-to-one ratio of cones to bipolar cells at the fovea. The combined rod/cone response is the summation of the scotopic and photopic systems. In the dark or resting state of the retina, the Na+ channels located in the plasma membrane of the photoreceptors remain open. Na+ passively enter the photoreceptor and are actively removed by the means of Na+ pumps also located in the plasma membrane of the photoreceptors. This movement of Na+ through the outer segment of the phototreceptors causes a standing voltage gradient, called dark current, which tends to depolarize the cell membrane. The stimulation of the photoreceptors by light hyperpolarizes the cell membrane and the neural signal is thus propagate to the bipolar cells. The photoreceptors are unique among neural tissue in that they are the only type that produce action potentials via hyperpolarization. When light hits the retina rhodpsin

is broken down to all trans retinal plus the protein molecule opsin. Opsin is then activated which in turn activates transducin found in the disc membrane of the photoreceptors. Active transducin stimulates specific phosphodiesterases in the disc membrane which in turn hydrolyzes cyclic GMP causing a decrease in cGMP in the areas near to the Na+ channels. Simultaneously, light causes the Ca+2 channels in the disc membrane to open. This increase in Ca+2 along with the decrease in cytoplasmic cGMP causes the Na+ channels to close. It is believed that the Ca+2 is needed for specific conformational changes to occur which allow cGMP to bind to a receptor membrane organelle closing off the Na+ channel. This closing of the Na+ channels hyperpolarizes the photoreceptor cell membrane and intiates an action potential. The action potential stimulates the release of a chemical transmitter at the synaptic junction where the signal is passed on to the bipolar cells. Action potentials in bipolar cells are produced by either hyperpolarizing or depolarizing leading to a net zero potential difference. These action potentials, either hyperpolarized or depolarized, cause an increase in the K+ concentration in the extracelluar space. Lying adjacent and in close proximity to the bipolar cells is the glial structure called the Mueller cell. The proximal portion of Mueller cells form the internal limiting membrane and its distal ends form specialized appositions into several receptor inner segments forming the external limiting membrane. Mueller cells are K+ sensitive and their membranes change potential as a function of the extracelluar concentration of K+. The depolarization of Mueller cells is picked up as a cornea-positive potential by the ERG and gives rise to the formation of the b wave. Even though much of the b waves origin is derived from Mueller's cells, other unidentified neural structures also participate in its development.[3,1,2]

There are three different types of ERG's: Focal, Pattern, and Diffuser Flash or Gansfeld ERG. Focal stimulus ERG is used to measure small focal lesions of the macula and retina. One main disadvantage of this technique is that it is difficult, if not impossible, to prevent stray light from stimulating adjacent areas of the retina. Eye movements and blinks can also be a big problem and artifact reset must be incorporated into the over-all computer program. Light emmitting diodes (LED's), grouped together inside a diffuser, work best especially in patients with reasonably good vision and whose maculas are only slightly involved. Pattern ERG uses an alternating striped pattern in such a way as to elicit a response from the ganglion cells. The checkerboard pattern, the most commonly used stimulus, changes its pattern from black checks to white checks at some preset rate called reversal per second. Four reversals per second equals two hertz with each check being 1.2"x1.2" in size. Eight reversals per second with 80 to 100% contrast at 100cd/mm2 background illumination is typically

used to detect glaucoma and optic nerve disease which both show a decrease in PERG amplitude. Any condition that affects macular function will produce an abnormal PERG. These must be ruled out first before testing for optic nerve disease. Diffuser Flash or Ganzfeld ERG is a summed or massed discharge of large numbers of receptors and is not sensitive to small focal lesions. It can be used to measure how well the retina is functioning and can help to differentiate between rod and cone system diseases. The diffuse flash produced by a ganzfeld ensures that the entire retina is stimulated evenly while allowing for better stimulus control. This technique is used primarily to identify nyctalopia or night blindness, retinitis pigmentosa and differentiate between the two. It is also used to monitor the progression of certain retinal diseases, laser treatment of retinal detachments and to rule out retinal involvement when psychological problems are suspected.[3]

Clinically, b wave amplitude and implicit time and a wave slope are the most widely used aspects of the ERG in determining retinal function. B wave amplitude and implicit time reflect how efficiently the photoreceptors and midretinal neurons convert the absorption of quanta to a detectable electrical signal. The a wave slope shows the efficiency in which the photoreceptor membrane hyperpolarizes and reflects their functional integrity. There are several factors which can influence the ERG wave: 1) Stimulus intensity 2) Stimulus duration 3) Background illumination 4) Stimulus frequency 5) Stimulus wavelength 6) Time of day 7) Level of dark adaption 8) Pupil size 9) Age of Patient 10) Area of the retina testing 11) Amount of fundus pigmentation 12) Refractive error. The proper protocol is necessary so that as many of these factors can be controlled as possible. Stimulus intensity, frequency, duration and wavelength can be controlled by using a constant, maximal setting on the ERG photostimulator unit. Level of dark adaptation, area of retina tested, background illumination, time of day and pupil size can all be controlled by using consistent testing parameters. Refractive error must be taken into account as the test is not valid for high myopes. Fundus pigmentation can not be controlled but should be noted at the time of the examination(ie. light, moderate or highly pigmented). Age is accounted for by running normative standards for each age group.[3]

Due to the fact that the ERG b wave amplitude is sensitive to the variables mentioned in the preceding section, it is necessary to not only minimize variation in any of the recording parameters, but also to establish normal ranges for the ERG amplitudes and implicit latency times which are specific for each laboratory testing situation. Although published values exist, sources recommend that approximately

ten normal patients from each decade(10 to 70years) be done. This number represents the minimium adequate sample size for each age group. The International Society For Clinical Electrophysiology Of Vision(ISCEV) has accepted as of December 1989 standards for the testing of ERG's with the hope of establishing uniformity and consistency in testing worldwide. It is the sum of these recommendations which provided the basis for this paper. Thus, the focus on the establishment of the normal ranges for b wave amplitude and implicit time for the twenty-year-old age decade. These normals may then be used in clinical application to more effectively evaluate patients with retinal disease or suspected of having retinal disease.[4,5]

METHODS AND MATERIALS:

Materials used:

1) Venus Electrodiagnostic System
   a) Venous model 1020
   b) AST computer keyboard
   c) AST premium 286 disk drive
   d) Princeton ultra 14 computer display screen
   e) Mitsubishi video display screen(for VEP)
   f) Panasonic KX p1180 multi-mode printer
   g) Grass RPS 107 regulated power supply
   h) Grass PS 22 photostimulator
   i) Model 7313 oscilloscope
   j) Ganzfeld apparatus
   k) Computer interfacing box

2) Burian-Allen Bimodal contact lens electrode
3) Ground electrode
4) EEG conductive paste
5) Alcohol pads
6) Tape
7) Sterile saline
8) Spectro-caine(proparacaine hydrochloride 0.5%)
9) Celluvisc (carboxymethlycellulose 1.0%, non-preserved)
10) Cellufresh (carboxymethylcellulose 0.5%, non-preserved)
11) Eye patch
12) Red light lamp
13) Dark adapting room

We chose at random eleven normal, healthy individuals between the ages of 19 and 22. The ERGs were run from 10:00am to 12:00 noon on four different Saturday mornings. Patients were dark adapted for 10 minutes and both eyes were tested with the non-tested eye being patched during the procedure. The 10 min. dark adapting period was chosen because it requires less time while still ensuring that the scotpic response is dominant. Ambient room lighting was controlled at very dim levels by the use of a single red light lamp. This helped to maintain the dark adapted state since the light level was below the level for cone response and red light has least effect of all wavelengths for stimulating the rod photoreceptors. The dim light also helped to control pupil size. The patient's cornea and eye lashes were anesthetized with 0.5% proparacaine. Both eyes were done in all patients with the right eye always being the first eye done. The non-tested eye was patched during this procedure to prevent light adaptation from occurring EEG conductive paste was placed on the ground electrode and taped to the opposite cheek. One drop of

celluvisc was then placed upon the contact lens electrode and inserted into the eye. This was done by first having the patient look down and placing the top portion of the contact lens/electrode into the upper fornix. Next the patient was asked to look up and the bottom portion of the contact lens/electrode was then placed into the lower fornix. After properly positioning the patient in the ganzfeld flash apparatus, they were instructed to look straight ahead. Three separate tests were then run on each eye. The first sequence of flashes tested rod function at low light levels. The second sequence of flashes tested rod/cone function at high light levels. The third sequence tested cone function only. The first sequence was done by using white light and setting the PS 22 photostimulator stimulus intensity on I, the lowest setting, the frequency on 5 cps and presenting fine separate flashes each spaced five seconds apart. In the second sequence, white light was again used with the photostimulator stimulus intensity set on 16(the highest setting), the frequency on 5cps, and presenting five separate flashes each spaced five seconds apart. The final sequence used white light with a stimulus intensity on 16 and a continual flash flickering at 30 Hz for 30 seconds. ERGs were run on eleven patients(22 eyes), the data compiled, analyzed and the standard deviation calculated for each test sequence. The results of these tests are listed in the following tables.

Protocol summary:

1) Normal, healthy person around 20 years of age with less than 8.5 diopters of myopia.
2) 10 minutes of dark adaptation with patching of non-tested eye.
3) Very dim ambient room illumination with red light as only light source.
4) Anesthetic administered to cornea and eye lashes.
5) Ground electrode placed on opposite cheek with EEG conductive paste.
6) Contact lens electrode placed onto cornea with lubricating solution.
7) Test sequence:

OD1	intensity 1	5Hz	5 flash
OD2	intensity 16	5Hz	5 flash
OD3	intensity 16	30Hz	30 second duration

(sequence repeated for left eye)

RESULTS:
The data from eleven individuals(twenty-two eyes) were analyzed and compared with norms established by international standards. In each of the three trials implicit latency time and b wave amplitude were measured. Implicit latency time, the time from stimulus onset to b wave peak, and b wave amplitude, measured from a wave trough to b wave peak were measured by placing the cursors in the proper location on the computer video display screen. Cursor #1 was placed at the stimulus onset location and cursor #2 was placed at b wave peak for implicit latency time. Then, by simply moving cursor #1 to the a wave trough b wave amplitude can be determined. The data was then transposed into a log with implicit latency time being recorded in milliseconds and b wave amplitude in microvolts. Latency, the time from stimulus onset to first electrical response, a wave slope, c and d wave amplitudes were not used in this study. In the newer, more sensitive recording systems the latency time should be zero. The shape of the ERG curve for each response can be seen in the following pages. The small, rounded a wave normally seen in the rod only response was not the response that was typically seen in this study. A sharp, fast a wave was frequently seen suggesting a partial cone response was present.

The mean and standard deviation were calculated and tabulated. Normal ranges were determined to two standard deviation(95% confidence). To compensate for random experimental variation the high and the low values in each trial was not used. In test sequence number one runs six and seventeen were not used, in sequence two runs six and twelve were not used and finally, in test sequence number three runs thirteen and nineteen were not used in calculatin SD for b wave amplitudes. For implicit time SD calculations runs ten and eighteen were not used in trial one, runs four, nine and twenty were not used in trial two and runs fourteen and twenty were not used in trial three. The raw data, means, standard deviations and normal ranges are listed on the following pages.

TABLE I

	I PS#1,5flash,5Hz		II PS#16,5flash,5Hz		III PS#16,30Hz,30sec	
	b wave amplitude (uV)	implicit time (msec)	b wave amplitude (uV)	implicit time (msec)	b wave amplitude (uV)	implicit time (msec)
1)	191.4	52	218.5	50	18.7	19
2)	158.7	54	236.	50	21.1	19
3)	183.6	50	222.6	51	24.4	17
4)	191.7	53	227.1	53	20.3	18
5)	221.7	50	318	48	24.4	17
6)	222.2	52	336.9	46	20.3	18
7)	203.1	50	244.7	42	22.3	18
8)	135.7	50	209.1	43	15.0	18
9)	213.8	55	271	53	23.5	19
10)	205.5	56	263.7	50	28.4	19
11)	107.9	50	191	46	15.8	17
12)	108.9	53	169.3	45	14.6	18
13)	185.6	53	244.6	50	33.8	18
14)	180.2	52	248	47	23.7	20
15)	168	50	193.4	46	14.9	17
16)	171.4	51	239.7	45	17.1	16
17)	86.1	51	245.1	41	22.2	16
18)	202.1	44	235.8	39	24.4	17
19)	154.3	47	194.8	38	14.2	15
20)	191.0	47	217.8	37	17.3	13
21)	159.5	53	210.6	40	17.8	16
22)	159.5	56	202.2	40	17.4	18

Table II

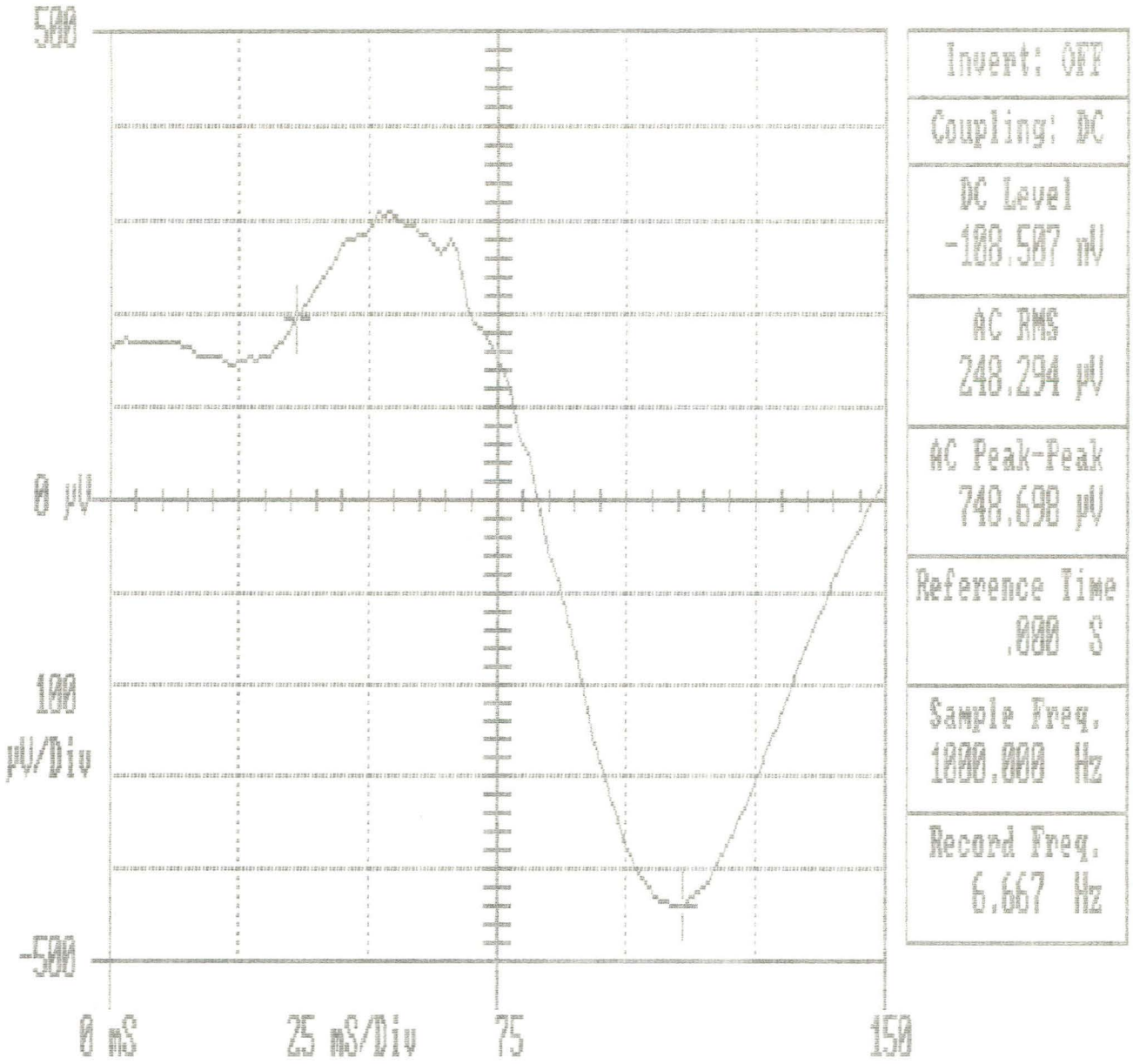
Mean, Standard deviation, and Normal Ranges

	I PS#1,5flash,5Hz		II PS#16,5flash,5Hz		III PS#16,30Hz,30sec	
	b wave amplitude (uV)	implicit time (msec)	b wave amplitude (uV)	implicit time (msec)	b wave amplitude (uV)	implicit time (msec)
X	174.68	51.45	231.69	45.11	20.18	17.5
SD	31.46	2.33	30.50	4.19	3.92	1.15
2SD	62.92	4.66	61.0	8.38	7.84	2.30
Normal Ranges:	111.76to 237.6	46.79to 56.11	154.58to 312.41	31.73to 53.49	12.84to 28.02	15.3to 19.8

Previously Established Norms For The ERG [3,2]

	b wave amplitude (uV)	Implicit time (msec)
Rod only response (30 min dark adapt.)	200 - 350	50 - 60
Rod-Cone response	350 - 600	45 - 60
Cone only response (10 min light adapt.)	100 - 200	23 - 25

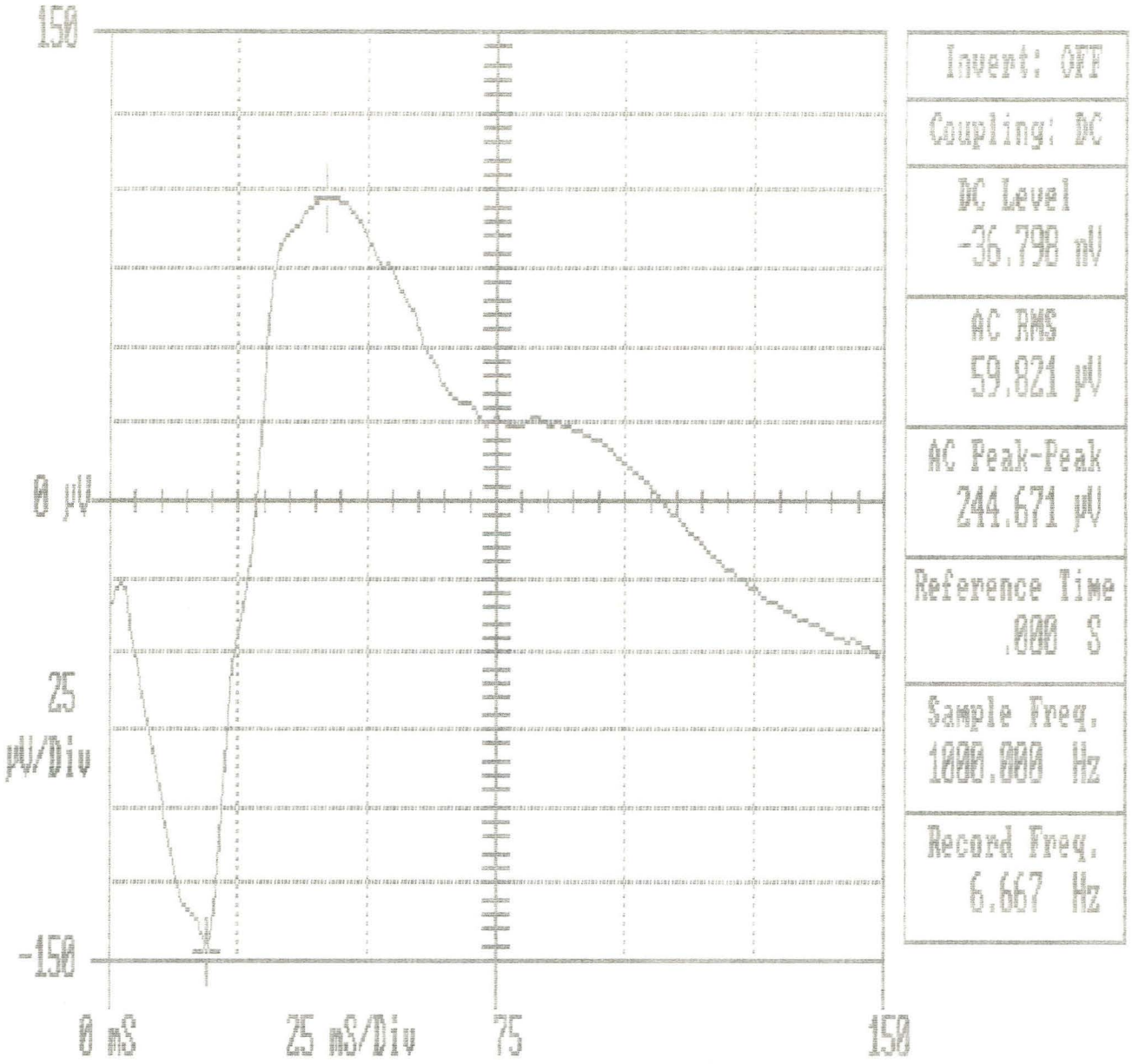
File: ZIELIMS.OD1 Channel 1 Raw Data



Cursor	Amplitude	Time	Sample #
#1 ↔	194.499 µV	36.000 mS	37
#2 ↓↑	-437.826 µV	111.000 mS	112

95% ConInt = 434.57 µV

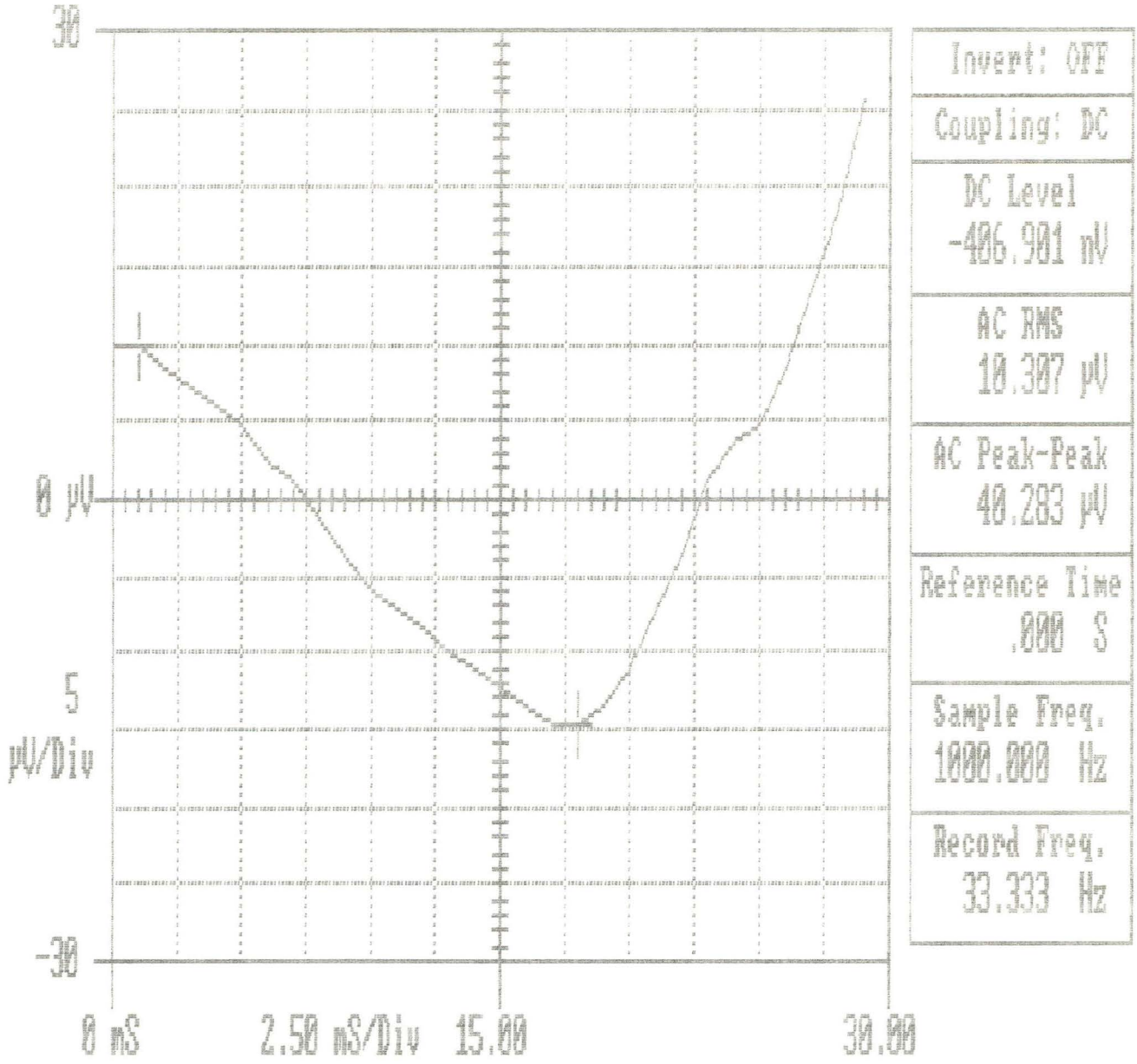
File: HENNING.002 Channel 1 Raw Data



Cursor	Amplitude	Time	Sample #
#1 ↔	-146.591 µV	19.000 mS	20
#2 ↕	98.081 uV	47.000 mS	43

95% ConInt = 75.37 µV

File: HACK.003 Channel 1 Raw Data



Cursor	Amplitude	Time	Sample #
#1 ↔	9.766 µV	1.000 mS	2

95% Conint = 78.80 µV

DISCUSSION/CONCLUSION: The ISCEV has developed recommendations for the standardizing of the ERG. The following is a summary of these recommendations:

1) Full field ganzfeld apparatus for uniform stimulation
2) Contact lens electrode(either bipolar or unipolar) applied with one drop of 0.5% carboxymethlycellulose
3) Skin area should be cleaned and conductive paste used prior to the placement of skin electrodes
4) Skin electrodes should have a resistance of no more than ten kilohms with a frequency range of 30 to 200Hz
5) Assure baseline voltage is stable in the absence of light
6) Proper disinfection of electrodes to prevent spread of infectious disease
7) Single flash stimulus duration should not exceed 5msec
8) White light used with diffusers having a color temperature near 7000K
9) A standard flash strength (SF) of 1.5 to 3.0 cd/m2sec
10) Background illumination should be steady and be adjustable to the strength of at least 17 to 34cd/m2(5 to 10FL) across the full field for cone only resonses.
11) A light source capable of attenuating the flash strength by 3.0 log units continuous or in steps of no more 0.25 log units.
12) Amplifiers and pre-amplifiers should have a frequency range of 0.3 to 300 Hz. Pre-amplifiers must have an impedence of 1 megaohm. Amplifiers shoud be AC-coupled.
13) Instuments should be adjustable for oscillatory potential recording.

Protocol:

1) Pupils should be dilated and measured if maximium dilation is not achieved.
2) Dark adaptation of at least 20 minutes. FANG or fundus photography should not be done before an ERG. If it is, one hour of dark adaptation is required.
3) Insertion of contact lens electrode can be done under dim red light.
4) Standarization reports should contain: waveform tested, amplitude and implicit time calibrations, state of dark adaptation, and stimulus parameters.
5) Standards should include: rod only response, maximium or rod-cone response, an oscillatory potential response, a single flash cone response and a cone flicker response.

Rod-response

a) This should be the first signal measured since it is the most sensitive. The stimulus strength should be 2.5 log units below SF with at least two seconds between each flash.
b) A low frequency stimulus is used to maximize the rod response. A frequency of 5Hz is recommended.

Maximum or Rod-Cone response
- a) A SF is used with at least five seconds between flashes
- b) A frequency of 5Hz is recommended

Oscillatory Potential response
- a) SF in dark adapted eye
- b) Use of high pass filters set to 75-100Hz so the over-all band pass has a low end cut off of 75-100Hz and a high end cut off of 300Hz.
- c) Flashes 15sec apart, discarding first response.

Single Flash cone response
- a) SF strength is used
- b) Background illumination of 17 to 34cd/m2(5-10fFL) to suppress the rod response
- c) Patients should be light adapted for ten minutes before recording the cone ERG

Continual Flicker Cone response
- a) Use of rod suppressing background illumination as described above.
- b) Recommend light adapted state as above
- c) SF stimulus strength
- d) 30 Hz flicker frequency
- e) Continual stimulus for 30 seconds [4,5]

Comparing our norms with pre-existing norms it can be seen that there is an over-all reduction in b wave amplitudes. This can be explained by the different states of dark adaptation used in each standard. Our standarization used an abbreviated protocol that only required ten minutes of dark adaptation while the established norms used a 30 minute time period. Unfortunately, no norms were found in the literature that used a ten minute dark adaptation period, so a direct comparison could not be made. Implicit latency times compared very favorably with published values.The implicit time for the rod only response was 46 to 56 msec which compared with the pre-existing values of 50 to 60 msec. For the rod cone rsponse, implicit times were 32 to 53 msec as compared with the published norms of 45 to 60 msec. The cone only response had an implicit time of 15 to 20 msec as compared to standard implicit times of 23 to 25 msec. In each trial comparison our implicit times were slightly faster than recorded values. These differences were not considered to be clinically significant and can be the result of normal experimental variation.

Our testing procedure closely followed international standards established for the ERG. The areas of non-compliance would include: 1) Patients were not dilated prior to testing. For most patients, since illumination levels were controlled, pupil size would remain fairly constant and a small reduction of b wave amplitudes would result, but be accounted for in the standardization. This is not

true, however, for patients with miotic pupils secondary to therapeutic drops or disease states. 2) Single flash cone only response was not performed. 3) Patients were not light adapted for ten minutes prior to the cone only response. 4) A rod suppression background illumination was not used for cone only responses. Even though a 20 minute dark adaptation period is recommended, the ten minute abbreviated protocol is also clinically correct and useful, especially when time is a factor or in very young children who may have difficulty dark adapting for 20 to 30 minutes. The disadvantages of the ten minute abbreviated protocol are the smaller b wave amplitudes and established norms, if they exist, are not readily available.

In order to produce better and more reliable ERG normative data we recommend the following: 1) Dilation of patient prior to dark adaptation period. 2) Light adaptation for ten minutes prior to testing cone only responses. 3) Test a single flash cone only response. 4) Change background illumination to a rod suppression by increasing it to 17 to 34cd/m2. 5) Consider running two sets of standards, one an abbreviated ten minute protocol and another a twenty minute dark adapted protocol. 6) Consider using a blue filter for the rod only response in the abbreviated protocol. As mentioned in the result section, the typical rod only response was always acheived. Since blue light produces more of an affect on the rod system then on the cone system, the blue filter should help to elicit a rod only response. If these recommendations were followed, only a few changes need be made to the abbreviated protocol with the expanded protocol implemented with the above suggestions already in place.

Clinically, the ERG can be used to diagnose many conditions before any retinal signs are present. Ikeda et al state that changes in the electrical potential of the retina (ERG) are the earliest detectable signs in inflammatory eye disease. Some biochemical changes appear to take place before any pathological changes in these structures or in the retinal vessels are detectable by ophthalmoscopy or fluorescein angiography. In some disease states specific portions of the ERG are altered while the rest appears normal. The oscillatory potential can be abnormal early in some diseases even though the b wave itself is normal. In diabetes, before any signs of diabetic retinopathy can be seen, the ERG shows a delay in the oscillatory potential while the b wave is normal.

The primary role of the ERG has been in the differential diagnosis of retinitis pigmentosa (RP) from the different forms of congenital stationary night blindness (CSNB). Early in RP the ERG will show decreases in a and b wave amplitudes and a delay in the implicit latency time. In CSNB, the a and b wave amplitudes are also decreased but the implicit latency time is normal. This is the only test

available that can make the distinction between these two disease entities. The ERG is also useful when there is a suspected field loss secondary to emotional and/or psychological distress. In such patients, the ERG will be normal. Other uses for the ERG include systemic conditions associated with RP, Leber's amaurosis, and cone dystrophies.[8]

In conclusion, the ERG is a very sensitive electrodiagnostic tool used in the early detection of specific retinal diseases like retinitis pigmentosa. In order to tell what is abnormal a value must first be given to what is normal. Normal ranges set limits on what is normal. If a value falls outside of this set range it can be considered abnormal with a high degree of confidence (2SD range, as used in this study, gives a 95% confidence value). The ISCEV and the National RP Foundation came up with a standard procedure with the hope of establishing unified ERG testing throughout the world and to obtain true comparability of retinal responses over time and place. Even though they recommend five basic responses be tested, not all of these responses may be needed or required in a given laboratory. No matter what standard test procedure is used their major recommendation is that each laboratory establish or confirm normal values for its own equipment and patient population. This last recommendation was achieved in this study; normal ranges were established for the twenty-year-old age group.

1,3,8,9

Conditions Associated With Abnormal ERGs

1) Retinitis Pigmentosa a) RP sine pigmento b) Retinitis puncta albescens c) Sector RP d) Pericentric RP e) Unilateral RP(DUSN)	Marked decrease in a and b wave amplitudes and implicit latency
2) Systemic conditions associated with RP a) Bassen-Kornzweig syndrome(abetalipoproteinaemia) b) Refsum's syndrome(phytanic acid storage disease) c) Usher's syndrome d) Cockayne's syndrome e) Kearns Sayre syndrome f) Mucopolysaccharidoses(types 1,2 and 3) g) Laurence-Moon-Biedl syndrome h)Friedriech's ataxia	
3)Leber's congenital amaurosis	Marked decrease in ERG amplitudes,(a and b wave) normal looking fundus
4) CSVB a) normal fundus	Marked decrease in b wave amplitude,normal latency Also can have a decrease in both a and b wave amplitudes
b) Fundus albipunctatus	3 hrs. for normal ERG. Fundus signs present
c) Oguchi's disease	Normal a decreased b wave amplitude.Mizuo phenomenon
5) Favre Goldman syndrome	Decrease in a and b wave amplitudes(non-readable)
6) Cone dystrophies a) Rod monochromatism	Abnormal photopic, normal scotopic ERG. Macular changes noted
b) Progressive cone dytstrophy	Abnormal photopic, normal scotopic ERG.Fundus changes variable
7) Cancer-associated retinopathy (CAR-syndrome)	Extinguished ERG. Mild retinal changes

1,3,8,9

Abnormal ERGs associated with gross retinal changes

1) Chorioretinitis	No ERG in end stage.
2) Metallosis	Unilateral. No ERG
3) Retinal detachment	Unilateral. No ERG
4) Drug toxicity	
a) Chloroquines and derivatives	No ERG in affected areas
b) Phenothiazines	No ERG in affected areas
c) Diphenylhydantoin	Decreased b wave similar to CSNB
5) Gyrate atropy	Marked decrease in ERG at end stage of disease
6) Choroideremia	Normal early when fundus appears normal
7) Wagner's disease	ERG normal to subnormal
8) Stargardts/Fundus flavimaculatus	ERG decreased only in advanced stages
9) Pattern dystrophies	Only slight reduction in ERG amplitudes
a) Butterfly	
b) Sjogren's reticular	
c) Macroreticular	
10) Vitreal hemorrhage	No ERG to Mark decrease in a and b wave amplitudes Usually can't be performed
11) Central retinal artery occlusion	Normal a wave decreased b wave amplitude
12) Central retinal vein occlusion	Normal a wave decreased b wave amplitude
13) Optic atrophy	Normal a wave decreased b wave amplitude
14) Juvenile retinoschisis	Normal a wave decreased b wave amplitude. Normal when fundus appears normal

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