An Application of Electrical Excitability Test in Addition to ERG and EOG as a Diagnostic Method for Fundus Diseases

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(Received March 3, 1969)

Introduction

It has long been recognized that light sensation can be produced by electrical stimulation of the eye. The sensation of phosphene has been well known and long established. A considerable amount of fundamental work along these lines has been and is being done by physiologists, such as studies of color vision by Motokawa and his coworkers in our country. Besides such fundamental works, the electrical excitability of the human eye was used as a diagnostic method for ocular diseases by ophthalmologists. But a majority of the work was done prior to the time that the electro-retinogram became common in eye clinics. And in those days, ophthalmologists had to use electrical excitability as a single electro-physiological index to diagnose ocular diseases.

Now, there is ERG to use in clinics, and also for the standing potential of the human eye, EOG techniques can be used easily.

It may be supposed that if those electro-physiological tests were used together in a clinic, further information to discribe ocular diseases in more detail might be given. And the most interesting point for us is that light and electric stimulation seem to affect a different layer or layers of the retina.

This is the starting point of this work.

Procedure

To examine the electrical excitability of the eye, a twenty cycle oscillator modified by Motokawa (Tōadenpakogyo K. K.) was used.

Figure 1 shows how the electric current of the device changes.

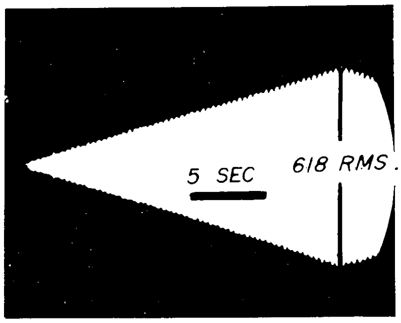

Fig. 1. Shows the increasing retio of current by the twenty cycle oscillator used for these experiments. In this model, instead of a subject, a 15 KΩ resistor was inserted between the two electrodes.

In this case, instead of subject a fifteen Kilo-Ohms resistor was inserted between the two electrodes. Fifteen Kilo-Ohm approximately corresponds to our experimental conditions.

The current increases along straight line, and its increasing ratio is about 41 μA p-p (peak to peak) or 29 μA R. M. S. (root mean squared) every second. The maximum current which can be applied by this device is around 875 μA p-p or 618 μA R. M. S.

Round shaped silver, silver-chloride plates, 1 cm in diameter are placed on the skin with electrode-paste around the upper and lower orbital margin of either eye. The current is then slowly increased in ratio. At the point when the subject begin to recognize phosphenes, that amount of current is recorded as the threshold. The threshold is recorded every minutes during 10 minutes of 20 Lux prelight adaptation, followed by 15 minutes of darkness, and then 15 minutes of 1250 Lux light adaptation. The methods for ERG and EOG will not be discribed here for they are similar to those we reported elsewhere.[1]

Results

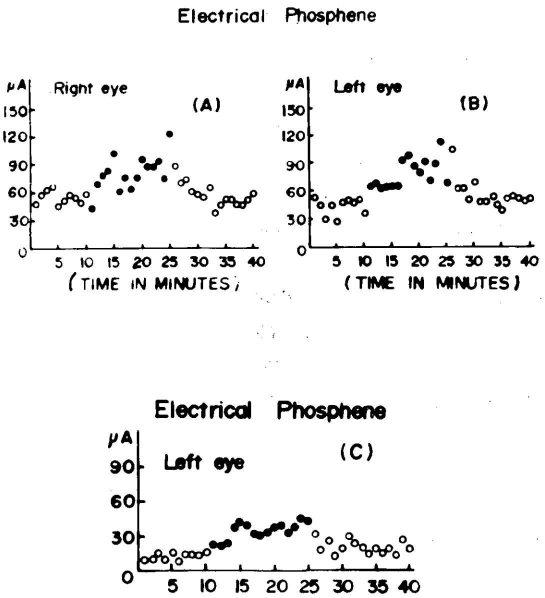

Fig. 2. Shows the results of electrical excitability of two normal subjects. A and B were recorded from each eye of the same subject but C was made with a different subject. A and C show differences in value under the same condition for two normal subjects. A and B though done at different times but under similar conditions on the same subject show quite similar results.

Figuie 2 shows the results of electrical excitability of two normal subjects during the illumination changes. In the figure, the ordinate shows thresholds in arbitary units: this means, to describe the intensity of the current, the scale attached to the device was used in this experimental series, so that the value shown here is a little different from actual ones. That is, 300 μA in the figure roughly corresponds to 618 μA R. M. S.

In each figure, the first 10 open circles represent values during the 20 Lux illumination. Sometimes the term prelight adaptation is used for this phase. The solid circles represent the values in darkness, and the last 15 open circles were values obtained during 1250 Lux illumination.

Of course, the threshold value varies a great deal from person, to person due to the position of the electrodes, impedance variation, unknown personal sensitivity and so on. But so far as the tests have been done on normal subjects, the threshold in prelight adaptation was found to be below 60 μA in the arbitary units. In normal subjects the threshold in darkness becomes higher than in prelight adaptation, and in bright light the values are lower than in darkness but a little higher than in prelight adaptation.

Case 1:

A 16 year old male: He has corrected vision of 0.6 in both eyes, though he has high grade myopia. In both of his eyes, he has ring scotoma between 10° to about 20° or 30°, but central field appears to be normal and peripheral field tested by 10/330 white target is still within normal range. His dark adaptation, however, is affected slightly: i. e. $1^2/4^2$ by Förster's photometer in both eyes. Ophthalmoscopically, except for slight attenuation of the retinal vessels and a few pigment deposits in his right eye, no characteristic finding was found. The patient had not been aware of any visual disturbance, but an uncle who was aware of hereditary factors brought him to the clinic.

Case 2:

A 37 year old male: His pigmentary degeneration has progressed further than that of his nephew. Though in both eyes the visual field is restricted to 5° from center, corrected vision for both eyes is 0.6. Ophthalmoscopically, both eyes show charactristic findings of pigmentary degeneration.

Figure 3 shows the results of these electro-physiological tests upon Case 1 who is in a relatively early stage of pigmentary degeneration. The electro-retinograms of the patient are shown in the top of the figure. The recordings are somewhat distorted, but the patient was a little nervous during the test and had a strong blinking reflex to light stimulus.

However, both of his eyes show some negative response to stronger stimuli. The electro-oculograms of both of his eyes are illustrated in the middle of the figure. The recordings were actually done for other purpose, so the experiment was of longer duration than we usually make. Here, the amplitude of excursion of EOG is plotted along the ordinate in μV. The same illumination system as for electrical excitability test was used for EOG, so that the first open circles are values during the 20 Lux illumination, the solid circles represent the values in darkness, and the last open circles show the values during 1250 Lux illumination.

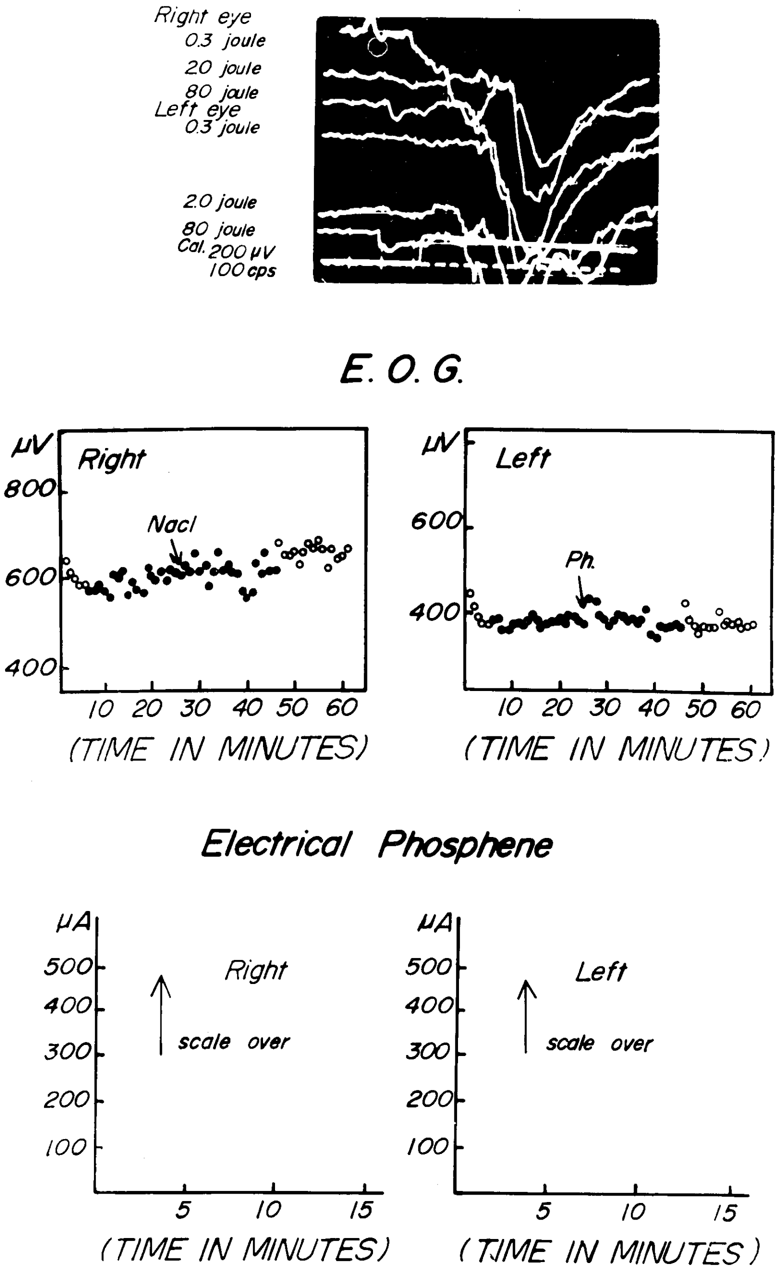

Fig. 3. Electrophysiological findings of Case 1.

Neither dark trough nor light rise can be seen in the figures from both of his eyes. In the bottom of the figure, his electric excitability is illustrated but as shown in the figure, he could not see any phosphene even when maximum current was applied by our oscillater. This means that his thresholds were higher than 618 μA R.M.S. in both of his eyes.

A similar illustration for Case 2 is shown in Figure 4.

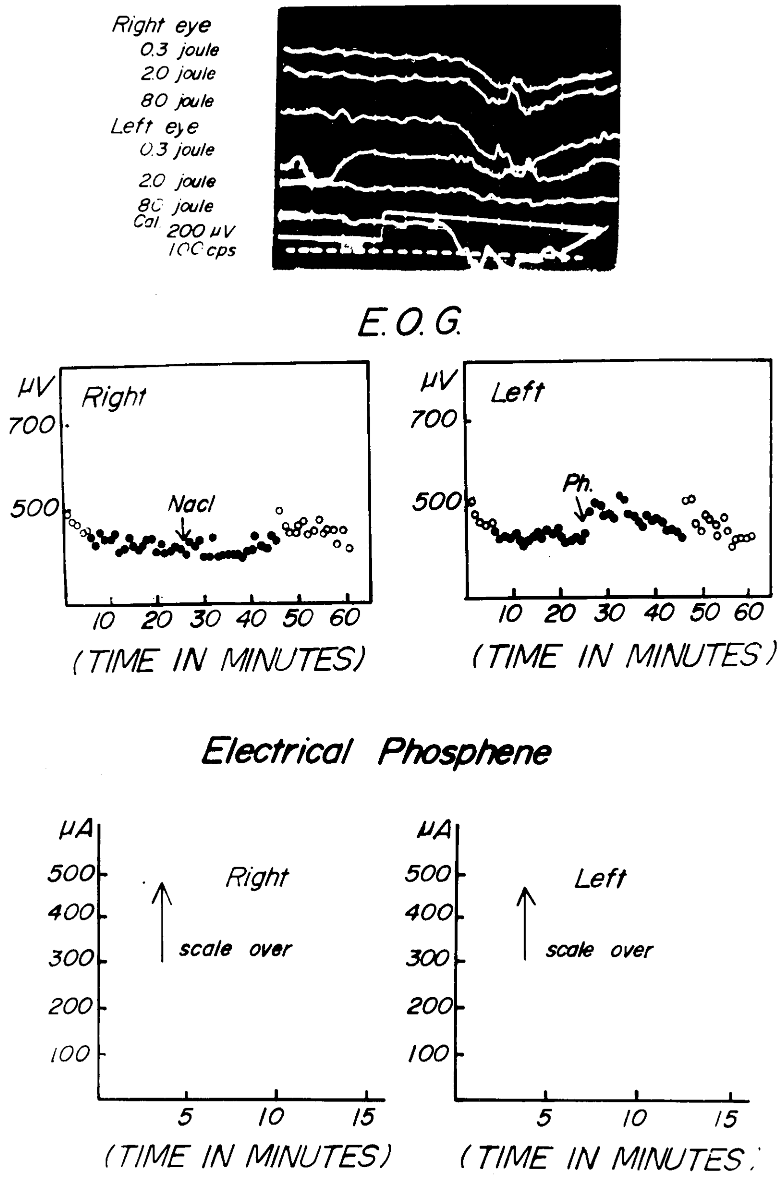

Fig. 4. Electrophysiological findings of Case 2.

The subject has an extinguished ERG and a flat type EOG during illumination changes as well as a higher threshold for phosphene than the maximum current available on our equipment.

Case 3:

A 66 year old female: Vision in her right eye was 0.9 and in her left eye it was 1.0. She did not complain of any visual difficulties in darkness, but Förster's photometer revealed a dark adaptation disturbance in her left eye. It was $1^2/1^2$ in her right eye and $1^2/10^2$ in her left eye. Visual field in her left eye was restricted to about 10° from center, while in her right eye it was about normal in range. Ophthalmoscopically, in the left eye many pigment deposits similar to primary pigmentary degeneration were found, but narrowing of the retinal vessels

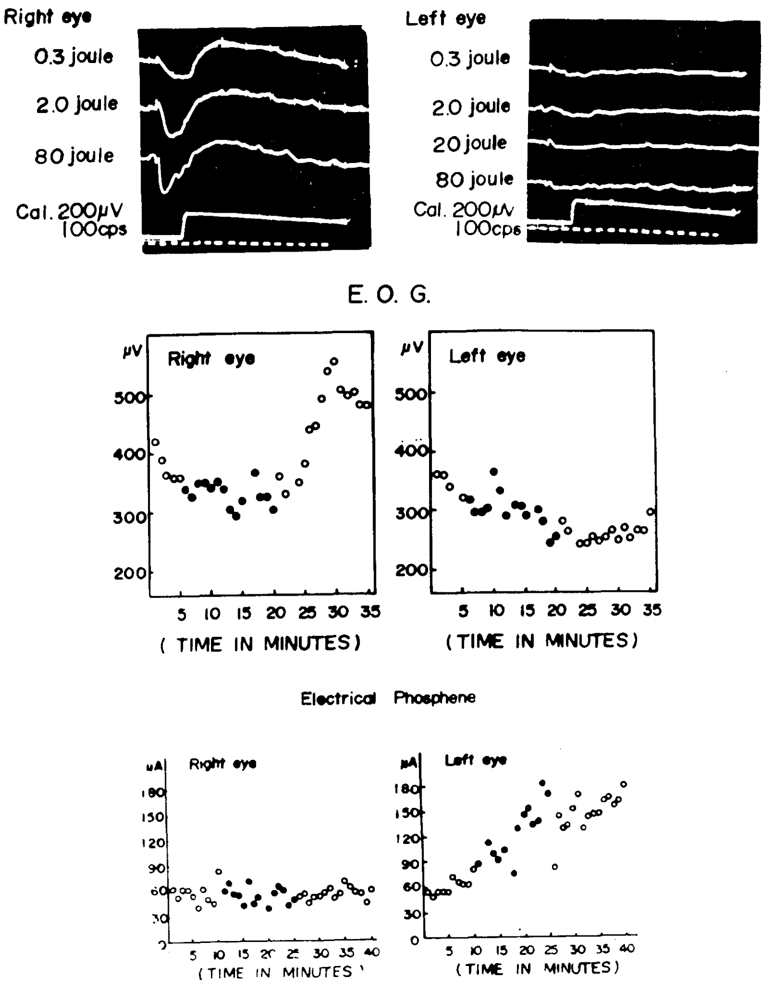

Fig. 5. Electrophysiological findings of Case 3.

was not significant. In the right eye no pigment deposits were found but in the peripheral fundus there were some areas of clouded nuances which could not be clearly diagnosed. Her Wasserman test was positive.

Case 4:

A 32 year old female: She had had Harada's disease a month before the tests. When the tests were made, the vision in her right eye was 0.3 and in her left eye it was 0.5. The subject had had a periphehal retinal detachment in both eyes which had been successfully resolved and the subject was tested shortly after retinal restoration. Some retinal opaqueness remained at the time of the tests.

Figure 5 shows the results of the electro-physiological tests on Case 3.

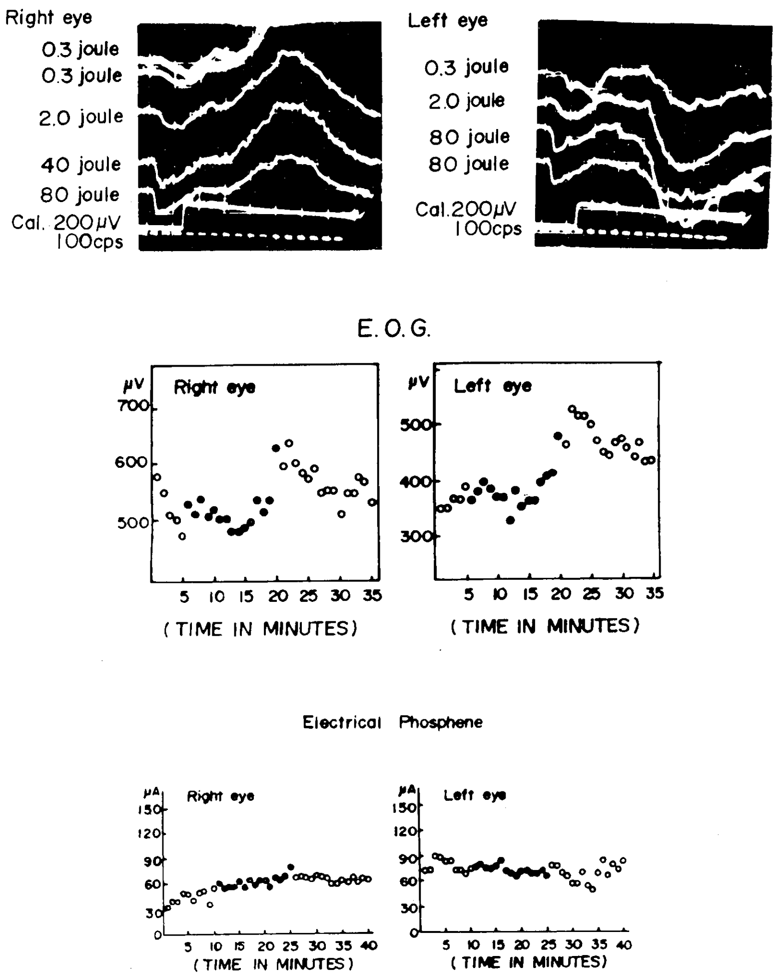

Fig. 6. Electrophysiological findings of of Case 4.

The ERG of her right eye is about normal in shape and amplitude, but her left eye has an extinguished ERG. The EOG of her right eye is also normal with the ratio of light rise to dark trough being 1.94. But in the left eye no light rise was observed. These finding of ERG and EOG for the left eye are similar to those of pigmentary degeneration, as has already been mentioned.

However, thresholds for electric phosphene of both of her eyes in prelight adaptation are almost the same, about 60 μA, which are in normal range. In her right eye there was no significant threshold change during the alterations of the illumination, and in her left eye the lowering of the threshold was not found during reillumination. Figure 6 shows those results upon Case 4. In that figure both of her ERGs have a big swing for blinking reflex which destroyed the normal ERG course, but a and b waves can be seen though they are depressed.

Both of her EOGs show an abnormal course during the illumination changes. There is no typical light rise as in normal eyes which usually peak around 8 minutes after illumination. Though it is difficult to calculate the ratio of her light rise to dark trough, it seems that to say that the EOG is abnormal is a proper judgment of the results.

Concerning the electric excitability of this patient, though the response to illumination changes is poor for both eyes, their thresholds in prelight adaptation are about normal in range, even though in the left eye it is a little high.

Discussion

By using special electrodes to stimulate the human eye, Brindley[2] tested the relation-ship between the place stimulated and the place of felt phosphene, and also the effect of blinding the eyes by pressure on the phosphene. He found that one hundred times threshold current caused no visual sensation when both eyes were pressure-blinded, and suggested that the structures stimulated may be bipolar cells or the parts of rod and cone cells lying inside the external limiting membrane. Mita, Fujimaki and Yaegashi[3] tested the relation-ship between electric threshold and log-illumination according to the frequency of the alternating current, and found the electric threshold for frequencies around 3 cps had the closest correlation with CFF but the same correlation was not found in cases of other higher frequencies. They suggested that the structures stimulated by the sinusoidal alternating current at 3 cps might be the cone and rod cells, while those stimulated by the current at 15 or 20 cps might be, supposedly, the bipolar cells.

Other evidence by Motokawa[4] using a micro-electrode on a carp's excited retina suggested that the retinal network intervening between the receptor cell layer and the ganglion cell layer gave the greatest response to electrical stimulus.

Recently, Potts, Inoue and Buffum[5] succeeded in recording with scalp electrodes the human occipital response to electrical stimulation of the globe. They found that the response had a measurably shorter latency than that of VER of the same subjective brightness. They suggested that at least one step in the retinal transmission chain has been bypassed by electrical stimulation.

The layer or layers which can be stimulated electrically within the range of intensities we have used is not yet certain. But it now seems very probable that the layer or layers which can be stimulated electrically by threshold current are situated further inward than the layer stimulated by light.

In the cases we have discussed, electro-physiological results seem to show that the layers destroyed by chorioretinitis are relatively localized in outer layers. However, in pigmentary degeneration, even in its very early stages, inner and outer layers seems to be affected simultaneously.

By the example of the cases discussed here, it is shown that a combination of electro-physiological tests can reveal the pattern of fundus diseases in more detail and that such tests can be useful and helpful for clinical use.

(This paper was presented at SYMPOSIUM ON ELECTRORETINOGRAPHY in KAMOGAWA, CHIBA on Feb. 28, 1969 to welcome Dr. R. Granit and Dr. H. E. Henkes. The authors should like to thank Dr. R. Granit for his kind comments, and also to acknowledge the technical assistance of Miss S. Nakao.)

SUMMARY

The electrical excitability of the eye was tested in addition to ERG and EOG. The relation ship between the results obtained by those tests is examined for primary and secondary pigmentary degeneration, and on chorio-retinitis.

In primary pigmentary degeneration, even in its very early stage, the electrical excitability, ERG and EOG are affected simultaneously. But in secondary pigmentary degeneration and chorio-retinitis, the electrical excitability is moderately well retained though EOG and ERG are significantly affected.

It is considered that the layer or layers which can be stimulated by threshold electric current are situated further inward than the layer stimulated by light, so the electro physiological results seem to show that the layers destroyed by chorio-retinitis and secondary pigmentary degeneration due to chorio-retinitis are relatively localized in outer layers. But in primary pigmentary degeneration, inner and outer layers seem to be affected in parallel.

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