ELECTRO-OCULOGRAPHY*† A SEMI-AUTOMATIC RECORDING PROCEDURE

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ELECTRO-OCULOGRAPHY has been established as a valuable clinical procedure for measuring indirectly the standing corneo-fundal potential, of importance in the investigation of retinal and choroidal function.

Although the technique of clinical recording is not very complicated, the load of a great many records is a burden for the technical staff of an electro-diagnostic clinic. Semi-automatic recording, using a simple and reliable technique, has proved to be of help in this situation.

FIG. 1.—

(A) Principle of recording of standing potential based upon alterations in the electric field resulting from eye movements.

(B) Resulting changes in potential between the electrodes.

(C) The upper trace of the original graphs shows movements of the right eye; the lower one of the left eye. The amplitude of the initial vertical excursions is a measure of the height of the standing potential.

(a) after 12 minutes dark adaptation; (b) 8 minutes after re-illuminating the retina.

Calibration bars: 500 microvolts, 500 msec. (after Arden and Kelsey, 1962).

* Received for publication December 12, 1966.

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Clinical electro-oculography measures the standing corneo-fundal potential indirectly by voluntary eye movements. When the eyes are moved and the head remains still, a change in potential can be recorded between two electrodes attached to the skin at either side of the eye. After amplification, this change is fed into a direct recording system (*e.g.* an electro-retinogram or electro-encephalogram apparatus). Thus a kind of square wave is produced in which the vertical deflections correspond to the height of the standing potential (Fig. 1, opposite).

The height of these deflections depends not only on the angle through which the eye is moved (30° in our set-up), but also on the condition (*e.g.* the adaptive state) of the structures responsible for the generation of the corneo-fundal potential (*i.e.* retina and choroid: photoreceptors, pigment epithelium, Bruch's membrane and choriocapillaris).

An absolute measurement of the standing potential is not intended here. A valuable datum appears to be the relationship between the smallest deflection recorded during a period of 12 minutes in the dark, and the largest one recorded in a subsequent period of about 15 minutes in the light (the L/D ratio: Arden and Kelsey, 1962; Arden, Barrada, and Kelsey, 1962; Arden and Barrada, 1962).

The L/D ratio may vary considerably from person to person, as well as in the same person from time to time. We found for example that the blood sugar level plays an important role (Henkes, van Lith, Gaisiner, and de Haas, 1966).

A concise description of the clinical procedure has been given by Kelsey (1966). Every minute five to six successive eye movements are made during a period of approximately 10 seconds. In the normal routine procedure a curve is constructed representing height of deflections *v.* time, under both dark and light adaptation (Fig. 2*). To construct the graph, the mean value of three deflections is taken. The selection of deflections to be measured is easily done if the subject produces regular eye movements, but may be difficult if the voluntary eye movements are irregular.

FIG. 2.—EOG curves recorded twice in the same subject. Height of deflection *v.* time during dark and light adaptation (retinal illumination about 20,000 trolands).

To simplify the procedures of measuring and constructing the graphs, we used an oscilloscope with a very slow time base (the light spot covers the CRO screen in 30 minutes). The signal is fed into the vertical amplifier, so that successive eye movements are each displayed on the screen as one straight vertical bar. Every minute one bar is produced and photographed.

* This figure illustrates a case of tapeto-retinal dystrophy of the left eye, the right eye being normal. Records of this patient were taken on two different occasions.

Only if the subject's eye movements are regular, can the L/D ratio be easily measured from the Figure (Fig. 3).

With untrained subjects, the records may be grossly distorted, but the introduction of a selective amplifier tuned to the frequency of the eye movements improved this situation, and to assist the rather laborious technique, a semi-automatic procedure was introduced.

FIG. 3.—EOG bar-figures recorded in a trained subject. Each bar has been produced by five to six successive deflections (eye movements). The procedure was repeated each minute for 25 minutes. Time base: full CRO screen (10 cm.) in 30 minutes. DA: dark adaptation during 12 minutes. LA: light adaptation. The L/D ratio can be measured from this Figure. Selective amplification was not used in this case.

FIG. 4.—Frequency response of selective filter.

Method

A magnetic tape provides instructions for the subject and operates two fixation lights, only one of which is lit at a time. They alternate at a frequency of 0.5 per second and the eyes move once a second from one fixation light to the other. This alternation is carried on for 15 sec. every minute. The eye movements cause a potential change between the electrodes, and this electro-oculogram signal is amplified and fed into a frequency selective filter (quality factor $Q \approx 2$), tuned to 0.5 c.p.s. (Fig. 4).

As a result of this, only the fundamental frequency component of the eye movements passes through and the irregularities are highly reduced. As, in the first few seconds of the period during which the fixation lights are followed, the transients are preponderant, only the last 5 seconds of each 15-second fixation period are used. Because of the slow time base, only one vertical bar becomes visible on the screen and is photographed during this period. The bars, which are recorded each minute for 25 minutes, build up composite figures as in Figs 6 and 7 (overleaf).

As we expected, a given irregularity in eye movements while following the fixation lights is now less disturbing.

A block diagram of the set-up is shown in Fig. 5A, and a schematic drawing of the tape controlling the various procedures in Fig. 5B (opposite).

EOG bar-figures obtained by this method are reproduced in Fig. 6A–C.

In most clinical cases the results are good, and even in less co-operative patients (Fig. 7) passable recordings are obtained.

FIG. 5A.—Block-diagram of semi-automatic recording procedure.

F₁, F₂: fixation lights subtending 30°.

E₁, E₂: skin electrodes attached to each side of the eye.

FT: 13 fluorescent light tubes, providing background illumination during light adaptation.

OSC I: monitor CRO.

OSC II: recording CRO provided with camera.

FIG. 5B.—Tape with strips of aluminium foil provides instruction for the subject, operates fixation lights (which in turn govern the eye movements), turns on the adapting lights, and operates the brightness of the oscilloscope screen II.

Summary

A semi-automatic recording procedure for clinical electro-oculography is described. A tape-recorder provides instructions for the subject and controls the fixation lights, background illumination, and recording system. A selective amplifier is used to reduce the disturbing effect of possible irregularities in eye movements.

FIG. 6A.—Representative EOG bar-figure obtained with the aid of a selective amplifier. The L/D ratio can be accurately estimated.

Upper figure: right eye. The increase in corneo-fundal potential in light adaptation is within normal limits for both eyes.

FIG. 6B.—EOG bar-figure in a case of unilateral tapeto-retinal dystrophy. In light adaptation a slight decrease in standing potential of the left eye becomes visible, implying a complete functional loss of tissues generating the corneo-fundal potential.

FIG. 6C.—EOG bar-figure in a psychiatric patient suffering from phenothiazine-retinopathy. The L/D ratio is subnormal in both eyes.

FIG. 7.—Although distorted by lack of co-operation, the semi-automatic record of the EOG in a phenothiazine-treated patient can still be evaluated as normal.

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