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The eye blink electro-oculogram

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SUMMARY An electro-oculogram (EOG) was derived from potentials recorded from electrodes placed above and below the eye during voluntary vertical eye movements. Concurrent measurement of the amplitude of eye blink potentials recorded from the same electrodes produced curves which were highly correlated with the EOG measured from stereotyped eye movements. Recordings from a patient with a missing globe, owing to trauma, revealed eye movement and blink responses only from the intact side. A patient with no light perception showed blink responses which were less variable than responses measured during attempts voluntarily to move the eyes vertically in 60° excursions. An EOG calculated by measurement of eye blink potentials may be possible in clinical situations where traditional electro-oculography techniques are not feasible.

The electro-oculogram (EOG) is considered to reflect the integrity of the pigment epithelium and adjacent photoreceptors of the eye.[1] The EOG is conventionally derived by having a patient alternately fixate targets placed to the right and left during dark and light adaptation. The potential is measured differentially from electrodes placed on each side of the bony orbit during stereotyped horizontal eye movements. The size of this potential is related directly to the magnitude of the corneoretinal potential.[2] Individuals with large central scotomas, patients with very small residual central visual fields, and subjects unable or unwilling voluntarily to produce standardised eye movements may present obstacles to the recording of the EOG by standard techniques.

Although the exact origin of the potential associated with involuntary eye blinks remains controversial, the major component unquestionably requires the presence of the optic globe and by implication the presence of a corneoretinal potential.[3] In this report the amplitude of potentials recorded during vertical eye movements and the amplitude of spontaneous blink potentials have been compared. An EOG derived by measurement of eye blink responses may represent an alternative to the usual clinical method in certain situations.

Subjects and methods

Twelve subjects with normal vision ranging in age from 20 to 51 were studied. One 67-year-old blind subject with congenital glaucoma and one adult subject who had lost the right eye from trauma at the age of 10 were also evaluated.

Silver-silver chloride electrodes were placed above the eyebrow and on the malar prominence in a vertical plane in line with the pupil. In a few cases leads were also placed in a horizontal plane opposite the medial and lateral canthi.

Subjects were seated before a perimeter with the chin in a firm rest 30 cm from a dim red fixation light located at 0°. Two intermittently illuminated targets were located 20° above and below the horizontal. The height of the chin rest was adjusted until the subject could look upward and downward with equivalent subjective effort.

Eye movement responses to alternating illumination of the upper and lower targets were recorded on a polygraph (pass band 0·1–35 Hz). Vertical placement of the recording electrodes maximised the recording of responses to spontaneous eye blinks.

Responses to a series of vertical movements of the eyes were recorded at 3 minute intervals for 45 minutes. Between measurements subjects were instructed to remove themselves from the chin rest and look in the direction of the light panel. Fifteen minutes of exposure to room light of approximately 500 lux was followed by 15 minutes of dark adaptation and then by 15 minutes of light adaptation to 1200 lux. Because the pupils were not artificially dilated actual retinal illumination could not be calculated.

Eye blinking was not mentioned to the subjects spontaneously. If asked, the experimenters merely

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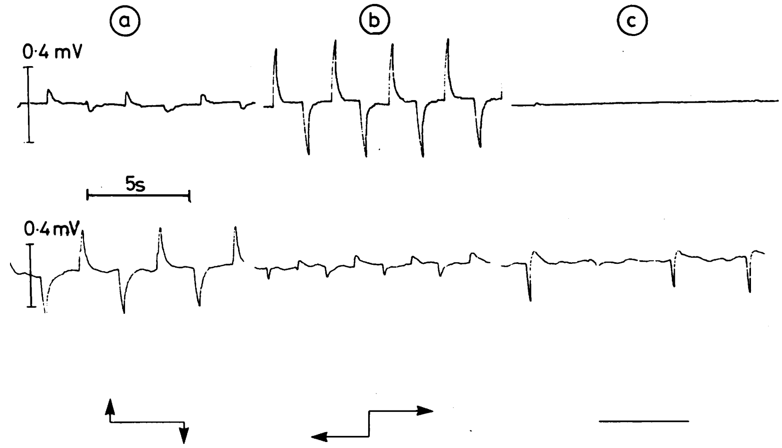

Fig. 1 *Comparison of potentials recorded from vertically placed (upper tracing) and horizontally placed (lower tracing) recording electrodes.* A. *Subject alternately gazing 20° upward and downward.* B. *Subject gazing alternately 20° to the left and to the right.* C. *Spontaneous eye blink potentials. Blink responses appear only in the vertically orientated leads and mimic an upward movement of the eyes.*

assured the subjects they need not worry about it one way or the other. Average eye blink potential amplitude was measured from the 5 responses before and the 5 responses after each series of vertical eye movements.

The blind subject was studied similarly. He refused formal ophthalmological examination, but had been told many years previously that he suffered from congenital glaucoma. He lost all subjective light perception at age 40, but was otherwise in good health and active in volunteer activities involving services for the visually impaired. The patient was unable to detect the fixation lights or the background panel even at its brightest setting of 2500 lux. Prior to the experiment his hand was passively located 30° upward and 30° downward. On verbal commands, 'up' and 'down' he was asked to direct his eyes to the imagined hand locations.[1] There was no visible impairment in his ability to move his eyes in any plane.

Results

Electrical responses to vertical and horizontal eye displacements in a normal subject (40° total excursion) are compared in Fig. 1. The EOG calculated from vertical movements was indistinguishable from that derived from the conventional clinical method utilising lateral eye movements and canthal leads.

Fig. 2 contains data from a typical subject with normal vision. Both vertical eye movements and blink responses are present. After 15 minutes of dark adaptation both responses were smaller. Subsequent exposure to a diffuse background light of 1200 lux increased the amplitude of both potentials significantly.

An EOG derived from vertical eye movements is compared to a curve derived from measurement of blink potentials in Fig. 3. The cross correlation

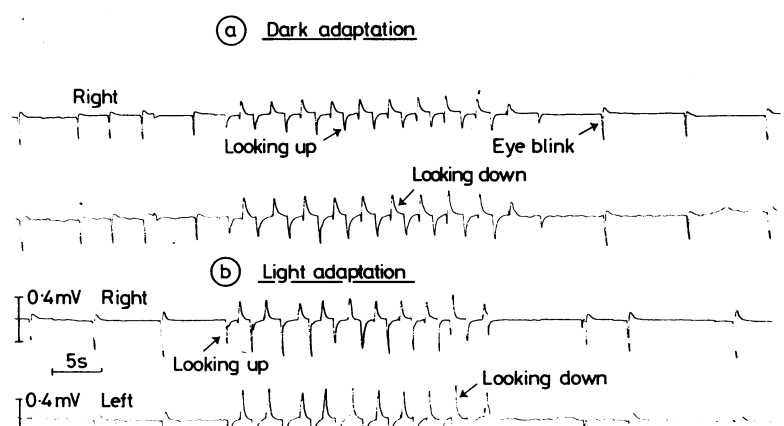

Fig. 2 *Bilateral recordings during voluntary vertical eye movements and spontaneous blinks from the right (upper tracing) and left (lower tracing) electrode arrays.* A. *Responses after 15 minutes of dark adaptation.* B. *Responses after 9 minutes exposure to a diffuse background at 1200 lux. Light exposure increased the amplitude of both responses.*

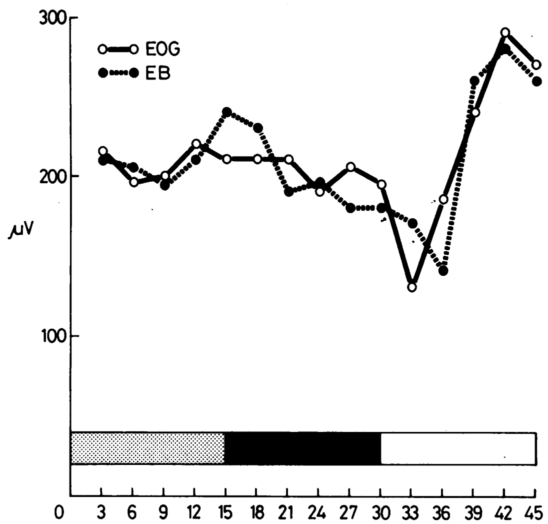

Fig. 3 *Comparison of the EOG derived from measurement of responses to vertical eye movements (open circles) and spontaneous eye blinks (closed circles).*

coefficient for these data was 0·9. Cross correlation coefficients for all 12 subjects with normal vision ranged from 0·67 to 0·92.

EOG ratios were calculated for all 12 subjects with normal vision utilising both measures and the data are contained in Table 1. Although criteria for abnormal ratios vary, 185 is the cut-off utilised in our own EOG laboratory. By this standard one subject with a normal EOG would be considered abnormal by the eye blink method—'false positive'.

The subject with a missing globe on the right showed a typical EOG and a nearly identical curve measured from eye blink potentials from leads on the left side. A small response from the side of the missing globe was recognisable only at high gain. This response did not vary during dark and light adaptation. No blink responses were identified on the blind side.

Table 1 *EOG ratios* derived from measurement of eye movement and eye blink responses.*

Subject	*Eye movement*	*Eye blink*
1	239	236
2	188	270
3	194	187
4	229	252
5	218	208
6	227	250
7	237	238
8	250	149
9	206	191
10	226	198
11	241	220
12	220	219

$^*\text{Ratio} = \frac{\text{Light peak}}{\text{Dark trough}} \times 100.$

Eye blink responses and an eye movement response were both present in the blind subject, the latter elicited by having the patient imagine himself looking at his index finger raised 30° above or below the horizontal. Sample responses are shown in Fig. 4. Neither dark adaptation nor exposure to the brightest available light altered the amplitude of his movement or eye blink responses. Cross correlation of the 2 curves was 0·90. Of particular practical significance, however, was the finding that the variation associated with eye movement responses was significantly greater than that of the eyeblink responses (t test for homogeneity of variance of related measures, t=30·6, p<0·001). Thus the eye blink response was more stereotyped than the response associated with voluntary eye movement in an impaired subject unable visually to track the target.

This subject generated a larger potential with downward gaze than with upward gaze. Even with the most extreme upward gaze of which he was capable, the response was only about 20% larger than that shown in Fig. 4 (downward deflections). It is therefore of some interest that his blink response

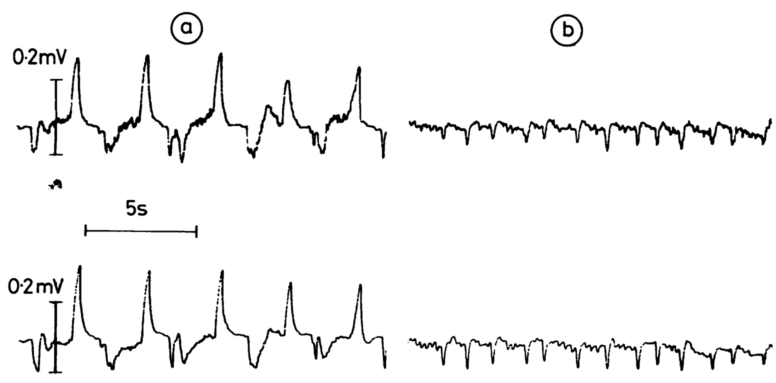

Fig. 4 *Responses to voluntary eye movements and during spontaneous eye blinks in a subject without light perception. On verbal command subject looked upward or downward at an imagined target 20° above and below the horizontal.*

was also small in absolute amplitude and correlated somewhat more closely with upward movements (r=0·92) than with downward movements (r=0·78).

Discussion

Others have shown that the presence of the globe is necessary to generate the eye blink potential.[3] Data from our subject blinded in the right eye by trauma confirm this. The only response from the blind side was a small deflection less than 5% of the amplitude of response from the normal side and presumed to be an electromyographic (EMG) response.

Since EOGs derived from standardised eye movements and from the blink potential appear to be similar, it is reasonable to assume that both measures reflect activity from the same generator, namely the corneoretinal potential.

Individuals with severely impaired vision have difficulty in fixating targets and thereby produce eye movements of varying magnitude. As demonstrated by our blind subject the eye blink potential amplitude appeared to be less variable than responses to gaze towards an imagined target. It has also been possible to measure the blink EOG in several psychotic patients who had great difficulty in sustaining attention and attending to the flashing fixation targets.

Although the rate of blinking varied considerably among subjects,[4 5] even the lowest rates permit the corneoretinal potential to be sampled frequently and conveniently. Thus it would be possible to plot an EOG with many more data points should that be desirable. Measurement of continuous voluntary eye movement responses, by contrast, was very fatiguing for one of the authors (D.D.).

As a practical point attachment of electrodes in a vertical line was faster for the technician, and more comfortable for the patient, than the conventional horizontal placement, which required attachment of electrodes near the medial canthus.

It has generally been assumed that the eye rotates upward during eye blinks, thus generating a potential analogous to a vertical eye movement.[6–8] However, Matsuo and his colleagues were unable to see eye movement or record an eye blink potential from a patient with unilateral total facial nerve palsy. The blink potential from the non-paralysed side was normal.[3] Unfortunately the data in this report do not aid in resolving this controversy. It is of some interest, however, that our blind subject generated a larger response when looking down than when looking up. When asked to look up as far as possible he generated a response only 20% larger than those shown in Fig. 4. In comparison with our normal subjects his eye blink response amplitude was also much smaller. This suggests, although it does not prove, that eye movement does occur during the blink response. If, as Matsuo *et al.* suggest, the response is produced by a wiping action of the eyelid over a stationary cornea, one would assume that the absolute magnitude in this subject would have been larger and similar to the amplitude of response from combined upward and downward movement.

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