ELECTRO-OCULOGRAPHY AS A FUNCTIONAL TEST IN PATHOLOGICAL CONDITIONS OF THE FUNDUS*

II. BASE-VALUE AND DROP DURING DARK ADAPTATION

BY

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IN our first paper (François, Verriest, and De Rouck, 1955) we reported upon the modifications of the normal human electro-oculogram (EOG) by light adaptation (2,000 asb for 5 min.) and subsequent dark adaptation; if the former generally gives only a slight decrease in the initial value, the latter is constantly characterized by an initial increase in the recorded deflections (for 1 to 3 min.), followed by a large decrease which lasts about 10 min.; this drop is followed by a slight new increase.

In a second contribution (François and others, 1956) we studied an arbitrary and standardized base-value M in normal and pathological cases, and recognized that this value was often too low in cases of microphthalmia, primary pigmentary degeneration, cicatricial chorio-retinitis, and retinal detachment.

As a third step in the physio-pathological study of the electrical standing potential of the eye, we now refer principally to the drop in the EOG during dark adaptation in pathological cases as compared with normal cases and with the base-values.

Technique

The electrode-scheme, the ocular movements, the registration, and the calculation of the mean deflection are identical with those described in our previous paper (François and others, 1956). We determined first the base-value M (obtained, as before, in a moderate surround brightness of 10 lux, to which the patient adapts during the preparatory period). The subject is then light-adapted (whole binocular field; 2,000 asb for 5 min.), and the eye movements are recorded during the second or third minute. The subject is subsequently dark-adapted, and to obtain an estimate of the drop in the EOG it is sufficient to make records every 2 or 3 min. for 15 to 20 min.

The mean deflection is calculated for each period of time. We have called the difference between the greatest and the least deflection d , and the quotient of d divided by the value of the greatest mean deflection r . Very small drops ($d < 10 \mu V$) are indistinguishable from artefacts.

The patients used in this work had normal ocular motility. A comparison of the technique described with galvanometric records obtained in the same conditions proved the reliability of the results.

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Physiological Values

We have already referred to the physiological values of M . For normal subjects, m , the arithmetical mean of d , is equal to $143 \mu\text{V}$, and its standard deviation σ is equal to $38.5 \mu\text{V}$. On the other hand, for r , these values are 0.33 and 0.11 respectively. The normal values $m \pm 2\sigma$ are 285 to $525 \mu\text{V}$ for M , 66 to $220 \mu\text{V}$ for d , and 0.11 to 0.55 for r .

The graphical representation of the modifications of the EOG of normal subjects during dark adaptation is also interesting (Fig. 1). The decrease is most conspicuous between the third and the ninth minute; between the ninth and 12-15th minute, the EOG often continues to fall but much more gradually (20 to $30 \mu\text{V}$).

In most cases, we measured the degree of adaptation at the same time as the EOG was obtained (integral thresholds : 1 hertz), and we usually recorded the electroretinogram immediately after the EOG. The physiological range of the amplitude of the b -wave in scotopic conditions is 125 to $250 \mu\text{V}$ by our technique.

Pathological Eye-Conditions

(1) Congenital Functional Abnormalities of the Retina

Four protanopic eyes showed normal values of M and very pronounced drops during dark adaptation, although in the physiological range. Values of 430 , 297 , 297 , and $347 \mu\text{V}$ for M corresponded to 165 , 150 , 150 , and $153 \mu\text{V}$ for d , and to 0.43 , 0.50 , 0.44 , and 0.46 for r .

FIG. 1.—Normal drops in EOG during dark adaptation.

FIG. 2.—Pathological drops in EOG in cases of retinitis pigmentosa.

Our case of Oguchi's disease, to the normal base-values of which we have already referred, also showed normal drops:

d Right Eye 163; Left Eye 180 μ V
r Right Eye 0.40; Left Eye 0.42.

(2) Tapeto-Retinal Degenerations

In four cases of primary pigmentary degeneration (Fig. 2) with normal or slightly subnormal base-values $M=460$ and 427μ V; 352 and 340μ V; 305 and 265μ V; 290 and 352μ V, the changes during dark adaptation were frankly pathological:

d Right Eye 35, Left Eye 30 μ V; Right Eye 7, Left Eye 8 μ V; No drop; No drop.
r Right Eye 0.08, Left Eye 0.07; Both eyes 0.02; No drop; No drop.

During further dark adaptation, the deflections increased for three of the four patients.

A case of unilateral primary pigmentary degeneration (fully described in a previous communication: François and Verriest, 1952) showed very interesting features. The affected eye had a pathological base-value ($M=142 \mu$ V) and showed practically no drop during dark adaptation ($d=7 \mu$ V; $r=0.06$) and the electroretinogram was absent. The contralateral eye, affected only by a macular pseudocoloboma, had a slightly subnormal base-value ($M=270 \mu$ V) but an entirely normal drop during dark adaptation ($d=175 \mu$ V; $r=0.50$) and the electroretinogram was normal (0.41μ V with the technique of Karpe).

The EOG and ERG of a young girl with fundus lesions of the heterozygotic type were entirely normal. We also obtained normal values in two cases of juvenile macular degeneration and in one case of angiod streaks.

In a young man with delayed puberty and perfectly normal ophthalmoscopic features, visual acuity, visual fields, and adaptometry, the base-value of the EOG was normal ($M=475 \mu$ V), but the drop was extremely small ($d=20 \mu$ V; $r=0.04$), and the ERG was also subnormal (75μ V).

(3) Chorio-retinitis (Fig. 3, overleaf)

In a case of extensive acute diffuse chorio-retinitis of the left eye, we found a base-value which was significantly diminished in comparison with the sound eye (M : Right Eye 517, Left Eye 335 μ V) and scarcely any drop during dark adaptation ($d=10 \mu$ V; $r=0.03$); the ERG was absent.

Seven eyes with a cicatricial diffuse chorio-retinitis and normal base-values had pathological to slightly subnormal drops during dark adaptation, the *d* and *r* being 40 μ V and 0.09; 23 μ V and 0.06; 35 μ V and 0.10; 70 μ V and 0.14; 50 μ V and 0.15; 55 μ V and 0.18; and 45 μ V and 0.18 respectively. The drops were characterized not only by small amplitude but also by late onset and a gradual slope. The ERG was generally subnormal.

On the contrary, five eyes with localized chorio-retinitis showed normal drops.

(4) Myopia Gravis and Retinal Detachment (Fig. 4, overleaf)

Several eyes with myopia gravis had normal EOGs and ERGs, but five cases of retinal detachment had pathological drops during dark adaptation. The base-value of the affected eye was more or less significantly reduced in comparison with the sound eye and the ERGs were absent or subnormal. One patient had a base-value of 325 μ V and no drop during dark adaptation; a month later the EOG was absent.

FIG. 3.—Pathological drops in EOG in cases of chorio-retinitis.

FIG. 4.—Pathological drops in EOG in cases of retinal detachment.

Four cases of healed retinal detachment also showed pathological drops.

Two cases of incipient atrophy of the eyeball had pathological base-values ($M=167$ and $70 \mu V$), but one of them showed a marked drop during dark adaptation ($d=145 \mu V$; $r=0.65$), and the ERG was present ($80 \mu V$) despite a complete cataract.

A case of siderosis bulbi with persistent intra-ocular body had a subnormal base-value ($M=260 \mu V$) and practically no drop ($d=5 \mu V$), and the ERG was absent.

(5) Vascular Disturbances (Fig. 5, opposite)

In mild cases of vascular retinopathy (hypertensive and diabetic) we found entirely normal values. In more advanced cases, however, the drop was subnormal or frankly pathological.

In a case of periarteritis nodosa (a man aged 37, with papillary oedema and typical pigmentary changes of the fundus), the base-values were pathological (M : Right Eye 147 , Left Eye $127 \mu V$), but there was a small but undisputable drop during dark adaptation:

d : Right Eye 21 , Left Eye $57 \mu V$
 r : Right Eye 0.15 , Left Eye 0.31 .

The ERG (75 and $60 \mu V$) and the subjective dark-adaptation-curve (threshold after 15 min.: $\log \mu \text{ asb } 2.0$) were both subnormal for both eyes.

Similar changes were seen in a case of advanced retinitis diabetica with rubeosis iridis:

M : Right Eye 135, Left Eye 185 μV

d : Right Eye 30, Left Eye 20 μV

r : Right Eye 0.20, Left Eye 0.10

Amplitude of the b -wave: Right Eye 85, Left Eye 70 μV .

Threshold after 15 min. : Right Eye log μ asb 2.6 : Left Eye 3.3.

In another case of retinitis diabetica with rubeosis we found pathological base-values ($M=175$ and $245 \mu V$) but normal drops.

A comparison between two cases of embolism of the central artery is particularly interesting:

(i) The base-value was normal (M : 445 μV affected eye, 435 μV sound eye) but the drop was barely demonstrable ($d=8 \mu V$; $r=0.2$); the ERG was absent.

(ii) The base-value was significantly reduced (M : 325 μV affected eye, 510 μV sound eye), but there was a marked drop ($d=43 \mu V$; $r=0.12$); the ERG was present although subnormal (amplitude of b -wave 50 μV).

FIG. 5.—Pathological drops in EOG in cases of retinal vascular disturbance.

The results in these two cases support the view that the base-value of the EOG is independent of the ERG and depends merely on the presence of the photo-receptors, whereas the drop in the EOG during dark adaptation and the amplitude of the b -wave of the scotopic ERG are interdependent and express the *intra-retinal conductivity*. If this is true, the first of these two cases of embolism is characterized by the integrity of the receptors with abolition of retinal conduction, and the second by partial destruction of the receptors, with better preservation of the intra-retinal pathways.

In several cases of retinal periphlebitis, the EOG and the ERG were perfectly normal.

In a case of choked disc with a supranormal ERG (Right Eye 410; Left Eye 400 μV), the base-values of the EOG and its modifications during dark adaptation were normal and high

d : Right Eye 182, Left Eye 172 μV

r : Right eye 0.41, Left Eye 0.39.

(6) *Glaucoma*

In cases of wide-angle glaucoma, normal values were obtained even in a practically blind eye:

$$M=357 \mu V; d=155 \mu V; r=0.40; \text{amplitude of } b\text{-wave } 155 \mu V.$$

On the other hand, in a case of congenital glaucoma, one eye was normal and the other subnormal.

(7) *Optic Pathways*

The values were entirely normal in cases of retrobulbar neuritis, tumour of the hypophysis, and homonymous hemianopia of vascular aetiology.

Significance of EOG-Changes

(1) Base-Value.—This present investigation confirms our previous conclusions (François, Verriest, and De Rouck, 1956) concerning the pathological conditions in which the base-value is diminished, but severe vascular affections and siderosis may also be added to the list. We have also noted absent EOGs in one case of retinal detachment and one case of microphthalmia with no vision.

The graphic study of the interrelation between the base-value and other visual functions does not demonstrate any direct inter-dependence of the base-value and the adaptometric thresholds, the amplitude of the scotopic *b*-wave, or even the drop of the EOG itself during dark adaptation. A blind eye can have a normal base-value, and conversely a seeing eye can have a subnormal base-value; an eye with retinitis pigmentosa has no *b*-wave and yet can have a normal base-value, and conversely our case of periarteritis nodosa had diminished base-values and present, although reduced, *b*-waves; many eyes had very high base-values and no drop, or else low base-values and a marked drop.

The base-value seems, as previous authors have established on physiological grounds, to be related to the existence of functioning visual receptors. When the base-value is diminished, there are always great defects in the visual fields or an actual diminution of the dimensions of the eye (microphthalmia). An eye with no EOG is blind, but the EOG may be normal in cases of amaurosis caused by extra-receptor lesions. These lesions may be extra-ocular (*e.g.* retrobulbar neuritis, atrophy of the optic nerve), intra-ocular (*e.g.* opacification of the media), or even intra-retinal (*e.g.* retinitis pigmentosa). Cases of initial retinitis pigmentosa with practically normal subjective visual functions have a normal base-value and an absent ERG; if the visual receptors are necessary for the production of the ERG, their existence and even a normal visual perception is not sufficient to elicit it.

For these reasons, the determination of the base-value of the EOG is a new means of functional examination of very great theoretical and practical interest; perhaps it is hitherto the only technique which permits us to estimate objectively the isolated function of the visual receptors, even in blind eyes.

(2) **Drop during Dark Adaptation.**—We have already stated that this drop is independent of the base-value of the EOG; nor is there any connexion with the adaptometric thresholds and other visual subjective functions. However, the cases described above show that the drop and the amplitude of the *b*-wave of the scotopic ERG are interdependent. Despite numerous minute experimental errors in recording both functions, this interrelation

is also seen graphically (Fig. 6).

FIG. 6.—Comparison between drops in EOG during dark adaptation and amplitude of *b*-wave of scotopic ERG.

Like the base-value, the drop during dark adaptation and the amplitude of the *b*-wave are affected not by extra-ocular causes of blindness or diminution of vision (e.g. retrobulbar neuritis) but only by intra-retinal disease. In incipient retinitis pigmentosa, for example, the EOG-drop and the ERG may be much more affected than the subjective functions, and are perhaps related to a mechanism of conduction

in which severe interference is not necessarily fatal to vision.

The parallelism between EOG-drop and scotopic *b*-wave does not hold true in congenital hemeralopia: in our case of Oguchi's disease the response to light-stimuli was negative and the scotopic *b*-wave was absent, yet the drop during dark adaptation was normal. This illustrates the extremely aberrant character of the mechanisms of vision in that disease.

Generally the drop in the EOG during dark adaptation and the amplitude of the scotopic b-wave are affected to the same degree. Both functions are conditioned not only by the function of the photo-receptors but also by an intra-retinal mechanism. Their apparent disappearance is not incompatible with the preservation of vision.

Summary

The authors have studied an arbitrary standardized base-value and a standardized drop during dark adaptation in the electro-oculogram for normal and pathological eyes. The base-value is not directly related to the subjective visual functions, the ERG, or the drop in the EOG during dark adaptation, but appears to offer a means of estimating the isolated function of the visual receptors. On the other hand, the drop during dark adaptation and the amplitude of the scotopic *b*-wave of the ERG are interrelated and

their presence requires the existence not only of functional receptors but also of an intra-retinal mechanism the apparent suppression of which is not incompatible with vision. Details are given of various cases of retinal diseases.

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