Principles and Practice of Clinical Electrophysiology of Vision

Editors

John R. Heckenlively, M.D.
Professor of Ophthalmology
Jules Stein Eye Institute
Los Angeles, California

Geoffrey B. Arden, M.D., Ph.D.
Professor of Ophthalmology and
Neurophysiology
Institute of Ophthalmology
Moorfields Eye Hospital
London, England

Associate Editors

Emiko Adachi-Usami, M.D.
Professor of Ophthalmology
Chiba University School of Medicine
Chiba, Japan

G.F.A. Harding, Ph.D.
Professor of Neurosciences
Department of Vision Sciences
Aston University
Birmingham, England

Sven Erik Nilsson, M.D., Ph.D.
Professor of Ophthalmology
University of Linköping
Linköping, Sweden

Richard G. Weleber, M.D.
Professor of Ophthalmology
University of Oregon Health Science Center
Portland, Oregon

Mosby
Year Book

St. Louis Baltimore Boston Chicago London Philadelphia Sydney Toronto

Mosby
Year Book

Dedicated to Publishing Excellence

Sponsoring Editor: David K. Marshall
Assistant Director, Manuscript Services: Frances M. Perveiler
Production Project Coordinator: Karen E. Halm
Proofroom Manager: Barbara Kelly

Mosby-Year Book, Inc.
11830 Westline Industrial Drive
St. Louis, MO 63146

1 2 3 4 5 6 7 8 9 0 CL CL MV 95 94 93 92 91

Library of Congress Cataloging-in-Publication Data
Principles and practice of visual electrophysiology / [edited by]
John R. Heckenlively, Geoffrey B. Arden.
p. cm.
Includes bibliographical references.
Includes index.
ISBN 0-8151-4290-0
1. Electroretinography. 2. Electrooculography. 3. Visual evoked response. I. Heckenlively, John R. II. Arden, Geoffrey B. (Geoffrey Bernard)
[DNLM: 1. Electrooculography. 2. Electrophysiology. 3. Electroretinography. 4. Evoked Potentials, Visual. 5. Vision Disorders—physiopathology. WW 270 P957]
RE79.E4P75 1991 91-13378
617.7 1547—dc20 CIP
DNLM/DLC
for Library of Congress

PART XIII

Evaluation of Retinal Toxicity: Functional and Practical Problems

71

Evaluation of Ocular Trauma, Opaque Media

G. F. A. Harding

All opacities of the media present the ophthalmologist with an obscured view of the retina of the eye. The degree of loss can be assessed by psychophysical methods of varying types ranging from simple acuity measures (Snellen chart) to more complex measures of the effect of glare (contrast sensitivity function). The opacity of the media certainly affects the pattern evoked visual potential (VEP) where even less slight opacities delay the P100 component of the VEP to smaller check sizes (20 minutes or less).[12]

It is not in the area of assessment of opacity, however, that electrophysiology makes its contribution. It is in assessment of the function of the retina, optic nerve, optic tract, and visual cortex behind opacities of the media. The concern of the ophthalmologist is whether the opacity provides the sole reason for the reduction in vision or whether there are coexisting retinal and neural problems. From this point of view, therefore, the role of electrophysiology is in *prognosis,* that is, indicating to the surgeon the likely outcome following the removal of the opacity. The most common opacities are opacities of the lenses (cataract) or opacities of the aqueous or vitreous humor, which are often produced by blood.

Most electrodiagnostic studies have concentrated on assessment of function behind a dense cataract. The earliest study is that of Copenhaver and Perry,[5] who showed a reduction in the amplitude of the flash VEP in patients with opacities of the lens. Although the reduction in amplitude correlation did not reach statistical significance, Ebe et al.[7] investigated five eyes with cataracts and demonstrated that patients with normal preoperative flash VEPs had postoperatively normal retinal function and visual acuity. In one of the five eyes the electroretinogram (ERG) was abnormal preoperatively. This insensitivity of the flash VEP to density of the cataracts is essential for an accurate assessment of retinal and neural function. It is somewhat surprising that the VEP is a better predictor of postoperative vision than the ERG is. In part this may be due to the opaque lens acting as an almost perfect light diffuser producing total retinal illumination and a supranormal response.[4] However, the use of red stimulation appears to have a better prognostic value, a normal amplitude, waveform, and oscillatory potential of the ERG being a positive prognostic indicator.[3] If the amplitude of the ERG is maintained, 92% of patients achieve a visual acuity of 6/5. However, patients with a reduced-amplitude b-wave do not usually achieve this vision, although surprisingly 22% do.[16] In a study of 20 eyes with mature cataracts Tsinapoulos et al.[19] found that 16 had normal ERGs. The three patients who had reduced b-wave amplitude had postoperative visual acuities of 3/36, and one patient with a markedly reduced b-wave had a postoperative vision of 6/60.

Since the VEP mirrors the cortical magnification of central vision in humans to some extent, it is not surprising that the VEP provides the best correlation with postoperative visual acuity.[13] A number of studies have confirmed the prognostic value of the preoperative flash VEP for cataract surgery.[2, 8, 18] Thompson and Harding[18] reported a study of the prognostic value of the VEP in 20 patients who received surgery for dense unilateral cataracts. The VEP was elicited by flash stimulation at two intensities (68 and 96 nit/sec) by using a conventional stroboscope. The VEPs were independently assessed by the two authors, the response from stimulation of the affected eye being compared with that obtained by stimulation of the normal eye. The responses were graded in terms of both amplitude and latency by using a criteria of abnormality of 2 SD from the normal interocular range, that is, a reduction in amplitude of greater than 33% or a delay of more than 12 ms of the major P_2 component. Grade 1 VEPs were therefore within normal limits, and grade 2 VEPs showed a reduction in amplitude of more than 33% but less than 50%. In addition, for this latter grade when the intensity of stimulation was increased to 96 nit/sec, the difference between the two eyes did not increase. Grade 3 showed a reduction in amplitude of more than 50% or a delay of 30 ms or more. When the intensity of stimulation was increased, the VEPs from the affected eye showed a greater difference in comparison to the unaffected eye. Of the 14 patients who achieved a postoperative vision of 6/12 or better, 12 had grade 1 VEPs, and the other 2 patients had grade 2 VEPs but were over 75 years of age and, in 1 case, certainly showed senile macular changes in the "good" eye. Of the 6 patients whose postoperative vision was worse than 6/24, 5 had grade 3 VEPs, and the other 1 had grade 2 VEP.

Attempts have been made to use pattern stimulation to assess retinal function. Arden and Sheorey[1] applied Green's[11] laser interference fringe technique to produce pattern VEPs through a cataract. The laser fringes are not degraded by ordinary optical aberrations. In a study of this technique on 15 patients with cataracts and 3 with corneal opacities they found the VEP reduced or absent in 4 patients, 2 of them having trauma injuries, 1 having amblyopia, and 1 with diabetic neuropathy. Obviously the technique is a complicated one and for this reason has not been generally followed.

Vitreous hemorrhages from a nontraumatic source are of course the result of vascular problems. Thus the ERG will reflect any retinal damage since the amplitude of the ERG is dependent on the area of active retina stimulated. It is essential under these circumstances to use a very bright stimulus of approximately 10,000 cd/m^2 (500 nit/sec). Under these circumstances the ERG has been claimed to be superior to other tests of retinal function.[9] In vitreous hemorrhages associated with diabetic retinopathy there is of course a reduction in the oscillatory potentials of the ERG and in some cases a reduction and delay of the b-wave.[3] Galloway[10] proposes that ERG can differentiate between a variety of conditions producing vitreous hemorrhage. Retinal detachment with vitreous hemorrhage reduces the amplitude of the a-wave and b-wave. Central retinal vein thrombosis with vitreous hemorrhage reduces the oscillatory waves markedly as well as other components of the ERG (Fig 71–1). Eales disease, which produces dense vitreous hemorrhage with minimal vascular involvement, gives a normal ERG. The VEP can be used in a similar manner, but with a bright flash, to that outlined for assessment of retinal function behind opaque lenses and has similar prognostic value for vitrectomy.[15]

Ocular trauma, particularly that involving penetrating wounds to the eye, presents difficult prog-

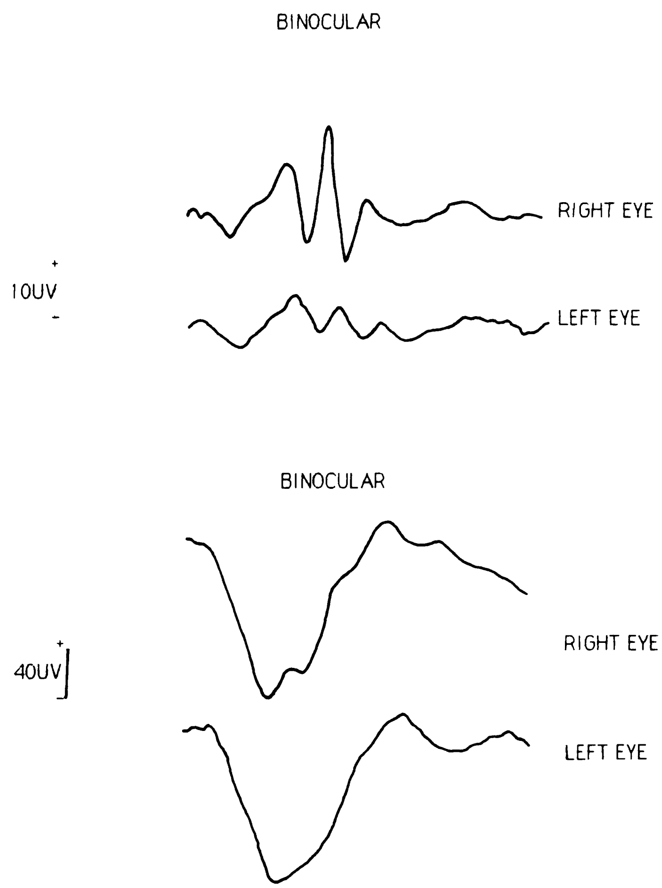

FIG 71–1.
ERG recorded binocularly in a patient with central retinal vein occlusion of the left eye. The two traces at the *top* of the figure show the oscillatory potentials recorded when using a short time constant to remove both the a- and b-wave of the ERG. It can be seen that all the oscillatory potentials are markedly reduced from the left eye. The *lower* two traces show the ERG recorded from a normal time constant, and both the a- and b-waves can be seen with superimposed oscillatory potentials. It can be seen that these are reduced or missing from the left eye. (From Harding GFA: Neurophysiology of vision and its clinical application, in Edwards K, Llewellyn R (eds): *Optometry.* London, Butterworths, 1988; pp 44–60. Used by permission.)

nostic problems for both the ophthalmologist and electrodiagnostician. Most of the studies that have been performed have involved the use of both ERG and VEP. The two techniques are complementary since the ERG to a diffuse flash gives a measure of the area of the retina remaining active. The VEP, on the other hand, accentuates central areas of retinal function, even to flash stimulation, due to the neural representation of visual space and, in addition, depends on integrity of the optic nerve, optic tracts, and cortex. With penetrating wounds to the globe the retina cannot be observed, and only electrophysiological techniques can be satisfactorily used to assess function. These techniques are superior, both to subjective assessment and to ultrasonography in terms of their prognostic value.[6] Ebe et al.[7] recorded both the flash ERG and flash VEP in nine patients with unilateral optic atrophy as a sequela to trauma. Although the ERG was usually normal, the flash VEP paralleled the visual impairment. The VEP was undetectable in four blind eyes and in one other patient with grossly impaired visual acuity. In two other patients with impaired vision the VEP was abnormal. Rouher et al.[17] confirmed these findings in 17 patients, although they also showed that the ERG was affected if there was severe retinal disturbance. If there was a total lesion of the optic nerve, the VEP was absent, while partial lesions produced a proportional reduction in the VEP. By utilizing colored stimulation they showed that a reduction in central vision produced a reduced VEP to white flash, an abolition of response to red flash, and a normal response to blue flash. Peripheral losses gave normal VEPs to red and white flashes but absent responses to the blue flash.

A prospective study was performed by Crews et

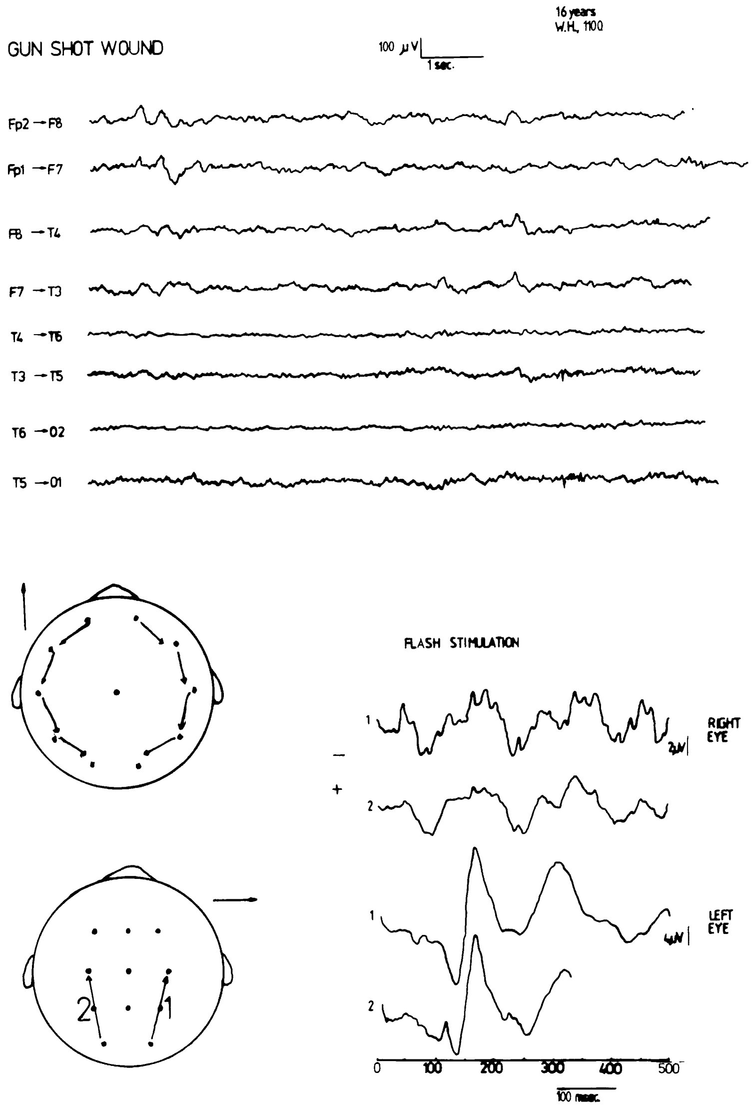

FIG 71–2.
Visual evoked response in a patient who had suffered a gunshot wound. The missile had entered the left side of the head, traversed the left orbit, ricocheted from the floor of the right orbit, and exited from the right temple. It can be seen that on flash stimulation of the right eye no VEP could be recorded from either cerebral hemisphere. When the left eye was stimulated, a clear VEP was recorded with a P_2 component around 130 ms. It should be noted that the electroencephalogram seen in the *upper* eight traces shows slow wave abnormality of the frontal regions.

al.[6] on 64 eyes that had suffered recent penetrating wounds. Both flash ERG and flash VEPs were performed. In each of the eyes following initial reconstructive surgery the retina was unobservable due to hemorrhage. It is at this stage that prognostic assessment is most important. The visual potential of an eye must be set against the risk of leaving the patient with a blind and painful eye. The decision to enucleate or not and planning of further reconstructive surgery is dependent on accurate clinical assessment. In this study the surgeons were not informed of the electrophysiological findings until after this initial period and the completion of their clinical assessment. The amplitude of the a- and b-waves from the injured eye was compared with those of the fellow eye or, in the case of bilateral injuries, with previously established normative values. If the amplitude was 75% or more, the ERG was graded as 1; if more than 50%, grade 2; if less than 50%, grade 3; and if absent, grade 4. If the ERG was grade 1 or 2, 73% of the eyes obtained a vision of 6/60 or better within 1 year of follow-up, 43% reaching 6/12 or better. Of the grade 3 and 4 responses, 33 of the 34 eyes went blind or were enucleated.

Flash VEPs showed similar prognostic value. If the VEP was reduced by less than 50% or was not significantly delayed, 67% of eyes achieved a vision of better than 6/60, over 36% achieving 6/12 or better. When the flash VEP was reduced by 50% or more or was delayed by at least 30 ms, 94% went blind or were enucleated, only 1 achieving an acuity better than 6/60. The best results were obtained, however, by combining the two scores in a simple additive procedure ERG grade + VEP grade. The predictive power of this combined score (scores 2 to 4 being a good prognosis and 5 to 8 representing a bad prognosis) identified 91% of patients with poor visual outcome and all patients with good outcome. The failure of total prediction was due to 3 eyes that had been enucleated during the initial period with good electrophysiological prognostic signs and were later all found to have retina in situ. Sixteen of the 21 enucleated eyes were found to have detached retinas, and in all the amplitude of the ERG was less than 25% of the fellow eye. All but 2 had absent VEPs, the 2 patients showing markedly reduced and delayed VEPs.

This complementary technique allows the recognition of traumatic injury to the optic nerve. These injuries may be produced directly with injury to the globe or orbit or indirectly by contusion injury to the eyeball or head. Both types of injury produce similar results. Babel et al.[3] reported four patients with optic nerve trauma, all of whom showed a reduction or abolition of the VEP. Harding has reported seven cases of direct and indirect optic nerve trauma.[13–15] When utilizing monocular stimulation it was possible to demonstrate both the sparing of one optic nerve and the damage to the other in a case of direct injury from a gunshot wound (Fig 71–2). With indirect optic nerve traumas there is often no sign of penetrating injury because the damage to the optic nerve may be produced by a fall or a blow to the head. The reduction of the P_2 component of the VEP appears to parallel the damage to the optic nerve (Fig 71–3). In all cases of indirect optic nerve trauma consideration should be given to the possibility of simultaneous cortical damage. Harding[13] has described a case in which a 2-year-old child fell a distance of 30 m. The ERG was well preserved from both eyes, but on binocular flash stimulation the VEP was reduced over the right visual cortex. Monocular stimulation revealed no response on right eye stimulation and a similar asymmetry of the VEP on left eye stimulation to that seen on binocular stimulation. These findings suggest total indirect optic nerve trauma to the right optic nerve and damage

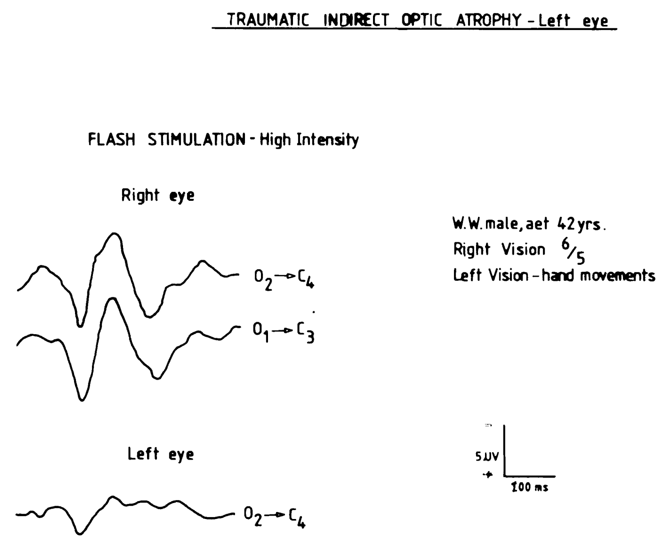

FIG 71–3.
VEP obtained from a male patient who had suffered a head injury. The VEP obtained by flash stimulation of the right eye is entirely normal (positivity is indicated downward), and it can be seen that a major positive component is elicited around 120 ms. When the left eye is stimulated a grossly reduced response is obtained.

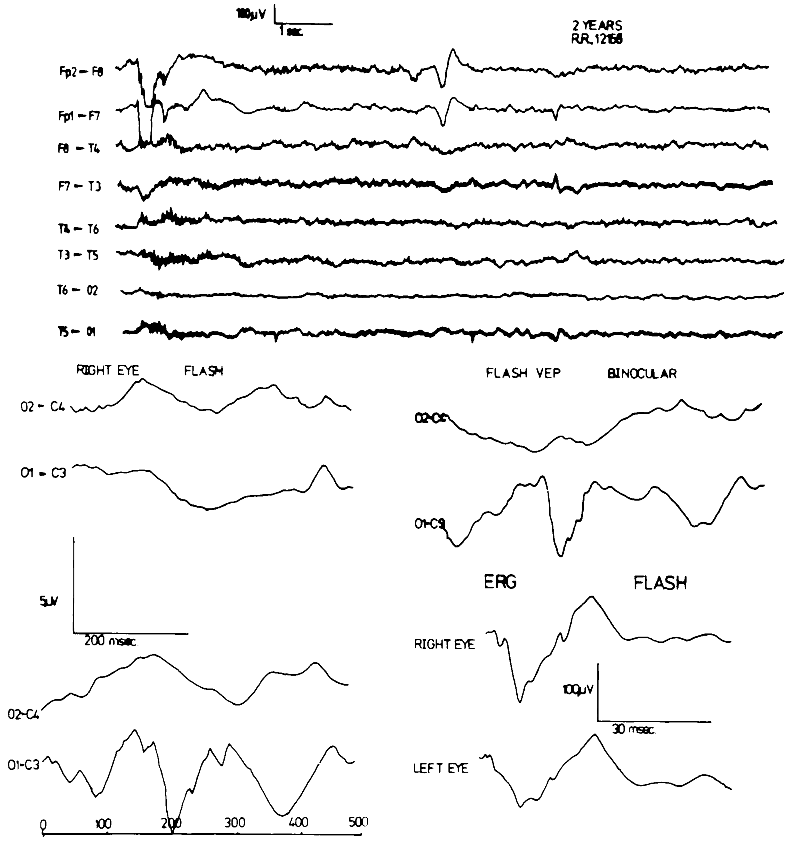

FIG 71–4.
Visual electrodiagnostic results from a 2-year-old child who had fallen 30 m. The photopic ERGs are shown in the *bottom right-hand* traces, and it can be seen that both a- and b-waves are apparently of normal latency and amplitude for noncorneal electrodes. There appears to be some slight reduction in the amplitude obtained from the left eye when compared with the right. The *upper* two traces on the left show the VEP from both the right and left cerebral hemispheres in response to flash stimulation of the right eye. No response is obtained which indicates that since the ERG from the right eye is normal there must be indirect optic nerve damage to the right optic nerve. When binocular stimulation is performed, a response is seen over the left cerebral hemisphere *(O1* to *C3)* but no response over the right cerebral hemisphere *(O2* to *C3).* When the left eye is stimulated as in the *bottom left-hand* traces, there is again a similar response occurring to that on binocular stimulation, with a clear but delayed P_2 component seen just before 200 ms from the left cerebral hemisphere but no response from the right cerebral hemisphere; this indicates that there has also been right cortical damage.

to the right visual cortex (Fig 71–4). There is no doubt that electrodiagnosis can play a very significant role in prognostic assessment in trauma.

REFERENCES

1. Arden GB, Sheorey UB: The assessment of visual function in patients with opacities: A new evoked potential method using a laser interferometer, in Desmedt JE (ed): *Visual Evoked Potentials in Man: New Developments.* Oxford, England, Clarendon Press, Ltd, 1977, pp 438–449.
2. Arnal D, Gerin P, Salmon D, Ravault M, Magnard P, Hugonnier R: Intèret des potentiels èvoquèes moyen visuel en ophthalmologie. *Electroencephalogr Clin Neurophysiol* 1972; 32:615–621.
3. Babel J, Stangos N, Korol S, Spiritus M: *Ocular Electrophysiology: A Clinical and Experimental Study of Electroretinograms, Electro-oculogram and Visual Evoked Response.* Georg Thieme Verlag, Stuttgart, West Germany 1977.
4. Burian HM, Burns CA: A note on senile cataracts and the electroretinogram. *Doc Ophthalmol* 1966; 20:141–149.
5. Copenhaver RM, Perry NW: Factors affecting visually evoked cortical potentials such as impaired vision of varying etiology. *Invest Ophthalmol* 1964; 3:665–675.
6. Crews SJ, Thompson CRS, Harding GFA: The ERG and VEP in patients with severe eye injury. *Doc Ophthalmol Proc Ser* 1978; 15:203–209.
7. Ebe M, Mikami T, Ito H: Clinical evolution of electrical responses of retina and visual cortex in photic stimulation in ophthalmic diseases. *Tohoku J Exp Med* 1964; 84:92–103.
8. Fricker SJ: Analysis of the visual evoked response by synchronous detector techniques. *Invest Ophthalmol* 1971; 10:340–347.
9. Fuller DG, Knighton RW, Machemer R: Bright flash ERG for evaluating eyes with opaque media. *Am J Ophthalmol* 1975; 80:214.
10. Galloway N: *Ophthalmic Electrodiagnosis,* ed 2. London, Lloyd and Luke, 1981.
11. Green DG: Testing the vision of cataract patients by means of laser-generated interference fringes. *Science* 1960; 168:1240–1242.
12. Halliday AM: *Evoked Potentials in Clinical Testing.* Edinburgh, Churchill Livingstone, Inc, 1982.
13. Harding GFA: Flash evoked cortical and subcortical potentials in neuro-ophthalmology. *Acta Neurol Belg* 1985; 85:150–165.
14. Harding GFA: The flash evoked visual response and its use in neuro-ophthalmology. *J Electrophysiol Technol* 1982; 8:110–130.
15. Harding GFA: Neurophysiology of vision and its clinical application, in Edwards K, Llewellyn R (eds): *Optometry.* London, Butterworths, 1988, pp 44–60.

16. Mikawa T, Tamura O: Relation between the electroretinogram and post-operation vision in cataract. *Jpn J Clin Ophthalmol* 1970; 24:43–46.
17. Rouher F, Plane C, Soul P: Intérêt des potentiels évoqués visuels dans les affections du nerf optique. *Arch Ophthalmol* (Paris) 1969; 29:555–564.
18. Thompson CRS, Harding GFA: The visual evoked potential in patients with cataracts. *Doc Ophthalmol Proc Ser* 1978; 15:193–201.
19. Tsinapoulos T, Karyophyllis K, Konstas P: Electroretinography in the detection of the functional condition of the retina in cataract. *Arch Ophthalmol Soc Northern Greece* 1972; 18:69–74.