

Occlusion of posterior ciliary artery

IV. Electroretinographic studies

DAVID McLEOD* AND SOHAN SINGH HAYREH

Department of Ophthalmology, University of Edinburgh

The effects of posterior ciliary artery (PCA) occlusion have been studied in rhesus monkeys by Hayreh and Baines (1972 a, b, c), who reported the effects of occlusion of the medial PCA, lateral PCA, and all the PCAs on the choroidal circulation (Hayreh and Baines, 1972a) and optic nerve head (Hayreh and Baines, 1972c), and the production of chorio-retinal lesions (Hayreh and Baines, 1972b). Their results were obtained from occlusions in 85 monkey eyes. The opportunity arose to study electroretinographic (ERG) changes in ten of these monkeys with unilateral PCA occlusion.

Since the PCAs supply the pigment epithelium, visual cells, and outer nuclear layer of the retina posterior to the equator, it might be anticipated that occlusion of these arteries would affect the electrophysiological responses from the retina. This study confirmed this, and as no similar study is available in the literature, our findings are reported below.

Materials and methods

In ten rhesus monkeys, the PCAs on one side were exposed by a lateral orbitotomy and cauterized near their entry into the globe. The extraocular muscles were not divided, and the central retinal artery and vortex veins were left undisturbed. ERGs were recorded at varying intervals after occlusion of the medial PCA (4 monkeys), lateral PCA (4 monkeys), and all PCAs (2 monkeys).

The monkeys were anaesthetized with intramuscular Nembutal and the pupils were dilated with cyclopentolate. The ERG was recorded by cotton-wick electrodes in response to a brief flash stimulus of varying intensity from a 'Flash-Tac' stroboscope after 15 minutes' dark adaptation. The ERG of the operated eye was compared with that of the unoperated control eye so that the effects of varying depths of anaesthesia, etc., could be minimized. ERGs were displayed on an oscilloscope and photographed (time-constant of recording system 0.5 sec.).

The ERG changes have been quantitated and correlated with the area of choroid supplied by the occluded PCA and with the chorio-retinal lesions seen in these eyes.

Results

(1) ELECTRORETINOGRAPHIC STUDIES

(a) ERG amplitude

A consistent reduction in the amplitude of the ERG was seen after PCA occlusion; the percentage change in the b-wave amplitude is shown in the Table (overleaf). The reduction was least apparent after medial PCA occlusion and most marked after occlusion of all the PCAs; preoperative comparison between the two eyes in these animals showed that the ERG amplitudes were very similar (± 5 per cent.).

Received for publication February 18, 1972

Address for reprints: S. S. Hayreh, F.R.C.S., Princess Alexandra Eye Pavilion, Chalmers Street, Edinburgh EH3 9HA

This project was supported by a grant from the Medical Research Council

* Present address: Moorfields Eye Hospital, City Road, London, E.C.1

Table Percentage change in scotopic b-wave amplitude seen in ten monkeys after unilateral PCA occlusion

<i>PCA occluded</i>	<i>Monkey no.</i>	<i>Time from occlusion (weeks : days)</i>	<i>Per cent. change in b-wave amplitude</i>
<i>Medial</i>	1	13 : 0	-13
	2	12 : 0	-25
	3	10 : 0	-12
	3	11 : 0	-15
	4	1 : 0	-11
	4	4 : 0	-18
<i>Lateral</i>	5	20 : 0	-30
	6	12 : 0	-38
	7	10 : 0	-45
	7	11 : 0	-36
	8	0 : 1	-36
	8	2 : 0	-31
<i>All</i>	9	12 : 0	-48
	10	0 : 2	-75
	10	2 : 0	-36
	10	6 : 0	-31

(b) ERG waveform

No difference was observed in the configuration of the ERG between control and operated eyes, *i.e.* the amplitude of the a-wave (as seen at higher stimulus intensities) was reduced proportionately to the b-wave. A 'subnormal' response was therefore seen.

We have insufficient data on the time-course of ERG changes after PCA occlusion, most of the changes seen in individual animals probably representing normal temporal variations. In monkey No. 10, however, a considerable ERG revival was seen between the second day and the second week after the occlusion (see Table).

(2) OTHER STUDIES

The findings described below in the ten monkeys were representative of the larger series described by Hayreh and Baines (1972a, b).

(a) Intravenous fluorescence angiography (IVFA)

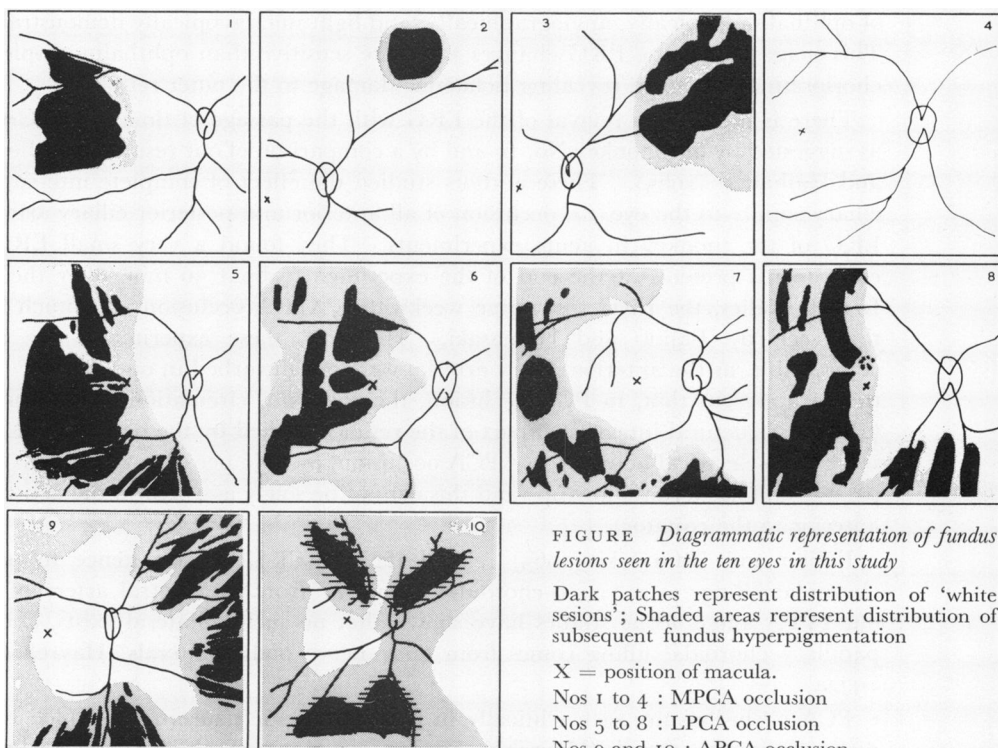
1 hour after the occlusion, IVFA showed non-filling of the choroid in the distribution of the occluded PCA during the dye transit. In MPCA occlusion, there was no filling of the nasal one-third to one-half of the choroid, and in LPCA occlusion, no filling of the temporal one-half to two-thirds of the choroid. In APCA occlusion, there was no choroidal filling at all. The retinal circulation was normal. However, in the post-venous phase of the retinal circulation, some filling of the previously non-filled choroid was observed to occur *via* various collaterals, *e.g.* the posterior episcleral arterial plexus, recurrent pial branches of the peripapillary choroid, and retrograde flow in the vortex veins. In the late phases (15 min. after the injection of the dye), faint fluorescence was seen in most of the choroid, indicating very slow perfusion from the collaterals; however, there were some areas which did not show any such perfusion.

At subsequent reviews, the rapidity and extent of choroidal filling in the occluded sectors steadily increased, though there was still some choroidal delay after 3 mths in most cases. This improvement in choroidal circulation was most rapid in monkeys with MPCA occlusion and least rapid after APCA occlusion.

(b) *Fundus changes*

Within 24 hrs of the occlusion, 'white lesions' were seen and appeared to lie deep to the retina. They were located in the distribution of the occluded PCAs, *i.e.* nasally in MPCA occlusion, temporally and sometimes inferiorly in LPCA occlusion, and all round in APCA occlusion (Figure). They were patchy, irregular, wedge-shaped, and always posterior to the equator. In MPCA occlusion, the lesions were smallest and not consistently seen; they were more extensive and consistent after LPCA and APCA occlusion. They corresponded in position to those areas of choroid showing no fluorescein perfusion even in the late phases of IVFA performed 1 hour after the occlusion.

After 2 to 3 weeks, the lesions resolved into depigmented granular scars and became surrounded by a zone of hyperpigmentation (Figure).



(c) *Histology*

In the fundus lesions, light microscopy showed loss of rods and cones and of the outer nuclear layer. More widespread involvement of the pigment epithelium was seen, varying from mild degeneration to complete disorganization or disappearance. There was occasional destruction of Bruch's membrane, but no significant involvement of the choroid, bipolar cell layer, or superficial retina. In the intervening areas, the choroid, pigment epithelium, and retina were entirely normal.

Discussion

The ERG changes in the present study are in keeping with existing concepts of the cellular origin of the ERG. The PIII component, responsible for the a-wave, is considered to originate in the receptor layer, while the PII component, responsible for the b-wave, is generated in the bipolar layer (Brown, 1968). Thus, the generalized ERG reduction seen above may be thought of as primarily due to a diminution in the PIII component (due to receptor damage), with concurrent secondary diminution in the PII component (the bipolar layer being deprived of stimulation).

The distribution area of the occluded PCA and the extent of the resulting white fundus lesions (and subsequent chorio-retinal scars) could be approximately related to the reduction in the ERG amplitude; these were all smaller in MPCA than LPCA occlusions, and greatest in APCA occlusions. However, such a correlation was not absolute, and the ERG reduction could not be directly related to the area of fundus showing loss of receptors. The reduction was usually in excess of such a loss of receptors, and in monkey No. 4 an ERG reduction was seen in the absence of any observed lesion. More subtle factors must therefore be operating, so that electrophysiological changes may occur in the absence of ophthalmoscopically, angiographically, and light microscopically demonstrable change. This suggests that the ERG changes are more sensitive than ophthalmoscopically visible chorioretinal lesions in revealing ischaemic damage to the outer retina.

There is probably a revival of the ERG with the passage of time after PCA occlusion, as suggested by our monkey No. 10 and by a comparison of our results with those of Fujino and Hamasaki (1965). These authors studied the effect of complete interruption of the ciliary supply to the eye, *i.e.* occlusion of all anterior and posterior ciliary arteries, on the ERG of the monkey in acute experiments. They found a very small ERG, with all components present, at the end of the experiment (about 30 min. after the occlusion). In our studies, the ERG seen some weeks after APCA occlusion was much larger than that seen by Fujino and Hamasaki. However, these experiments are not strictly comparable, as the anterior ciliary arteries were not disturbed in our studies. It is nevertheless apparent that, in PCA occlusion, the collateral circulation to the choroid maintains the structural integrity of part of the retina supplied by the occluded PCA, and also some of its electrical activity; in APCA occlusion, over 50 per cent. of the ERG amplitude persists on long-term follow-up (and this cannot be solely ascribed to the activity of retina anterior to the equator).

Fujino and Hamasaki (1965) related their small ERG persistence to peripapillary choroidal filling *via* a 'retino-choroidal collateral' from the central artery of the retina; our IVFA and silicone studies have shown that no such collateral exists, and that peripapillary choroidal filling comes from optic nerve pial collaterals (Hayreh and Baines, 1972a).

PCA occlusions are seen clinically in ischaemic optic neuropathy, which is commonly due to temporal arteritis (Hayreh, 1969, 1971). However, the ERG is usually unaffected after temporal arteritic ischaemic optic neuropathy (Palm, 1958; Younessian, 1962; Edmund and Jensen, 1967; Burian, 1963 (after steroids)), and chorio-retinal lesions are not usually seen in the peripheral fundus (Hayreh and Baines, 1972c); the reasons for this are discussed at length elsewhere (McLeod, Wyllie, and Hayreh, 1973). We have seen three patients (5 eyes) with peripheral chorio-retinal scars associated with temporal arteritic ischaemic optic neuropathy, and in all cases the electrophysiological responses reflected the involvement of the PCA supply. In one of these patients, only one eye was

affected and the clinical and ERG findings were very similar to those described above in unilateral APCA occlusions in monkeys.

Summary

Electroretinographic studies were performed in ten rhesus monkeys during the follow-up period of up to 20 weeks after experimental occlusion of various posterior ciliary arteries. A subnormal ERG response was seen, and was related to the ophthalmoscopic, histological, and angiographic changes in these eyes. A clinical correlation is mentioned.

We are grateful to Mr. Alasdair McDonald for the illustration, and to Miss J. A. B. Baines for technical assistance.

References

- BROWN, K. T. (1968) *Vision Res.*, **8**, 633
BURIAN, H. M. (1963) *Amer. J. Ophthalm.*, **56**, 796
EDMUND, J., and JENSEN, S. F. (1967) *Acta ophthalm. (Kbh.)*, **45**, 601
FUJINO, T., and HAMASAKI, D. I. (1965) *J. Physiol. (Lond.)*, **180**, 837
HAYREH, S. S. (1969) *Brit. J. Ophthalm.*, **53**, 721
——— (1971) In "Proc. int. Symp. Fluorescein Angiography, Albi, 1969", pp. 510-530. Karger, Basel
——— and BAINES, J. A. B. (1972a) *Brit. J. Ophthalm.*, **56**, 719
——— (1972b) *Ibid.*, **56**, 736
——— (1972c) *Ibid.*, **56**, 754
MCLEOD, D., WYLLIE, A. M., and HAYREH, S. S. (1973) *Ibid.*, **57** (in press)
PALM, E. (1958) *Acta ophthalm. (Kbh.)*, **36**, 208
YOUNESSIAN, S. (1962) *Ophthalmologica (Basel)*, **143**, 288