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Posterior Ciliary Artery Occlusion

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Purpose: To compare the severity of ischemic damage after posterior ciliary artery (PCA) occlusion in old, atherosclerotic, hypertensive monkeys with that in young monkeys.

Design: Experimental study.

Participants: Seven eyes of normal, healthy rhesus monkeys and 8 eyes of old, atherosclerotic, hypertensive monkeys.

Methods: By lateral orbitotomy, all PCAs were cut behind the eyeball in both groups of animals. The fundus and the optic disc were evaluated by repeated ophthalmoscopy, color fundus photography, and fluorescein fundus angiography before and immediately after cutting the PCAs and serially thereafter during the follow-up period.

Main Outcome Measures: Severity of acute ischemic damage to the choroid, outer retina, and optic nerve head.

Results: Cutting all the PCAs resulted in the development of ischemic infarction of the choroid, retinal pigment epithelium, outer part of the retina, and optic nerve head within 24 hours in both groups of animals. The severity of the various ischemic fundus and retinal lesions and of the optic disc during the acute phase showed no statistically significant differences between the 2 groups of animals. Fluorescein fundus angiography performed soon after cutting the PCAs showed no filling of the entire choroid and the optic disc in both groups of animals. On follow-up until approximately 3 months in both groups, the white opacity of the infarct in the fundus seen during the acute phase gradually resolved in approximately 2 to 3 weeks, leaving greyish, granular, depigmented fundus, unmasking of the large choroidal vessels, and optic atrophy; fluorescein angiography revealed gradual restoration of the choroidal blood flow and unmasking of the big choroidal vessels.

Conclusions: The study showed that the severity of ischemic damage after occlusion of all the PCAs was similar in both the young, healthy monkeys and the old, atherosclerotic, hypertensive monkeys. This is in contrast to the findings of our similar study dealing with central retinal artery occlusion, where the young demonstrated much more severe ischemic damage than the old. *Ophthalmology Retina 2018;2:106-111 © 2017 by the American Academy of Ophthalmology*

Our studies of central retinal artery occlusion in (1) young[1] and (2) old, atherosclerotic, hypertensive[2] rhesus monkeys show that acute retinal ischemic damage after central retinal artery occlusion is much less severe in old, atherosclerotic, hypertensive monkeys than in young, healthy monkeys. This indicates that the retina of the old, atherosclerotic, hypertensive monkeys tolerates acute ischemia much better than that of young monkeys. We discuss the reason for that disparity elsewhere.[2,3] No information is available about the difference in severity of acute ischemic damage produced by the occlusion of the posterior ciliary artery (PCA) between young rhesus monkeys and old, atherosclerotic, hypertensive rhesus monkeys. The present study investigated this. The PCA circulation is the most important component of ocular and optic nerve head circulation. This is because it is the main source of blood supply to the optic nerve head (Fig 1), the outer 130 μm of retina, the retinal pigment epithelium, the choroid up to the equator, and the medial and lateral segments of the ciliary body and iris.

Methods

In rhesus monkeys under intravenous pentobarbital sodium anesthesia, all PCAs were exposed in the retrobulbar region up to their sites of entry into the globe by lateral orbitotomy, without cutting any of the extraocular muscles or interfering with any other arterial supply to the globe. All PCAs were cut by a cautery near their site of entry into the eyeball in 7 eyes of normal, healthy rhesus monkeys and in 8 eyes of old, atherosclerotic, hypertensive rhesus monkeys. The orbitotomy wound was closed in layers. All the eyes were evaluated by repeated ophthalmoscopy, color fundus photography, and fluorescein fundus angiography before the occlusion, approximately 1 hour and 1 day after the occlusion, and serially thereafter during the follow-up period, until the animals were killed. The fundus was evaluated in the peripapillary, macular, middle, and peripheral regions and the optic disc. Intraocular pressure was measured in all the eyes serially during the initial and later stages of the study. The study design complied with the National Institute of Health's Guidelines, the Association for Research in Vision and Ophthalmology Statement for the Use of Animals in Ophthalmic and Vision Research, as well as the University of Iowa's Institutional Guidelines for the Care and Use of Laboratory Animals.

In the atherosclerotic, hypertensive monkeys, atherosclerosis had been produced experimentally by feeding the animals a special atherogenic diet continuously for many years. The atherogenic diet contained (according to the manufacturer) 17.45% protein, 20.92% fat, 44.52% carbohydrates, and 1.26% cholesterol, with a caloric value of 4.36 kcal/g of diet (16% from protein, 43.2% from fat, and 40.8% from carbohydrates). Serial fasting plasma lipid estimations in these animals showed a sustained rise in fasting plasma

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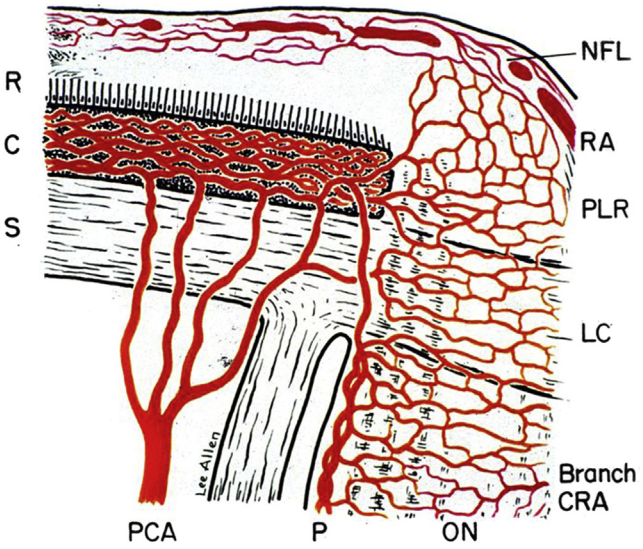

Figure 1. Schematic representation of blood supply of the optic nerve head. C = choroid; CRA = central retinal artery; LC = lamina cribrosa; NFL = surface nerve fiber layer of the disc; ON = optic nerve; P = pia; PCA = posterior ciliary artery; PLR = prelaminar region; R = retina; RA = retinal arteriole; S = sclera. (Reproduced from Hayreh SS. Structure and blood supply of the optic nerve. In: Heilmann K, Richardson KT, eds. *Glaucoma: Conceptions of a Disease*. Stuttgart: Georg Theime Publishers; 1978:78–96.)

cholesterol levels of up to 665%, without any significant change in the mean high-density lipoprotein values, and triglyceride levels were elevated in some of the animals. Autopsy studies performed in all animals in the atherosclerotic group showed extensive atherosclerotic lesions in the aorta and coronary, renal, and other major arteries. Also in these animals, chronic arterial hypertension was produced by modified Goldblatt's procedure[4] and maintained for a period of years, as confirmed by serial blood pressure measurements.

Results

Fundus Changes during the Acute Phase

Table 1 summarizes the severity of acute fundus changes after the occlusion of the PCAs in the young healthy monkeys, and Table 2 summarizes those in the old, atherosclerotic, hypertensive monkeys. The normal fundus in rhesus monkeys has a dark brown appearance; ischemic infarction of the retinal pigment epithelium and the outer retinal layers (Fig 2), supplied by the PCA circulation, initially manifested as whitish retinal opacity (Figs 3 and 4A). Acute ischemia of the optic nerve head resulted initially in development of optic disc edema (Figs 3 and 4A), which represented anterior ischemic optic neuropathy. There were no changes in the inner retina (Fig 2) or retinal vessels (Fig 4B and E).

To determine if there was any difference in the severity of the various acute ischemic lesions during the acute phase in the fundus and the optic disc between the 2 groups of animals, a statistical analysis was performed comparing the young, healthy monkeys without atherosclerosis and arterial hypertension with the old monkeys with atherosclerosis and chronic arterial hypertension. Table 3 summarizes the findings. It showed no statistically significant difference between the 2 groups in the severity of various acute fundus lesions during the acute phase.

Fluorescein Fundus Angiographic Findings during the Acute Phase

Soon after the occlusion of the PCAs, there was no filling of the entire choroid and the optic disc in both groups of animals (Fig 5), except for some late filling of the peripapillary choroid in most of them (Figs 4B and 6) and late staining of the edematous optic disc and patchy filling of the choroid via collaterals (described elsewhere[5]; Fig 4C). In eyes with no optic disc edema, the disc filled on fluorescein angiography. The retinal circulation filled normally in eyes in both the groups.

Late Fundus Changes

In all eyes with optic disc edema, later on optic atrophy developed progressively because of anterior ischemic optic neuropathy (Figs 4D and 7). In both groups, the white opacity of the fundus seen during the acute phase resolved gradually in approximately 2 to 3 weeks, and the involved part of the fundus assumed a greyish, granular, depigmented appearance, with unmasking of the large choroidal vessels, except for the peripapillary choroid in some of the eyes (Figs 4D and 7).

Late Fluorescein Fundus Angiographic Findings

One day after the occlusion, the vascular filling pattern usually was similar to that soon after the occlusion of the PCAs. After that, the

Table 1. Severity of Acute Fundus Lesions after the Occlusion of the Posterior Ciliary Arteries in Young, Healthy Monkeys

Eye No.	Interval between Posterior Ciliary Artery Occlusion and First Postocclusion Examination (Days)	Fundus Opacity*				Optic Disc Changes: Optic Disc Edema
		Peripapillary	*Macular*	*Middle*	*Peripheral*	
1	1	0	3	4	4	4
2	2	0	4	4	4	4
3	1	0	4	4	4	2
4	1	0	4	4	4	4
5	1	0	4	4	4	2
6	1	0	4	4	4	0
7	1	4	4	4	4	3

*0 = none; 1 = minimal; 2 = mild; 3 = moderate; and 4 = severe.