CIRCULATION IN THE IRIS AND CILIARY PROCESSES

POSSIBLE RECIPROCAL RELATIONSHIP*†

BY

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A RECENT observation in experimental animals suggests that there may be a reciprocal relationship between the arterial blood flow in the ciliary processes and the iris. While this process has not been conclusively proven, it appears of sufficient interest to warrant mention.

In mammals, the ciliary processes and iris derive their arterial supply solely from the major arterial circle of the iris‡. This circle is formed by anastomosis of the terminal branches of the medial and lateral long posterior ciliary arteries and anterior ciliary arteries. Besides the arteries subserving the ciliary processes and the iris, the major circle also provides some of the recurrent branches to the choroid though these tend to be small. There is little or no evidence to suggest a collateral arterial blood supply for the iris and ciliary processes by any other route. Thus the two tissues comprising a portion of the anterior uvea share a common vascular supply. It is difficult at present to ascertain how much blood either tissue takes from the major circle. Grossly (in rabbits, rats, and in guinea-pigs), it appears that ciliary processes have slightly wider arterial channels than the iris. However, the arterioles of the ciliary processes tend to bend obliquely backwards, whereas the vessels of the iris generally come straight forward off the circle, possibly favouring flow towards the iris. Not infrequently, a branch from the major circle supplies both iris and ciliary processes. Variations in size of the pupil with consequent change in the path of the iridic vessels would appear to modify blood flow to this tissue and perhaps secondarily affect flow to the ciliary processes.

The present report stems from the following observations:

In an attempt to outline the intra-ocular vascular tree of rats, Indian ink was injected into the still-beating heart of the terminally anaesthetized animal. In several instances the intra-ocular vessels, with the exception of those in the ciliary processes, filled completely, creating a rather striking picture (Fig. 1, opposite). In other instances, only a portion of the ciliary processes was filled with Indian ink, whereas blood could be seen in the uninjected portion of the process. It was noted, however, that when atropine had been instilled into the eye before injection the ciliary processes filled adequately with ink, and that the iridic vessels occasionally appeared less well filled (Fig. 2, opposite).

As a consequence of the above observations, the following experiment was performed:

Pilocarpine drops 4 per cent. were instilled into the right conjunctival sac and atropine

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‡ The position of the major arterial circle of the iris varies markedly from species to species, and even within individuals (Henkind, 1964). In rabbits, rats, and guinea-pigs a good portion of the circle lies within the peripheral iris.

FIG. 1(a).—Indian ink-injected rat. Pupil untreated. Note that all the vessels (except those in the ciliary process region (CP)) have filled well. $\times 15$.

R = retinal vessels
 C = choroidal vessels
 CP = ciliary process vessels
 MC = major arterial circle of the iris
 I = iris vessels

FIG. 1(b).—Higher power view of same specimen as (a), showing poor filling of ciliary process arterioles as compared with iris arterioles. $\times 48$.

FIG. 2.—Indian ink-injected rat. Pupil dilated with 1 per cent. atropine. Note markedly corkscrewed iris arterioles, which are poorly filled with ink when compared with the ciliary process arterioles. $\times 44$.

drops 1 per cent. were instilled into the left conjunctival sac of albino rabbits, rats, and guinea-pigs (two of each) until miosis and mydriasis were adequate. Lethal doses of Nembutal were then given to the animal, and before death the chest was opened, the descending aorta clamped, the pericardium incised, and Indian ink gently injected into the left ventricle of the still-beating heart. As the heart enlarged with the injection, the right auricle was incised to prevent vascular congestion. The eyes were immediately enucleated and placed in 10 per cent. formol saline. After several hours the globes were sectioned equatorially and the iris, ciliary body, and anterior choroid were removed *in toto* and either mounted in hanging drop slides (rat and guinea-pig), or placed in pots of formol saline (rabbit).

Observations

In the eyes treated with pilocarpine the pupil was miotic, and the iris vessels tended to be either straight or gently curved. The iris vessels were relatively full of Indian ink compared with the vessels of the ciliary processes (Fig. 3). In the atropinized eyes the reverse situation was seen: the pupil was dilated, and the iris vessels were markedly tortuous and only partially filled with ink compared with those of the ciliary processes (Fig. 4). The findings were most prominent in the guinea-pig eyes. It must be emphasized that this dichotomy was not always marked, and that relatively few sections of any eye showed complete filling of the iris with ink and absence of ink in the adjacent ciliary processes, and *vice versa*. It was especially noted that, at the

FIG. 3.—Indian ink-injected guinea-pig. Right eye treated with 4 per cent. pilocarpine. Note the well-injected, straight iris arterioles; the ciliary processes are less well injected. (The focus is on the major arterial circle of the iris in these hanging drop slide preparations.) $\times 44$.

FIG. 4.—Same animal as Fig. 3. Left eye treated with 1 per cent. atropine. Note the poorly filled corkscrewed iris arterioles compared with well-filled ciliary process arterioles; this is especially marked in the lower branch of the major arterial circle, where the ciliary process branches are black with ink and the iris arterioles almost empty. (Again, the focus is on the major circle and the ciliary processes appear slightly out of focus. The ink was not extravascular.) $\times 44$.

terminal portions of the major circle, the vessels of the adjoining iris and ciliary processes filled well with ink regardless of the state of miosis or mydriasis.

In one pigmented guinea-pig the right eye was dilated with 1 per cent. atropine and the left pupil constricted with 4 per cent. pilocarpine. The animal was then killed with Nembutal and the vascular system was flushed clean of blood with sodium nitrite solution (chosen to prevent any possibility of vasoconstriction due to ink injection). White ink was then injected into the heart until the conjunctival vessels turned white. Examination of the anterior uveal tract revealed the ciliary processes to be quite whitened in the atropinized eye, but only faintly so in that treated with pilocarpine, the reverse being true of the iris vasculature, with white vessels much more obvious in the eye treated with pilocarpine.

Discussion

Although both the experimental method and analysis of the above findings are subject to various interpretations, the observations suggest the possibility of a reciprocal relationship between blood flow in the ciliary processes and in the iris, at least in the experimental animals used (Fig. 5). Is it not conceivable that in mydriasis, with the pupil dilated and the iris vessels kinked, and notwithstanding their unique structure preventing collapse of the vessel wall during changes in pupillary size, the arterial flow to the iris may be hindered by increased resistance, and that blood may then preferentially flow *towards* the ciliary processes? Conversely, in miosis, would it not be possible for the straightened iris vessels to provide a route of least resistance for blood to flow *from* the major arterial circle of the iris?

It is premature to speculate too much on the possible role of a reciprocal mechanism between the blood flow in the iris and ciliary processes. Further methods are needed to confirm and possibly extend the above observations. It should, however, be mentioned that such a mechanism could provide a partial explanation for the

FIG. 5.—Diagram of possible reciprocal flow mechanism between iris and ciliary processes. In (1) the pupil is miotic, and the blood flow from the major circle of the iris tends to be in the direction of the iris arterioles. In (2) the pupil is dilated and the iris vessels are tortuous; the blood flow tends towards the ciliary processes.

action of miotics in lowering ocular tension through reducing the flow of blood in the ciliary processes (decreasing production of aqueous), particularly in cases in which outflow facility is apparently unchanged (Becker and Friedenwald, 1953; Krill and Newell, 1964). An alternative explanation, that the contraction of the ciliary muscle induced by miotics may cause compression of the ciliary arteries with a concomitant decrease in the blood flow in the ciliary processes, must also be considered (Swan, 1959). The finding by Scullica (1958; 1962) of possible shunt mechanisms within the ciliary body of rabbits also bears mention.

Summary

Observation of ink-injected eyes of rabbits, rats, and guinea-pigs during miosis and mydriasis suggests the possibility of a reciprocal relationship between arterial blood flow to the iris and to the ciliary processes.

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ADDENDUM

Several sources mention that pilocarpine dilates the pupils of both guinea-pigs and rats (the so-called paradoxical effect). This was not confirmed in guinea-pigs where in all instances the pupil actively constricted when pilocarpine 4 per cent. was instilled into the conjunctival sac, and this miosis was readily reversed by topical application of atropine 1 per cent. On the other hand, the normally very miotic pupil of the rat is slightly dilated by topical pilocarpine, and in retrospect this accounts for the fact that in a number of untreated rats miosis was better without pilocarpine and that in these animals Indian ink injection showed more inking in the iris vessels and less in the vessels of the ciliary processes than in the animals treated with pilocarpine. Atropine markedly dilates the pupil of the rat (even the animals treated with pilocarpine) and Indian inked specimens show excellent filling of the blood vessels of the ciliary process compared to the vessels of the iris.