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Key words: retinoblastoma, surface antigens, cytoplasmic antigens, cancer

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Studies on the angioarchitecture of the posterior choroid in rat and role of posterior ciliary vein. Hiroshi Yoshimoto, Mikio Murata, Kiyoshi Yamagami, and Shuichi Matsuyama.

Vascular casts were made by injection of low-viscosity plastic in eight Wistar-Kyoto rats, and the posterior half of the ocular wall was observed using the seminultrathin section method. Veins which connect with the capillaries of the posterior choroid include a venous system independent of the vortex vein and running parallel to the long and short posterior ciliary arteries. The veins flow into a venous ring which is located in the region at which the arterial circle of Zinn is said to be. There was no structure in this region which could be described as an arterial circle. From the above findings, it is concluded that these venous systems are part of the posterior ciliary vein and that they play an important role as a pathway for irrigation of blood from the posterior choroid.

Despite the clinical importance of the choroidal circulatory system, its fine structure has not been as fully clarified as that of the retinal circulatory system because of the anatomic difficulty of direct, in vivo, detailed observation. Nevertheless, due to the development of low-viscosity plastics suitable for preparation of vascular casts, the circulatory
system of the entire choroid is gradually being elucidated. Consequently, it has been argued that the vessel system of the peripapillary wall of the eyeball functions particularly as a connection with the vascular system of the optic nerve. Consequently, it is apparent that many unsolved problems remain concerning even the vessel structure of the circulatory system of the posterior choroid. Furthermore, there are few reports denying the presence of the arterial circle of Zima, which is said to be an important feeder vessel for the optic nerve, despite numerous detailed studies in the monkey, etc.

Here we report our observations on the vessel structure of the posterior half of the ocular wall in the area of the optic nerve of rats with the use of complete vascular cast samples. A previously unreported venous system with a ring structure in that area is described. The vessel structure of the posterior ocular wall in the rat is also described, and its role as a portion of the choroidal circulatory system is discussed.

Materials and methods. Materials included eight mature Wistar-Kyoto rats, six of which were used for vascular cast studies. Semithin sections were made from all four eyes of the remaining two rats for histologic studies.

Vascular casts were made under the administration of ether anesthesia. An 18-gauge (1.25 mm) blood transfusion set needle was inserted and fixed in the left ventricle of each rat following thorotomy. Simultaneously the auricle was opened and perfusion undertaken with a substitute serum. After replacement of all blood, perfusion fixation of the vessel tissue was undertaken with 2.5% glutaraldehyde, followed by injection of 20 ml of resin (Merox CL-28-1, Dai-Nippon Ink and Chemicals Inc., Japan) to which 1% accelerator had been added.

Fig. 1. Posterior view of a vascular cast of a rat eye. Two LPCAs (LA) arise from the ophthalmic artery (OA) and run along the horizontal meridian of the eye ball. A well-developed venous ring system (RING) is seen around the vascular network of the optic nerve. Inset: High magnification of the area pointed with an asterisk. The surface of the venous ring reveals a characteristic aspect of the vein. OV = ophthalmic vein; CC = choriocapillary. (Bar = 200 µm.)
Fig. 2. Posterior view of a venous ring system. Many confluent veins (stars) are seen around the venous rings (RING). An asterisk shows a short communicating vessels between two rings. An arrow shows an afferent arteriole toward the optic nerve. LA = LPCA; CRA = central retinal artery. (Bar = 200 μm.)

ed. Injection of the liquid was continued until the resin appeared at the auricle. The rats were then left alone for 1 hr before removal of the eyeballs, which were soaked in 15% KOH aqueous solution for 24 hr at room temperature and then rinsed and dried. In order to make scanning electron microscopic observations of the completed resin samples of blood vessels, gold-ion spattering were performed. For the semithin sections, the excised rat eyeballs were double-fixed with glutaraldehyde and OsO₄ and then dehydrated in a series of alcohol solutions. After block embedding in Epon 812 resin, 0.7 μm sections were prepared. Toluidine blue, 1%, was used for staining.

**Results.** Solely from the posterior surface of the vascular casts of blood vessels of the ocular wall, it was apparent that most of the capillaries within the optic nerve made contact superiorly and that the ophthalmic artery, which traveled rostral to the optic nerve, was divided into three branches immediately rostral to the capillary network of the choroid. The central branch was the central retinal artery which entered the optic nerve. The other two arteries branched to the left and right and ran along the horizontal meridian of the eyeball, across the surface of the choroidal vessels, and became the long posterior ciliary artery (LPCA) (Figs. 1 and 2). Two short posterior ciliary arteries (SPCA) per LPCA—for a total of four SPCA—branched from the LPCA and were distributed to the choroidal vessels of the posterior half, which were divided into about eight main branches. However, no connecting vessels were seen prior to their arrival at the capillaries. At one portion the thin afferent branches of the SPCA turned toward the capillaries within the optic nerve, and communication with that vessel was identified (Fig. 2). However, a ring structure of the SPCA
Figs. 3 and 4. In both sides of the LPCA (LA), two veins (stars) are found. However, the SPCA (SA) has only one parallel vein (small star). A thin arrow shows a junction of three collecting venules, and a thick arrow shows a junction between the vein and a venous ring (Fig. 3). An asterisk in Fig. 4 shows an intravenous anastomosis. (Bar = 200 μm.)

branches which could be considered to be the arterial circle of Zinn was not found.

A short collecting venule which collects three to six choroidal capillaries was seen, however, near the capillaries of the posterior half of the choroid (Fig. 3). After two or three of these venules ran together at the same point, they became a venule with a diameter of 50 μm, which then ran into veins with diameters of less than 100 μm. These veins of approximately 100 μm ran along the LPCA and SPCA and gradually increased in diameter. They then collected from all directions and turned toward the optic nerve. As seen in the sections, these veins were located at the border between the choroid and the sclera. In the vicinity of the optic nerve they completely entered the sclera. As shown in Fig. 4, in most cases two such veins ran parallel bilaterally to each branch of the LPCA, and one such vein ran along each SPCA. Peripherally, these veins assumed a looplike structure, and between that area and a venous branch belonging to the vortex veins small vessels of about 20 μm in diameter were seen, which communicated between them (Figs. 3 and 4). These veins, which separated from the choroid and extended nearly to the optic nerve, joined with a unique ringlike structure (“venous ring”) with vessels of 150 to 200 μm in diameter. The diameter of the ring itself was 600 to 900 μm. With the vessels within the optic nerve as the axis in two to three layers, each ring had short communicating vessels entering into it (Figs. 1 and 2). Very few vessels from within the optic nerve directly entered the venous ring. From the posterior (i.e., most centrally located) ring, the ophthalmic vein, which ran parallel to the ophthalmic artery, turned posteriorly from the superior surface of the optic nerve (Fig. 1).

Discussion. Great leaps in the elucidation of the vessel structure of the choroidal circulatory system
have been made possible by injection of low-viscosity (20 to 30 cps) liquid plastic monomers into arteries, thereby making it possible to obtain scanning electron microscopic observations of the vascular casts. The samples found with the use of this low-viscosity plastic reflect the ultrastructure of the internal surface of the blood vessels. It has therefore become possible to completely reexamine the vessel structure of capillaries, which have been known as the arteriolo-capillaries-venule unit. Needless to say, as also shown in the figures of these vascular casts, differences in the surface structure of arteries and veins are apparent at a glance—the details concerning which have been reported by Matsusaka.

The most interesting finding obtained in the present study is that a series of venous system—containing ringlike structures, which have not been previously reported, has been found in all of the rats observed. The principal vein of the choroidal circulatory system has long been known to be the vortex vein. It can be said, however, that the existence and nature of other veins has been largely ignored. It has previously been found that in the rat as well as in other species, four well-developed vortex veins are present, but distribution of these veins to the posterior half of the choroid has not been found. Distribution of these veins to this area, as we have found, is evidence that they are the primary drainage pathway of the posterior choroid in the rat. It is thought that they constitute evidence indicating the existence of a new drainage pathway of the choroidal circulatory system which does not travel via the vortex vein.

In contrast, many studies have recorded the presence of the arterial circle of Zinn as a major arterial source of nutrients for the optic nerve. Yet it is remarkable that there are very few reports dealing with the entire structure of that arterial ring. Only the findings of Wybar with the use of a neoprene cast can be referred to as the basis for belief in its existence. It is thought, however, that reference to this work with a high-viscosity plastic which would be incapable of elucidating the microcirculation should be avoided.

There are also a number of reports which deny...
the existence of this arterial ring based upon sections obtained from man and monkey.6-8 Although there are reports demonstrating a well-developed arterial circle of Zinn in the guinea pig12 and a thin vascular ring in the macaque monkey13 with the use of the same low-viscosity plastic we have used, no investigation was made in these reports in detail concerning the arterial nature of the ring vessels. In fact, we originally undertook this research firmly believing that the venous ring was in fact the arterial circle of Zinn. Ujite and Hanyuda2 showed a structure of peripapillary choroid, i.e., arteriole-arteriole (A-A) anastomosis at the edge of the choriocapillaries, in macaque monkey. They thought that the architecture corresponded to the arterial circle of Zinn. The vessels composing the anastomosis shown by them are too small in size and too much anterior in its position to estimate it the arterial circle of Zinn. And we consider that their peripapillary choroid A-A anastomosis is quite different structure from the venous ring shown in the present study.

We believe that a complete circle corresponding to the circle of Zinn is lacking in rat eye and that the incomplete arterial circle which was reported in the eye of primates as the circle of Zinn8 may be similar vascular structure to the afferent branches of the SPCA toward the optic nerve as we found in the present study.

We believe that since the veins which enter the venous ring run parallel with the SPCA and LPCA as described above, and following the custom of calling parallel veins and arteries by the same name, that these vessels should be called the short and long posterior ciliary veins. But judging from the similarities in size and structure, it is perhaps better to refer to them collectively as the short posterior ciliary vein, arterial circle of Zinn, angioarchitecture, vascular cast, posterior choroid

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Axial lengths and refractive errors in kittens reared with an optically induced anisometropia. EARL L. SMITH, III, GREGORY W. MAGUIRE, AND JON T. WATSON.

An anisometropia was simulated in kittens during the critical period of development by securing a high-