VASCULARIZATION OF THE OPTIC PATHWAY*

No. V. CHIASMA

BY

J. FRANÇOIS, A. NEETENS, AND J. M. COLLETTE

From the Ophthalmological Clinic, University of Ghent (Director: Prof. J. François) and the Institute of Radiology, University of Liège (Director: Prof. Leroux)

WHEREAS from the myelo-architectonic point of view the chiasma is merely an organ of transit, this is not so from the vascular point of view; there seems to be a partial dissociation between the myelo-architecture and the angio-architecture.

The vascularization of the chiasma has been investigated on the basis of 22 human specimens. The techniques used (dissection after fixation in 10 per cent. formaldehyde, injection of Indian ink, staining with benzidine, and microradiography) have been discussed in previous publications (François, Neetens, and Collette, 1955, 1956; François and Neetens, 1956).

I. EXTRACHIASMAL OR PERICHIASMAL VASCULARIZATION (FIG. 1)

The chiasma is completely surrounded by a vascular network which continues to the hypophysis, the pituitary pedicle, and the infundibulum of the 3rd ventricle. This network consists of arterioles and precapillaries arising from eleven different arteries, as shown by Abbie (1938). The internal carotid, the anterior cerebral, and the anterior communicating artery are the chief arteries among these eleven; the middle cerebral, the posterior communicating, and the anterior choroidal artery are less important. All these arteries send supplying branches to the interior of the chiasma, either directly or by the intermediary of the network on the surface of the chiasma.

An arteriolar arch is one of the structures found in front of the chiasma, as shown by Dawson (1949). This arch constitutes, to put it briefly, a replica of the circle of Willis. It is incomplete, however, as it covers only about 180°. It runs parallel with the anterior part of the circle of Willis, and thus forms a posterior concavity. It is chiefly made up of branches of the internal carotid, the anterior communicating, and the anterior cerebral artery, but this does not prevent these arteries from also extending collaterals directly to the chiasma.

The most important among these direct collaterals is a branch of the anterior communicating artery, which has not hitherto been described and which we shall call the chiasmal artery. This artery is found in about one-third of cases, and precisely in those in which the minute branches directed at the chiasma which issue from the anterior communicating artery and from

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the anterior part of the anterior cerebral artery are not numerous. Where these branches are numerous, this chiasmal artery does not exist.

The following ligatures must be used if the entire vascular system of the chiasm is to be filled (Fig. 1):

- (1) At the level of the two middle cerebral arteries, 1-2 cm. from the site at which they leave the internal carotid.
- (2) At the level of the two anterior cerebral arteries, immediately before the anterior communicating artery.
- (3) At the level of the two ophthalmic arteries, immediately before their site of origin.
- (4) At the level of the two anterior choroidal arteries and the two posterior communicating arteries, about 1 cm. before their site of origin.

Fig. 1. Sites of ligature.

FIG. 1.—Arterial and arteriolar supply of chiasma.

(1) Anterior communicating artery with chiasmal artery.	(4) Posterior communicating artery.
(2) Anterior cerebral artery.	(5) Anterior choroidal artery.
(3) Internal carotid artery.	(6) Middle cerebral artery.
(7) Prechiasmal arcade.	

The needles used for the injection of contrast medium or Indian ink are inserted at the point of section of the internal carotid. This is ligated as soon as the injection has been completed and before the needle is withdrawn. The region is previously bathed with 10 per cent. formaldehyde when Indian ink is injected, and with absolute alcohol when Thorotrast is injected.

If a single artery of the eleven supplying the chiasma is injected, then the chiasma is only incompletely and irregularly filled. On the other hand, if

the middle cerebral, anterior choroidal, and posterior communicating arteries are excluded, filling is almost complete, only a small postero-temporal part failing to be filled.

In one case we succeeded in injecting into the chiasmal artery, and this resulted in incomplete filling of the central part of the chiasma.

Our observations would seem to warrant the following conclusions being drawn:

- (1) The only specific and well-defined artery which we found at the level of the chiasma was the chiasmal artery, which supplies the central part of the chiasma. However, this vessel was not always found.
- (2) The only characteristic arteriolar formation is the prechiasmal arch.
- (3) The branches of the internal carotid reach the chiasma at its inferior temporal surface.
- (4) The branches of the anterior communicating and the anterior cerebral arteries reach the chiasma at its antero-superior surface.
- (5) Anastomoses can be observed between the small arterioles localized at the surface of the chiasma.
- (6) All these arterioles proceed to the chiasma, either directly or—more frequently—by way of the prechiasmal arch.
- (7) The ophthalmic, anterior choroidal, middle cerebral, and posterior communicating arteries are only slightly and at best indirectly involved in the vascularization of the chiasma.

We are inclined to agree with Abbie (1938) that the exclusion of one or two arteries of the chiasmal region would have no serious consequences in regard to the function of the optic pathways. Central or peripheral visual disturbances consequent upon a lesion of the chiasma are invariably due to direct mechanical compression of the latter and never to an affection of one or other of the supplying arteries. However this may be, the intrachiasmal arteriolar and capillary network is the most important.

II. INTRACHIASMAL VASCULARIZATION (FIG. 1, and FIG. 2, opposite)

(A) Arteriolar Vascularization

(1) Arterioles of varying calibre approach any free aspect of the chiasma. Their portal of entry is indicated by a slight unevenness. They are particularly numerous at the level of the temporal and inferior aspects and at the anterior border.

The arterioles of the temporal aspect show fan-wise ramifications in all directions. Those of the inferior aspect are directed towards the posterior part of the chiasma, in a more or less antero-posterior position. Those of the anterior border curve back to follow the tract of the nasal fibres of the optic nerve, crossing the median line (see Fig. 6).

(2) Arterioles also arise on one side from the optic nerve and on the other side from the optic tract. Those which arise from the optic nerve follow a rectilinear course; the nasal arterioles curve back towards the

FIG. 2.—Seven chiasmal capillary zones.

sagittal plane (Fig. 3) and the temporal arterioles for the most part adhere to their primary direction. Those which arise from the optic tract are directed towards the temporal zone (Zone 6, Fig. 2).

FIG. 3.—Photomicrograph after injection of Thorotrast. Chiasma Zone 1. Hairpin curving precapillaries and arterioles (*a*). Irregularly rectilinear capillaries on their way to the sagittal plane showing an anterior concavity. Antero-posterior section. $\times 50$.

Arterioles curving back in hairpin curves are found near the anterior border (Fig. 3).

(B) Capillary Vascularization

In the frontal plane, the capillaries of the chiasma show no systematic arrangement and no characteristic structure. The transverse pentagonal units of the optic nerve are no longer found. The capillaries are merely more numerous and slightly larger at the level of the inferior part than at the level of the superior part.

By combining several methods of examination, we have been able to obtain fairly exact data on the distribution of the chiasmal capillaries in the horizontal plane and in an antero-posterior direction. Seven different zones can be distinguished (Fig. 2):

(1) A zone occupying the nasal half of the optic nerve and the anterior part of the chiasma, showing fine and irregularly rectilinear capillaries following the direction of the fibres and becoming more irregular in the chiasma proper (Fig. 3). Briefly, these are the longitudinal units of the optic nerve which are prolonged into the chiasma, where they curve back towards the median plane, describing a loop with an anterior concavity. The hairpin curves are less numerous here than in Zone 2.

(2) A zone occupying the temporal half of the optic nerve and the anterior part of the chiasma, showing capillaries slightly larger than those in Zone 1 (Fig. 4).

FIG. 4.—Photomicrograph after injection of Thorotrast. Chiasma Zone 2. Angular and irregular capillary network radiating in all directions. Antero-posterior section. $\times 50$.

These capillaries radiate in all directions and make an irregular angular network.

(3) A zone continuing from the preceding and extending to the sagittal plane, showing finer and more regular capillaries (Fig. 5), reminiscent of those in Zone 1. It may be pointed out that the capillaries of the temporal part of the optic nerve do not continue to the optic tract but curve back to the sagittal plane after having penetrated the chiasma.

FIG. 5.—Photomicrograph after injection of Thorotrast. Chiasma Zone 3 (above) and Zone 7 (below). Capillaries above similar to Zone 1, but even smaller, and below similar to the optic-tract capillaries. Transition-type. Antero-posterior section. $\times 50$.

(4) The median zone, more or less hexagonal, extends from the anterior border of the chiasma to its posterior border. It shows capillaries which are larger and run in a transverse direction, connecting the left and right sides. These are the junction capillaries from which finer capillaries arise. The capillary network is less dense and less tortuous in the central part than in the paramedian parts (Figs 6, 7, 8, and 9). In a general fashion the capillaries follow the tract of the fibres. This is the only chiasmal zone in which characteristic capillaries appear, which form true meshes and show a regular aspect throughout the zone.

Fazio and Farina (1940) observed that the capillary network was less dense in the centre of the chiasma than in the paramedian regions.

(5) In the transitional region between the optic nerve and the chiasma, there exists, on the nasal side, a zone in which the capillaries are fairly fine, extremely irregular, and very confused. These capillaries, with no well-defined directional pattern, show abrupt changes in direction with rounded angles (Figs 10, 11, and 12).

FIG. 6.—Photomicrograph after injection of Thorotrast. Chiasma Zone 4. Greater vessels extending over central aspects (a) lying in the direction of fibres. Capillary junction pattern typical of the chiasma (b). Antero-posterior section. $\times 50$.

FIG. 7.—Photomicrograph after injection of Thorotrast. Chiasma Zone 4. Capillary junction pattern (a), larger than the network formed by the other capillaries (b) originating from that typical pattern of the chiasma. Very thin antero-posterior section. $\times 50$.

FIG. 8.—Photomicrograph after injection of Indian ink. Chiasma Zone 4. Capillary junction pattern (*a*) of larger size than the other capillaries. Antero-posterior section. $\times 18$.

FIG. 9.—Benzidin stain. Chiasma Zone 4. Capillary junction pattern (*a*) existing also in a smaller size. Antero-posterior section.

(6) A zone consisting of a triangular region with its base on the temporal border of the chiasma and directed towards the posterior border. Fairly important capillaries are found here, and those on the temporal side especially are closely similar to the capillaries of the optic tract (Figs 13 and 14).

FIG. 10.—Photomicrograph after injection of Thorotrast. Chiasma Zone 5. Irregular capillaries with curly meshes (a). Epichiasmal arterioles plunging into the chiasma (b). Anterior-posterior section. $\times 50$.

FIG. 11.—Photomicrograph after injection of Indian ink. Chiasma Zones 1, 2, 4, 5 and 6. Heavy contrast between Zone 5 and surrounding zones. Anterior-posterior section. $\times 18$.

(7) A transitional zone between the third and the sixth zones. It has the form of a half-moon and stretches from the temporal border of the chiasma to the median zone. It includes tortuous capillaries, fairly large but not numerous, which form a network with no apparent systematic arrangement and with no well-defined structure (Figs 5, 14, and 15).

FIG. 12.—Benzidin stain. Chiasma Zone 5. Irregular fine capillaries with angular subdivisions. Antero-posterior section.

FIG. 13.—Photomicrograph after injection of Thorotrast. Chiasma Zone 6. Different arterioles (*a*). Capillary pattern (*b*) is to be compared to that of the optic tract. Antero-posterior section. $\times 35$.

FIG. 14.—Photomicrograph after injection of Indian ink. Chiasma Zone 6. Larger vessels (a) and capillary pattern of the optic tract (b); Strong contrast with Zones 1 and 2. $\times 18$.

FIG. 15.—Benzidin stain. Chiasma Zone 7. Transitional pattern of capillaries somewhat larger and less numerous, with no definite structure. Antero-posterior section.

These findings may be summarized as follows:

In the chiasma there are capillaries of the type found in the intracranial optic nerve (Zones 1, 2, and 3), those of a type found in the optic tract (Zone 6), and some special types at the level of Zone 4 (typical junction capillaries), Zone 5 (an isolated group of irregular capillaries), and Zone 7 (atypical transitional capillaries).

The characteristics of the capillary network of the chiasma are therefore as follows:

- (1) Typical connecting capillaries (junction capillaries).

- (2) Different atypical capillaries of varying localization.
- (3) Dissociation between myelo-architecture and angio-architecture.

In considering the macroscopic and microscopic vascularization of the chiasma, therefore, we find that a chiasmal affection manifested by characteristic perimetric deficiencies could hardly be dependent on an interruption of the extratissular vessels, which are too numerous for this, but must be due to mechanical compression, which would have a direct unfavourable effect on the capillary network, certain zones of which may be more readily affected than others.

Summary

- (1) The chiasma is supplied chiefly by the internal carotid, the anterior cerebral, and the anterior communicating arteries.
- (2) An arteriolar arch with a posterior concavity is interposed between these vessels and the anterior part of the chiasma.
- (3) A chiasmal artery, a collateral of the anterior communicating artery, was found in one-third of the cases examined.
- (4) The arteriolar and capillary network of the optic nerve and the optic tract partly invades the chiasma.
- (5) Outside the median zone of the chiasma there is a rupture between the myelo-architecture and the angio-architecture of this organ.
- (6) Seven different capillary zones can be distinguished at the level of the chiasma.
- (7) Of these only the median zone (Zone 4) showed a typical structure with loops of connecting capillaries.
- (8) The significance of these different zones is not known.

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