

## OCCLUSION OF THE CENTRAL RETINAL VESSELS\*†

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A CONSIDERATION of the occlusion of the central retinal vein cannot be regarded as a new thing because a tremendous amount of literature exists on the subject. In spite of this, there are many lacunae in our knowledge, so that the existing information cannot explain all the various aspects of the clinico-pathological picture of central retinal vein occlusion. Any additional data based on experimental observations may help to resolve the numerous speculations and discussions that have continued until now.

The clinical findings in cases of so-called central retinal venous occlusion have suggested from time to time the possible involvement of the retinal arteries as well as the veins, and a close association between the two. This has been particularly so because of the following observations:

(1) Frequent association of central retinal vein occlusion with old age, arteriosclerotic changes, and arterial hypertension.

(2) The occurrence of a sector defect in the field of vision in cases of branch occlusion similar to that of an arterial branch occlusion.

(3) A very high incidence of permanent blindness in cases of clinical retinal venous occlusion (Cassady (1953) saw it in 80 per cent.).

(4) The histopathological examination in cases of obstruction of the central retinal vein shows atrophy of the inner layers of the retina up to the inner nuclear layer, though the visual cells are not affected (Elwyn, 1946), a picture similar to that of arterial occlusion.

Recently, while investigating the pathogenesis of oedema of the optic disc (papilloedema) (Hayreh, 1964), some interesting observations on this aspect of central retinal venous occlusion were recorded on direct blockage of the central retinal vessels in Rhesus monkeys. These have been considered worth reporting in detail.

### Material and Methods

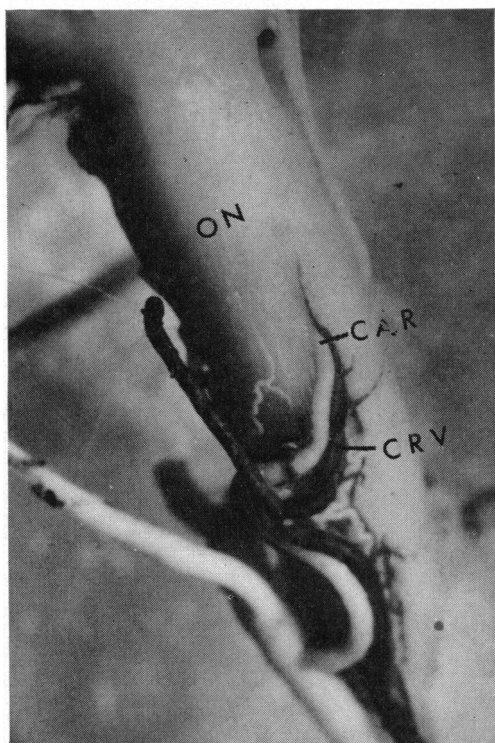
In 10 Rhesus monkeys the central retinal vessels were exposed by a lateral orbitotomy on one side, outside the sheath of the optic nerve during their intra-orbital course (Fig. 1a).

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The vessels were blocked by diathermy near their site of entry into the sheath of the optic nerve from the orbit in the following combinations:

- (1) Occlusion of the central retinal vein alone in 6 Rhesus monkeys (Monkeys No. 1 to 6) (Fig. 2).
- (2) Simultaneous occlusion of the central retinal artery and the vein in 3 Rhesus monkeys (Monkeys No. 7, 8, 9) (Fig. 3).
- (3) Occlusion of the central retinal artery alone in one Rhesus monkey (Monkey No. 10) (Fig. 4).



(a)



(b)

FIG. 1.—(a) The intra-orbital part of the central retinal vessels and their site of penetration into the sheath of the optic nerve in the Rhesus monkey. (b) Normal fundus of a Rhesus monkey (monkey No. 10). (ON = Optic nerve; CAR = Central retinal artery; CRV = Central retinal vein.)

Frequent fundus examination was done to observe the changes in the fundus. The animals were killed at different time-intervals, and histopathological examination of the eyeball and the optic nerve was carried out after injection of Prussian blue solution through the superior vena cava at the time of killing the animal.

**Observations.**—The fundus changes immediately after the block (i.e., after about half to one hour of the block) and subsequently, and histopathological findings in these animals were as follows:

#### Occlusion of the Central Retinal Vein Alone

**Monkey No. 1** (Fig. 2-1).

*Fundus Changes.*—Immediately after the operation the retinal veins were found to be engorged, turgid, and tortuous. No other changes were observed for the next eleven days and the animal was killed.

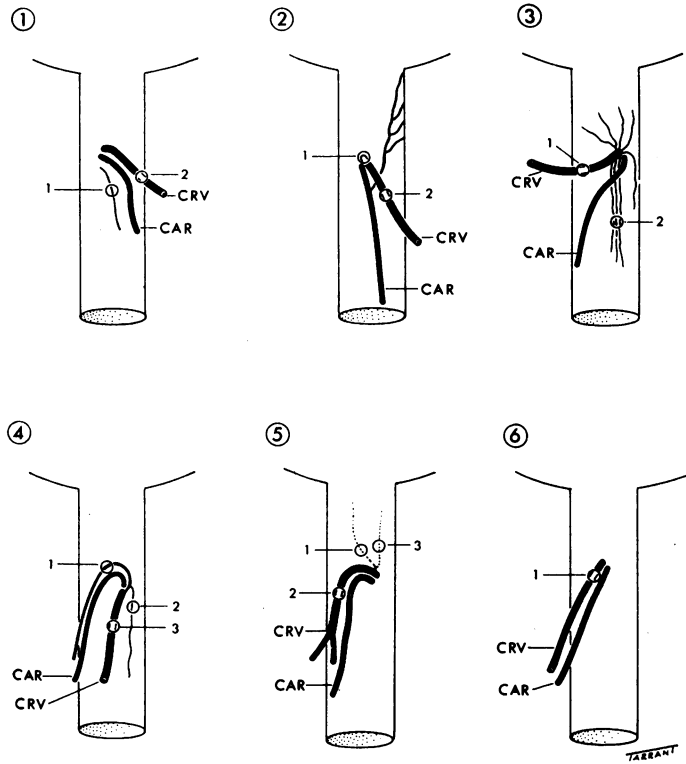


FIG. 2.—Sites of occlusion (1, 2, 3) of the central retinal vein and other adjoining venous tributaries on the inferior surface of the optic nerve in 6 Rhesus monkeys (1-6). (CRV = Central retinal vein; CAR = Central retinal artery, throughout.)

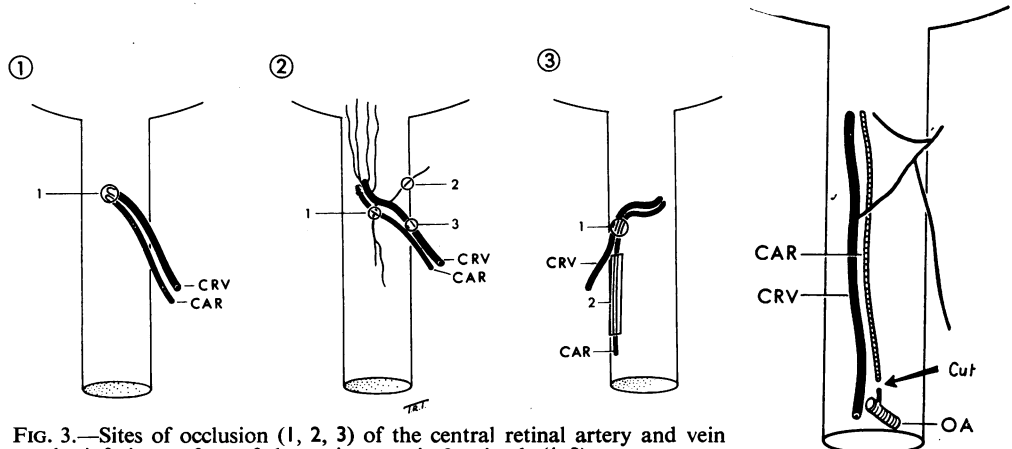


FIG. 3.—Sites of occlusion (1, 2, 3) of the central retinal artery and vein on the inferior surface of the optic nerve in 3 animals (1-3).

FIG. 4.—Site of interruption of the central retinal artery.

An injection of liquid neoprene latex into the veins showed no filling of the central retinal vein in the optic nerve and in the fundus.

**Monkey No. 2 (Fig. 2-2).**

*Fundus Changes.*—Immediately after the operation, the retinal veins were engorged, turgid, and tortuous (Fig. 5a). No other significant changes were seen in the fundus until the twelfth post-operative day, when the retinal venous changes started to subside. The fundus later on returned to normal (Fig. 5b).

*Histopathological Changes.*—A block in the vein outside the sheath of the optic nerve was seen. Prussian blue was seen in the vein at the disc. Small veins in the optic nerve, including the posterior central vein of the nerve, and the pial veins were full of the dye. The optic nerve was normal.

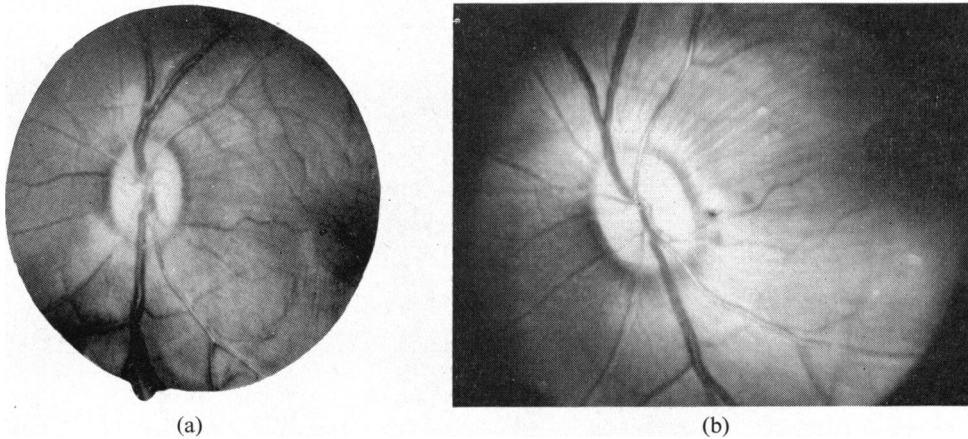


FIG. 5.—Monkey No. 2. Fundus photographs (a) immediately after the venous occlusion, and (b) fourteen days later.

**Monkey No. 3 (Fig. 2-3).**

*Fundus Changes.*—Immediately after the operation, the retinal veins were found to be engorged, turgid, and tortuous. On the third post-operative day the disc was very much hyperaemic, and its margins were blurred with the above-mentioned retinal venous changes. The fundus changes progressed after this to a certain extent (Fig. 6). On the fourteenth day the changes were found to be regressing, and on the twenty-third day the fundus was nearly normal.

*Histopathological Changes.*—The vein was patent during its intra-neural and intra-vaginal course, and no continuity of it was seen in the orbit. A big patch of atrophic degeneration was seen in the optic nerve, lying immediately in front of the site of entry of the central vessels with a small extension backwards.

**Monkey No. 4 (Fig. 2-4).**

*Fundus Changes.*—Immediately after the operation the retinal veins were very much engorged, turgid, and tortuous. On the second post-operative day the disc was hyperaemic with ill-defined margins, there was whitish striation of the surrounding

retina, and the retinal veins were as above. After this, there was some slight progress in these fundus changes. On the seventh day the changes started to regress, and on the sixteenth day the disc was normal with the retinal veins still engorged. On the thirty-sixth day the fundus was nearly normal.

*Histopathological Changes.*—Occlusion of the central retinal vein outside the sheath of the optic nerve was seen. On the pia (at its site of exit from the optic nerve), it communicated with a prominent pial vein, the latter running backwards on the optic nerve. A patch of atrophic degeneration was seen at the site of entry of the central vessels into the optic nerve, involving especially the central retinal artery.

#### **Monkey No. 5 (Fig. 2-5).**

*Fundus Changes.*—Immediately after the operation the retinal veins were found to be engorged, turgid, and tortuous. The fundus changes did not proceed beyond this stage of retinal venous congestion. On the twenty-sixth post-operative day, the fundus was normal.

*Histopathological Changes.*—The central retinal vein was full of Prussian blue during its intra-neural and intra-vaginal course (Fig. 7a). No continuity of it with the intra-orbital part was seen. At its site of exit from the optic nerve it communicated with pial veins (Fig. 7b). The optic nerve was normal.

#### **Monkey No. 6 (Fig. 2-6).**

*Fundus Changes.*—Immediately after the operation the retinal veins were found to be engorged, turgid, and tortuous. On the second post-operative day the disc was hyperaemic and its margins were blurred, except the nasal margin, with the above-mentioned retinal venous changes. On the sixth day the changes were more marked. On the twelfth day these started to regress and the fundus was nearly normal on the sixteenth day.

*Histopathological Changes.*—The central retinal vein was patent during its intra-neural and intra-vaginal course and communicated with the various pial veins running anteriorly and posteriorly (Fig. 8). Near the periphery a small patch of atrophic degeneration was seen in the optic nerve, a short distance behind the lamina cribrosa and another small one in front of the site of entry of the central retinal vessels.

In all these six animals with occlusion of the central retinal vein alone, the immediate changes, as observed after about an hour of the blockage of the central retinal vein, were engorgement, turgidity, and tortuosity of the retinal veins on that side. No swelling of the optic disc and no retinal haemorrhages were observed. Subsequently, in addition to the above changes in the retinal veins, in animals No. 3, 4, and 6, the disc became markedly hyperaemic with its margins blurred and there was a whitish striation of the retina surrounding the disc. These changes were noticed on the first post-operative examination on the second or third post-operative day. The fundus changes progressed for a short time and started to regress on the seventh, twelfth, and fourteenth days in animals No. 4, 6, and 3 respectively. The fundus was more or less normal in these in about sixteen to thirty-six days of the occlusion of the vein. In the remaining three, i.e., monkeys No. 1, 2, and 5, no significant

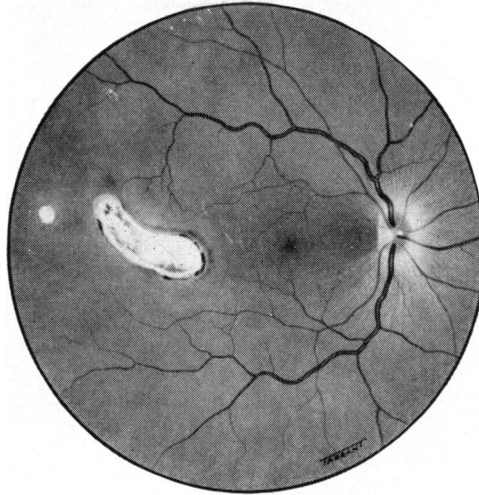
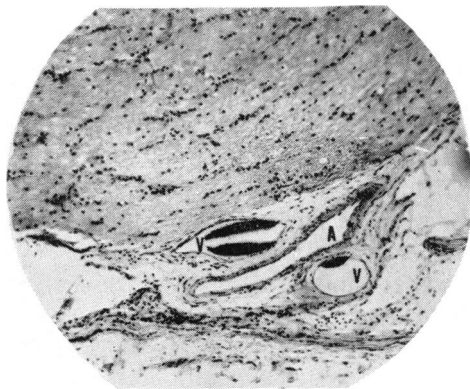
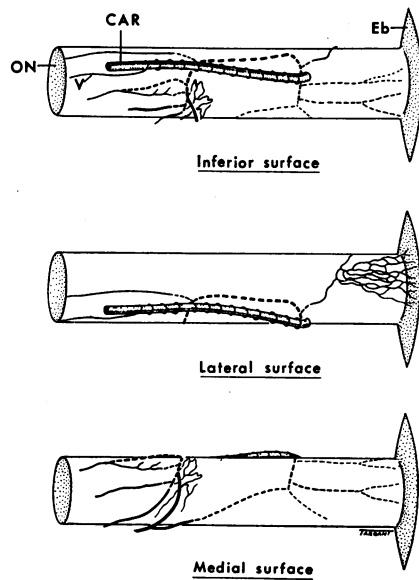


FIG. 6.—Monkey No. 3. Fundus picture on the eighth post-operative day of the occlusion of the central retinal vein. The two white spots are artefacts produced from accidental touching of the diathermy electrode on the eyeball.



(a)



(b)

FIG. 7.—Monkey No. 5. (a) A longitudinal section of the optic nerve showing the central retinal vessels during their intra-vaginal part, with the central retinal vein containing the Prussian blue (A = Artery; V = Vein). (b) Diagram showing different aspects of the optic nerve with the various collateral venous channels draining the blood after the occlusion of the central retinal vein. The dotted lines are the pial veins, and the continuous lines indicate the veins outside the dural sheath of the optic nerve (CAR = Central retinal artery; ON = Optic nerve; V = Vein; Eb = Eyeball).

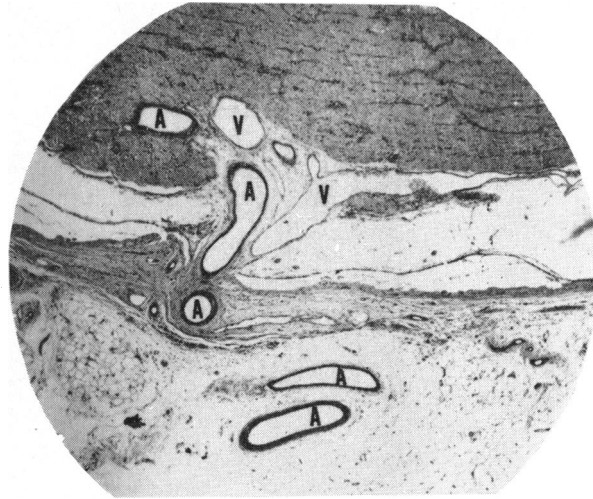


FIG. 8.—Monkey No. 6. A longitudinal section of the optic nerve showing the intra-orbital, intra-vaginal, and intra-neural part of the central retinal artery, with the intra-vaginal and intra-neural parts of the central retinal vein which communicate with a vein behind its site of exit from the nerve. (A = Artery; V = Vein.)

fundus changes other than the engorgement, turgidity, and tortuosity of the retinal veins were seen.

The presence of the block outside the sheath of the optic nerve was confirmed in all these at autopsy either by histology (No. 2, 3, 4, 5, and 6) or by injection of liquid neoprene latex (No. 1). On the pia, at its site of exit from the optic nerve, the vein communicated with pial veins, the communications usually being prominent.

The presence of the patch of atrophic degeneration in the optic nerve in monkeys No. 3, 4, and 6 was due to the burn caused where it was touched by the diathermy.

#### Occlusion of Both the Central Retinal Artery and Vein Simultaneously

**Monkey No. 7 (Fig. 3-1).**

*Fundus Changes.*—After about an hour's occlusion of the vessels the fundus was pale with no circulation in the retina. Vessels were very narrow. After about twenty hours' block, massive haemorrhages in the retina, particularly near the optic disc, were seen. The retinal veins were engorged and the arteries could not be made out. The retina looked milky white and the disc margins were not clear. On the second post-operative day the venous engorgement and retinal haemorrhages were more marked and arteries were not seen. On the fourth day extensive retinal haemorrhages were seen and vitreous haze appeared so that the fundus was not seen clearly. The vitreous haze increased subsequently, so that no details of the fundus could be made out, and the animal was killed on the ninth day.

*Histopathological Changes.*—The posterior part of the retina was full of haemorrhages but only a few were seen in the anterior segment. The retinal haemorrhages were in the outer plexiform layer and the layers internal to it, with absence of ganglion cells and the nerve fibre layer (Fig. 9a).

Haemorrhage in the vitreous was present (Fig. 9b). Sub-retinal exudate on either side of the optic disc was seen. In the optic nerve, a big patch of atrophic degeneration was seen at the site of penetration of the central vessels into it.

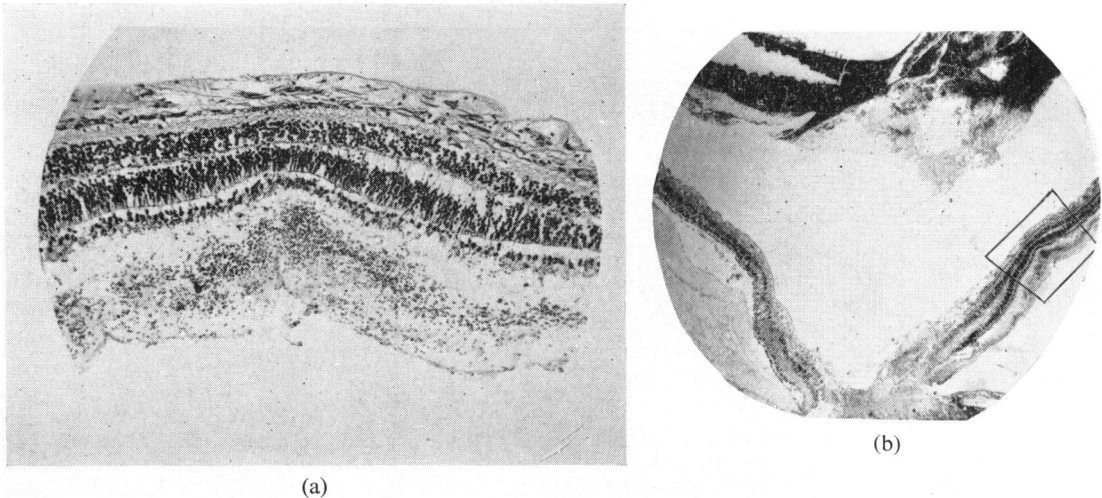


FIG. 9.—Monkey No. 7. (a) Magnified view of the retina, of the area enclosed in (b). (b) Section showing the posterior part of the eyeball and the optic disc, with vitreous haemorrhages, changes in the retina, and sub-retinal exudates.

**Monkey No. 8 (Fig. 3-2).**

*Fundus Changes.*—After about an hour of the block the arteries looked thread-like and the veins were empty. The disc was white and the retina was pale. After about twenty hours, the arteries showed patchy filling but there was no circulation in them while the veins were engorged. Retinal haemorrhages, most marked in the macular region, were seen. The fundus looked pale. On the second post-operative day, the

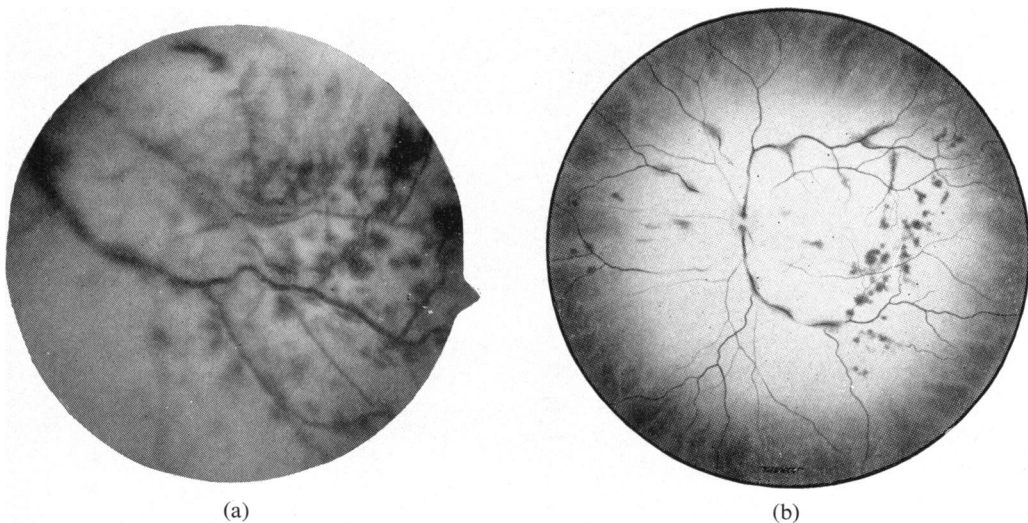


FIG. 10.—Monkey No. 8. (a) Fundus photograph of the macular region on the fifth post-operative day. (b) Fundus picture on the sixth post-operative day.



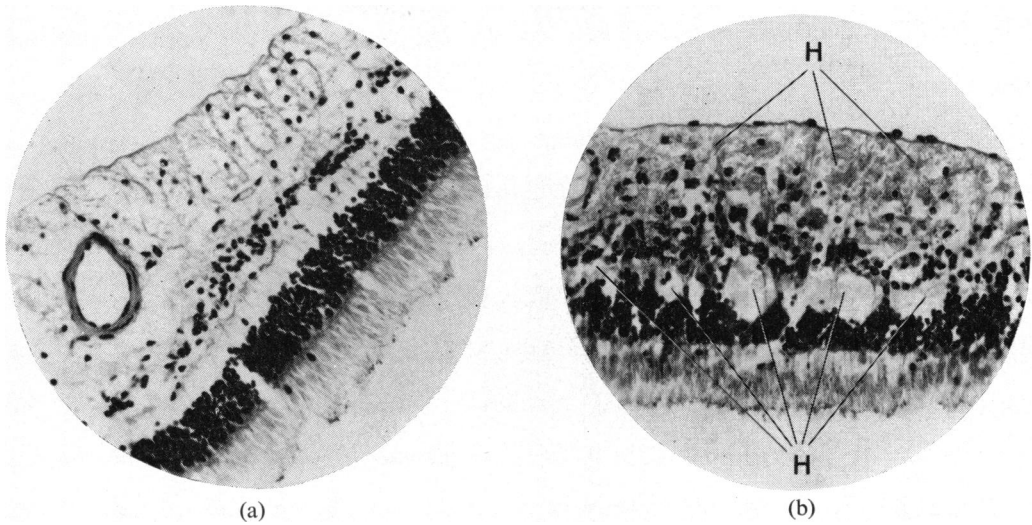


FIG. 11.—Monkey No. 8. Sections of the retina showing (a) the degenerative changes, and (b) haemorrhages as well.

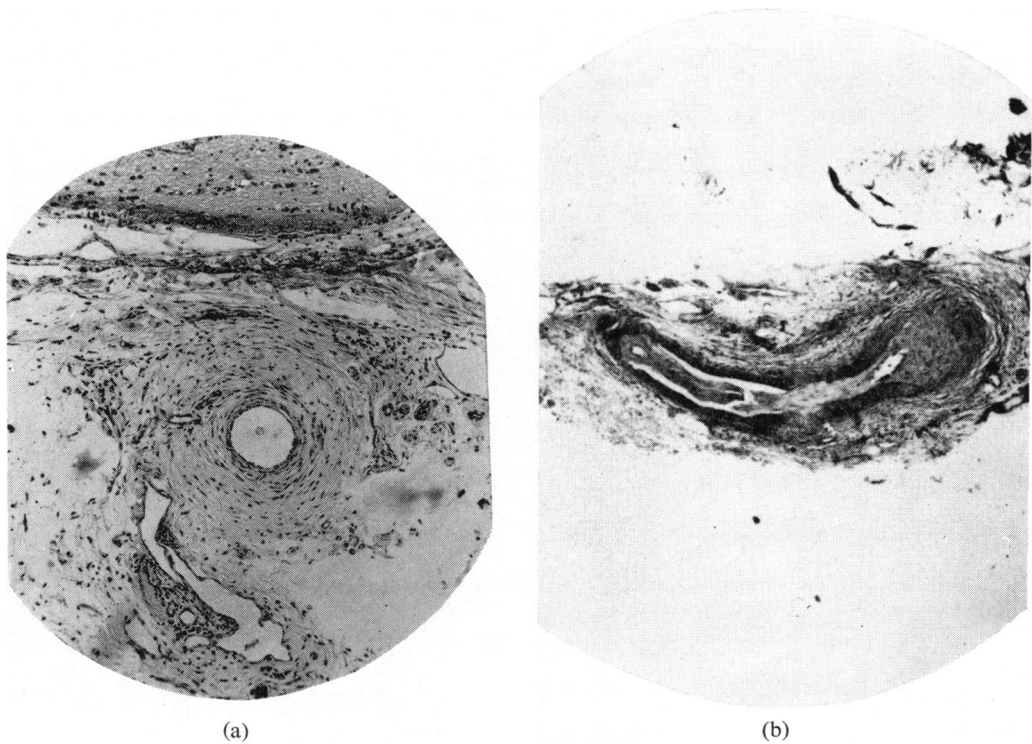


FIG. 12.—Monkey No. 8. Sections showing the changes in the central retinal artery outside the sheath of the optic nerve with the artery cut (a) transversely, and (b) longitudinally. Note thrombosis of the artery in (b).

retinal haemorrhages were more extensive, the filling of the arteries was more than above, and the disc was swollen with indistinct margins. On the fifth day there were much more extensive haemorrhages, particularly marked at the macular region (Fig. 10a). The fundus was pale, with a whitish swollen disc that had indistinct margins, and the veins were distended but the arteries were narrow (Fig. 10b). On the ninth day the changes were stationary, while on the twelfth day the haemorrhages were resolving, with the veins distended and of irregular lumen in places; the arteries were filled but narrow. On the fourteenth day, when the animal was killed, the haemorrhages were resolving, the rest being as above.

*Histopathological Changes.*—The retina showed absence of the nerve fibre layer and ganglion cells, with a diminished inner nuclear layer; the visual cells were normal (Fig. 11a). Haemorrhages were mainly in the macular region at this stage (Fig. 11b); the vitreous was clear. In the optic nerve, two patches of atrophic degeneration on the inferior aspect were seen, near the site of entry of the central vessels. Occlusion of the central retinal artery was clearly seen histologically (Fig. 12a, b).

### Monkey No. 9 (Fig. 3-3).

*Fundus Changes.*—After about half an hour of the block, the retinal vessels showed no circulation, although the blood was present in both the artery and the vein (in this animal the vein was blocked first followed after a few minutes by the blocking of the artery). After about two and a half hours, tiny haemorrhages were seen below the macula and in relation to small venules (Fig. 13a). The veins were engorged but the arteries were thread-like and the retina was pale. After about twenty hours, massive retinal haemorrhages, most marked in the macular region, and most of these in the posterior part of the globe, were seen; the disc was hyperaemic with indistinct margins; the veins were engorged and the arteries were narrow. The fundus changes on the third day are shown in Fig. 13b. On the fifth day, the

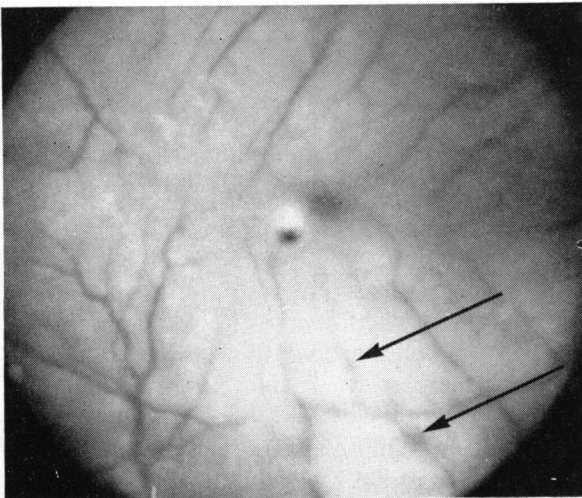


FIG. 13 (a)

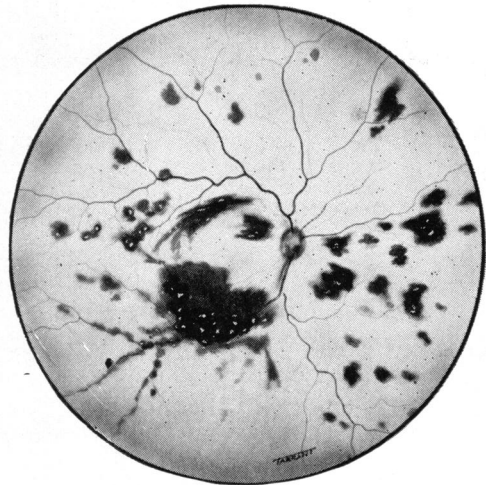
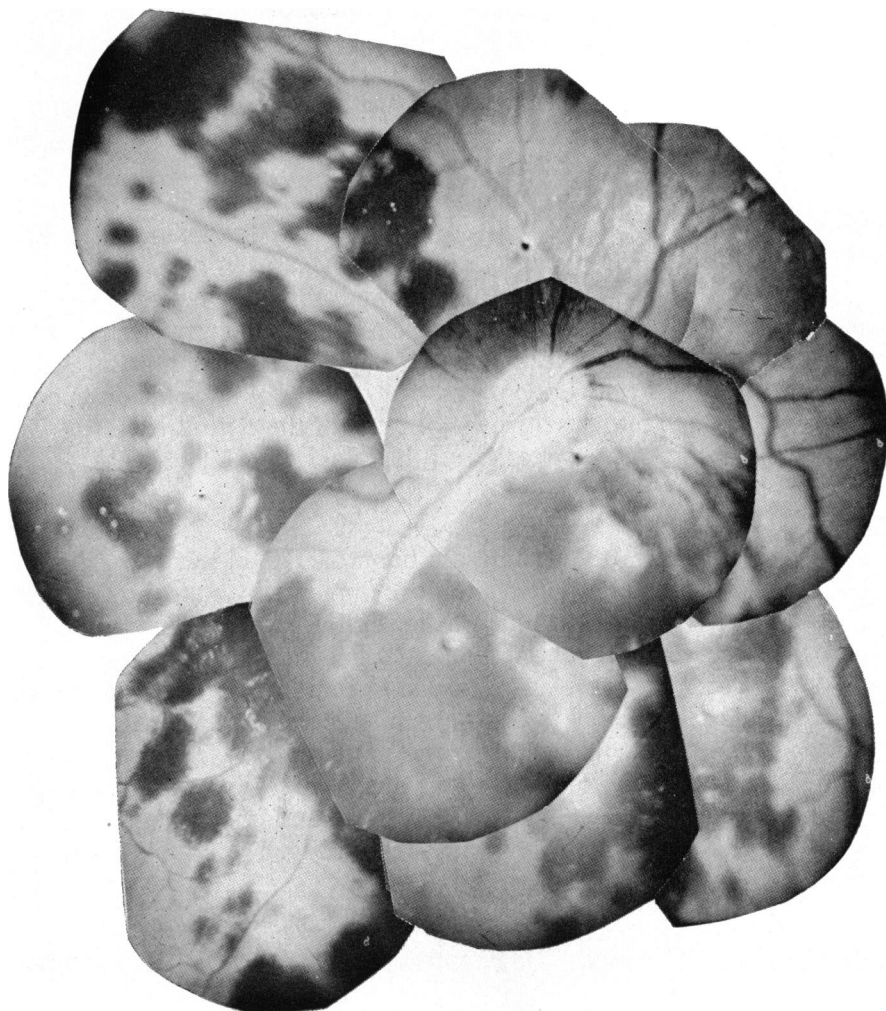


FIG. 13 (b)

(For legend, see p. 636.)



(c)

FIG. 13.—Monkey No. 9. (a) Fundus photograph of the macular region after two and a half hours of the block, showing small haemorrhages below the macula, in relation to the small venules (arrow). (b) Fundus picture on the third post-operative day, and (c) on the tenth post-operative day. (See p. 635 for (a) and (b).)

retinal haemorrhages were more marked; there was marked distension of the retinal veins with the arteries very narrow; the disc was swollen, particularly at the margins, so that the centre of the disc was depressed and nearly normal; the retina was pale. On the tenth day, the picture was nearly as above, with the arteries filled with blood, but narrow (Fig. 13c). On the twelfth day, the retinal changes were regressing, with the veins engorged and the arteries narrow and full of blood. On the thirteenth day, when the animal was killed, the retinal haemorrhages were regressing and the retinal vessels were filled with blood which was circulating.

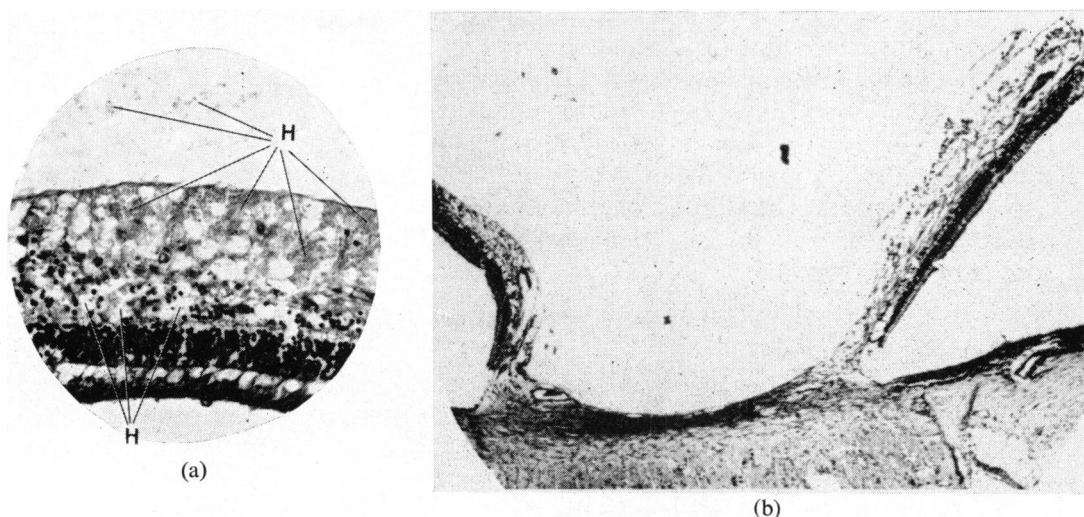


FIG. 14.—Monkey No. 9. (a) Section of the retina showing retinal haemorrhages (H) and atrophic changes in it. (b) Section of the head of the optic nerve and the adjoining retina showing atrophic changes.

*Histopathological Changes.*—There were retinal and pre-retinal haemorrhages. The retinal haemorrhages were situated in the inner layers of the retina, up to the outer plexiform layer. The nerve fibre layer and ganglion cells were absent, the inner nuclear layer was diminished, and the visual cells were normal (Fig. 14a). The optic disc was atrophic (Fig. 14b). No significant changes were noticed in the optic nerve.

In all these animals, after about half to one hour's blockage, no circulation was seen in the retina; the retinal vessels were very narrow and the retina looked pale. In one animal (No. 9), examination of the fundus after two and a half hours of the block showed tiny haemorrhages just below the macula in relation to the small venous tributaries, the retinal veins were filled with blood, and the arteries were thread-like. After about twenty hours of the block, in all three animals extensive retinal haemorrhages were seen, most marked in the macular region. Very few of these were seen in the anterior part of the retina; the retinal veins were engorged and the arteries were narrow. The disc had indistinct margins and there was retinal oedema so that the fundus looked pale. On the second post-operative day the retinal haemorrhages were found to be progressing, the veins were more engorged, and the arteries narrow. On the fourth or fifth day extensive retinal haemorrhages, most marked in the macular region, were seen; the disc was swollen and had indistinct margins; the fundus was pale due to retinal oedema and the retinal veins were distended. After this, the fundus changes were nearly stationary until about the twelfth day, when the retinal haemorrhages were found to be resolving and the retinal oedema was subsiding. The retinal veins were very much engorged and the retinal arteries started showing circulation, although these were still very narrow. The animals were killed within nine to fourteen days of the block.

Histopathological examination of the eyeball and the optic nerve showed complete absence of the nerve fibre layer and the ganglion cells in the retina, with a marked reduction in the inner nuclear layer; the visual cells were normal. Haemorrhages were seen in the inner layer of the retina, not extending beyond the outer plexiform layer. In monkey No. 7, vitreous haemorrhages were also present with sub-retinal exudate, while in animal No. 9 there were pre-retinal haemorrhages. The optic nerve showed patches of atrophic degeneration in animals No. 7 and 9, due to burns caused by touching of the diathermy electrode, while no significant changes were seen in monkey No. 8.

#### Occlusion of the Central Retinal Artery Alone

##### Monkey No. 10 (Fig. 4).

*Fundus Changes.*—After about an hour of the block, both the retinal arteries and the veins showed segmentation of the blood column, with no movement in it. The blood in the artery was dark coloured, like venous blood. The disc was white, with the lamina cribrosa seen through it, and the fundus was pale. About eighteen to nineteen hours after the block the entire fundus was pale with a white disc. The retinal vessels, which were very much narrowed at the disc, showed segmentation of the blood. The empty segments were longer, with their vessel-wall clearly seen (Fig. 15a, b; *see also* Fig. 1b). No haemorrhages were seen. The macular region showed a yellowish spot. On the second post-operative day the vessels were filled in, with segmentation only at a few places, mainly above and below the macular region (Fig. 15c). The disc and fundus were pale, as above, the paleness of the fundus being most marked for some distance around the macular region, with the macula showing a yellow spot and a horizontal fold in the retina. Some exudates were seen in the lower part of the retina at the periphery. On the sixth day the artery and the vein were full of blood with hardly any fragmentation of the blood column. However, the vein showed segments of narrowing of the lumen near the disc. The arteries, instead of being dark coloured, had the normal arterial red colour which indicated that the blood was flowing. On the ninth day the vessels were filled with blood, except for one small vein above the macular region which showed segmentation of the blood column (Fig. 15d). Retinal oedema in the macular region, with the yellow spot and the fold in the retina in this region, was still present. The rest of the retina looked normal and the disc, instead of being white, looked normal in colour and had small vessels on it which were not visible previously (Fig. 15e). The animal was killed on the tenth day.

On occlusion of the central retinal artery alone, no retinal haemorrhages were seen at all. Segmentation of the blood column in both the artery and the vein appeared soon after the occlusion, most of which disappeared by the second post-operative day. On the sixth day the artery showed signs of circulation because it looked bright red instead of dark red. The retina showed extensive oedema which was maximal at the macular region where it produced a horizontal fold. On the ninth day, except for the macular region, most of the retina looked normal; the macular region still showed oedema and the fold; the vessels looked normal, and the disc, instead of being white, was of normal colour with fine filled vessels on its surface. Therefore on this day, except for the oedema and the fold in the macular region, the rest of the fundus looked more or less normal.

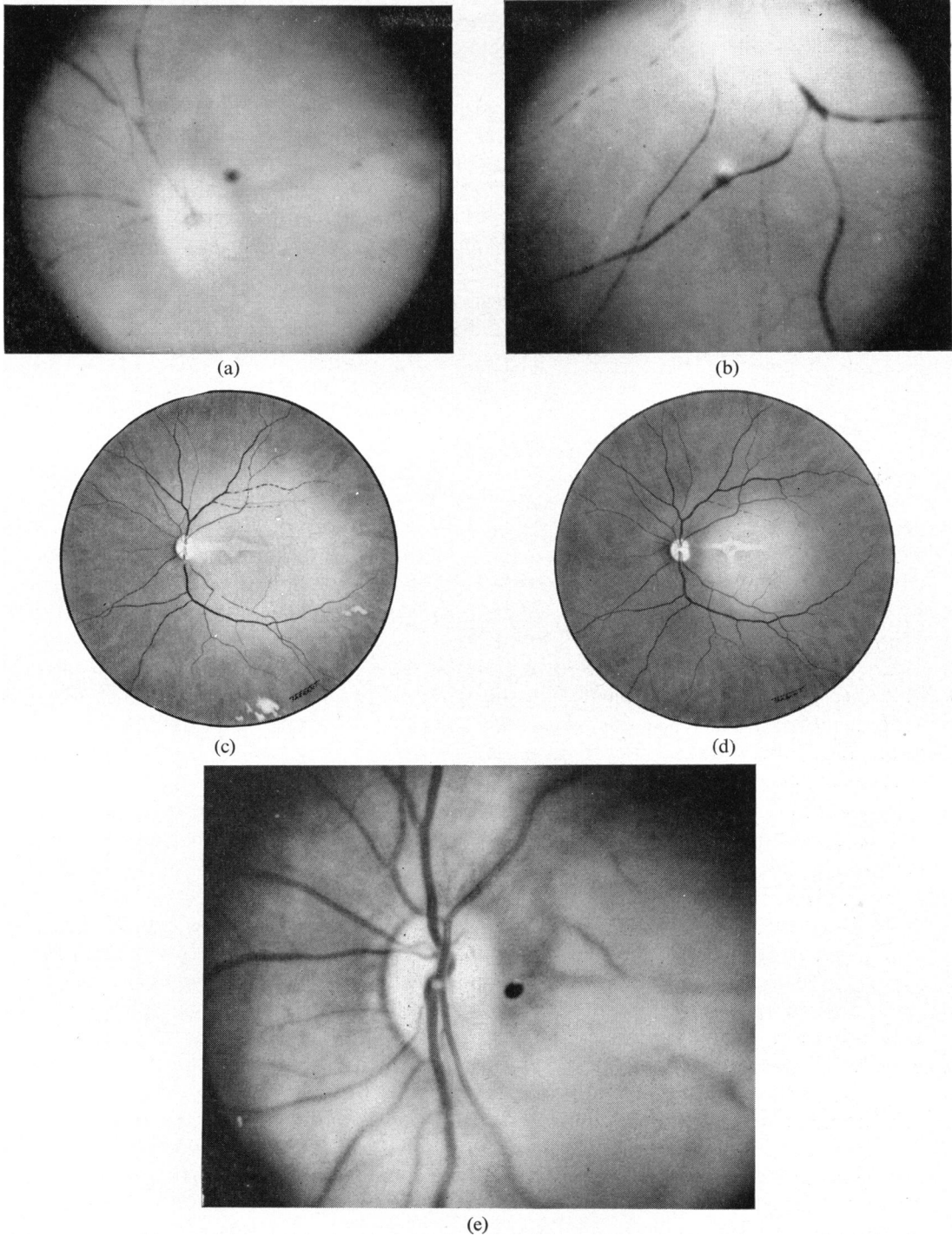


FIG. 15.—Monkey No. 10. Fundus photographs eighteen hours after the block of the central retinal artery, (a) above the disc, and (b) below the disc. Fundus picture (c) on second, and (d) on ninth post-operative days. (e) Fundus photograph on the ninth post-operative day. The normal fundus of this animal is shown in Fig. 1b.

### Discussion

Michel in 1878 first established central retinal vein occlusion as a clinical entity and regarded sudden onset of blindness, distended veins, small arteries, and large haemorrhages as important features in these cases. He stated that it was seen in persons of advanced age with sclerosis of the peripheral arteries and slight hypertrophy of the heart. Since then its association with the arterial diseases has been stressed by many authors. Reimar (1899), in a case of central retinal vein occlusion, found on ophthalmoscopy very narrow and almost imperceptible retinal arteries and the veins were dilated and covered in great part with haemorrhages. He regarded the diminished calibre of the retinal arteries as due to arteriosclerotic thickening of the vessel wall, with no changes in the vein.

Harms (1905) concluded from a detailed study of the subject that the distinction between embolism of the central retinal artery and thrombosis of the central retinal vein could not be retained, as both vessels were diseased in all cases, and the primary affection of either system could produce one or the other ophthalmoscopic appearance, according to its complication or otherwise with an affection of the other trunk. The affection of the system, which was secondarily involved, could be clinically more marked, while the lesion of the other system was anatomically preponderating. He asserted that "retinitis haemorrhagica is clearly a result of arterial disease".

Knapp (1869) reported a case of slow development of an arterial branch occlusion, which ended finally in a picture of venous thrombosis. A similar case was described by Seidel (1939), which was observed by him right from the onset of the process. Elwyn (1946) pointed out that in obstruction of the central retinal vein the slowing of the blood-stream extended backwards to the small venules, capillaries, and arterioles, and there was reflex constriction of the branches of the central retinal artery. Behrman (1962) described the relationship between the retinal venous and arterial circulation to a veno-vasomotor reflex because, he thought, it was suggested by the transient episodes of amaurosis preceding venous obstruction.

Association of arteriosclerosis with central retinal vein occlusion has been reported frequently in the literature after Reimar (1899) had stressed this relationship. Among the more recent reports are those of Braendstrup (1950), Cassady (1953), Lister and Zwink (1953), Morgan (1955), Paton (1964), and others.

Recently the role of arterial insufficiency in retinal venous occlusion has been investigated jointly by Paton (1964), Rubinstein (1964), and Smith (1964) in patients reporting to the Birmingham and Midland Eye Hospital in Birmingham. Paton (1964), from a study of 118 cases of thrombosis of the central retinal vein or a branch, concluded that there was an extraordinarily high incidence of arterial disease in patients with central retinal vein thrombosis which could have some bearing on the aetiology of the condition. Rubinstein (1964), after fluorescein fundus photography of 65 cases of central retinal vein occlusion and 55 cases of venous branch occlusion, found in all cases marked arterial constriction and occlusion; the dye passed through the so-called thrombosed veins promptly. He concluded that arterial changes were the primary phenomenon leading to the final haemorrhagic picture and the changes in the veins.

Smith (1961), on ophthalmodynamometry of 9 cases of central retinal vein occlusion, found evidence of co-existing central retinal artery occlusion in 5 and of arterial

branch occlusion in the sixth. In his further studies of 73 cases by ophthalmodynamometry, Smith (1964), found evidence of arterial insufficiency in 71 per cent., but no case showed complete arterial obstruction. This, according to him, might have been due to the fact that most of these cases were not examined soon after the onset of symptoms and the figures were possibly an underestimate of the arterial insufficiency in retinal venous occlusion, which had a much higher true proportion. He suggested that the capillary and venule walls were rendered abnormally patent to red cells by the ischaemia produced by the arterial occlusion, and that when the circulation was restored, the blood passes into the tissues of the retina.

Thus, clinically, there has been strong evidence of the arterial ischaemia being an important factor in the pathogenesis of the typical picture of central retinal vein occlusion or its branch occlusion.

Since most of the eyes examined histopathologically are enucleated a long time after the original occlusion for some subsequent complication (the commonest being secondary glaucoma), the pathological findings in such cases may well be misleading as an indication of the pathogenesis of the initial lesions of occlusion of the central retinal vein.

It is interesting to note in this connexion that in some of the experimental work done in the past to produce oedema of the optic disc (papilloedema) experimentally, some authors ligated the optic nerve at different levels. Kyrieleis (1936) tied the optic nerve in two Rhesus monkeys—in one involving both the central retinal vessels and in the other only the central retinal vein. In the first animal there was immediate engorgement of the retinal veins; after two and a half hours many haemorrhages appeared on the border of a markedly hyperaemic disc, with whitish striation of the surrounding retina; and after forty-eight hours a 2 D swelling of the disc with tortuous veins was seen. In the second monkey no haemorrhages were seen. Glew (1957) ligated the optic nerve close to the eyeball in two dogs and two monkeys—in both monkeys haemorrhages were produced adjacent to the disc and along the veins. In the dogs, however, no haemorrhages were seen, but only venous dilatation which, of course, was due to difference in the pattern of the central retinal vessels in the dogs.

Experimental blockage of a retinal vein in the eyeball has been done by Becker and Post (1951), Campbell (1961), and Linnér (1961). Becker and Post, in cats, applied diathermy electrode to one of the main retinal veins in the eyeball and noticed a “constriction of arterioles and marked dilatation of the veins . . . . In two or three days the fundi showed relatively normal arteries, dilated tortuous veins associated with exudates, and large, flame-shaped hemorrhages, retinal edema, capillary aneurysm, round hemorrhages, and occasional hemorrhages into vitreous”. Campbell (1961) blocked one of the retinal veins by light coagulation in cats and claimed that the arteries were not involved. He, however, has written that “if an arteriole lies in the area of coagulation it may show temporary narrowing which rapidly disappears”. Retinal haemorrhages were seen and on histology the internal layers of the retina showed cellular infiltration while the external layers were normal. Linnér (1961) blocked retinal vessels in the rabbit by light coagulation and noticed retinal haemorrhages with occlusion of the vessels.

These experimental observations show that both the retinal arteries and the veins were involved when the retinal haemorrhages and other signs typical of central



retinal vein occlusion were present, although the authors concerned attached no significance to this finding and ignored the condition of the arteries. They laid all the stress upon the fact that the involvement of the vein was responsible for the entire pathology.

The present investigation in the Rhesus monkeys showed that when the central retinal vein or the central retinal artery alone was occluded, no retinal haemorrhages were seen. On occlusion of the central vein immediately after its exit from the sheath, only engorged, turgid, and tortuous retinal veins were noticed which subsided after a period of sixteen to thirty-six days. No haemorrhages were seen during the entire period of observation. In these cases the blood was diverted to other channels by the collateral circulation of the central retinal vein on the pia (Fig. 7b) and within the optic nerve, and probably, at the level of the lamina cribrosa, to the choroidal circulation. In the blockage of the central retinal artery, a typical picture very characteristic of occlusion of the artery in man was produced. On occlusion of both the central retinal artery and the vein simultaneously, a fundus picture indistinguishable from the one seen in so-called central retinal vein occlusion was produced. The results were very consistent in the whole series of experiments. This indicated strongly that in these cases arterial ischaemia was an important factor in the causation of the typical fundus picture of so-called central retinal vein occlusion, particularly the haemorrhages.

Critics would immediately object to this conclusion of mine on the grounds that in human beings, the site of occlusion of the vein is usually at the lamina cribrosa instead of at the site of exit from the sheath of the optic nerve, as in the present study, and the former site of the blockage would exclude all the various collateral channels available in the latter site of the blockage. With the present state of our knowledge of the collateral communications of the central retinal vein within the eyeball and at the optic nerve head, it is difficult to comment either in favour of or against this objection. Moore (1925) stated that obstruction of a retinal vein did not stop circulation of the blood through the portion of the vein which was peripheral to the block, because of collateral venous circulation. The occasional recovery of good vision in cases of central retinal vein occlusion would be another objection to my conclusions, although such a recovery is seen in a few cases only, while in the majority the visual loss is generally very serious (Cassady (1953) found blindness ultimately in 80 per cent. of his cases). In cases where the visual recovery is reasonable, I feel that the element of temporary or slow ischaemia, from whatever cause, has to be taken into consideration and cannot be ruled out.

The present study strongly suggests that arterial ischaemia is an important factor in the production of the typical picture of so-called retinal venous occlusion. The findings in the Rhesus monkey can, for all practical purposes, be applied to man because of the similarity of the vascular pattern of the central retinal vessels in the two species (Fig. 16). However, there may be some difference in the vascular effect between a sudden experimental cutting off of the circulation and a gradual occlusion, which presumably is what happens clinically on most occasions.

In view of the above-mentioned evidence, it is suggested that the term "occlusion of the central retinal vein" is a misnomer, and it may be more appropriate to call these cases "occlusion of the central retinal vessels". The cases associated with

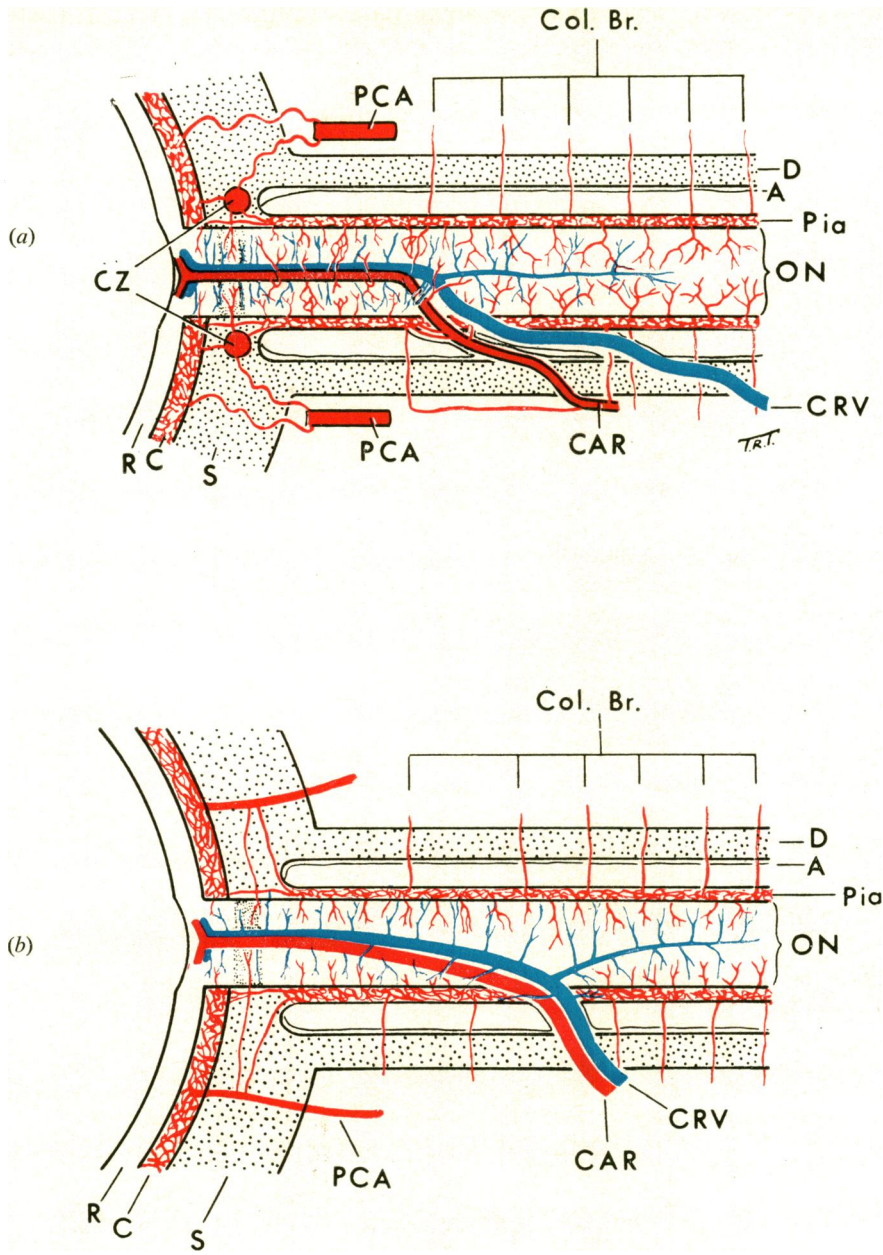


FIG. 16.—Pattern of the central retinal vessels in (a) human being, and (b) Rhesus monkey.

- |          |  |     |                            |
|----------|--|-----|----------------------------|
| A        | Arachnoid                                | D   | Dura                       |
| C        | Choroid                                  | ON  | Optic nerve                |
| CAR      | Central artery of the retina             | PCA | Posterior ciliary arteries |
| Col. Br. | Collateral branches of ophthalmic artery | R   | Retina                     |
| CRV      | Central retinal vein                     | S   | Sclera                     |
| CZ       | Circle of Zinn                           |     |                            |

simple engorgement and distension of the retinal veins and having no retinal haemorrhages may, in fact, be the true cases of central retinal vein occlusion, which are most probably being considered at present as cases of simple embarrassment to the blood flow of the central retinal vein. The picture of occlusion of the central retinal artery is quite characteristic, and has also been confirmed by the present experimental study.

To some, the above conclusions may seem rather dogmatic. In making these statements, I have been all along reminded of Duke-Elder (1927), who wrote: "If it is dogmatically stated, the reason is that it is difficult to deny myself the pleasure of so doing. However that may be, it is to be accepted in the light of a working hypothesis which may, or may not, aid after the manner of a temporary scaffolding in the erection of a building of whose very design we are ignorant. And as such it is to be treated. For the whole progress of knowledge is strewn with the wrecks of such systems."

### Summary

In Rhesus monkeys experimental occlusion of the central retinal vein (in six), central retinal artery (in one), and both the artery and the vein (in three) was done.

The occlusion of the vein produced engorgement, turgidity, and distension of the retinal veins which subsided in about sixteen to thirty-six days. *No retinal haemorrhages were seen.* The occlusion of the artery produced the typical characteristic picture of the occlusion of the central artery. The simultaneous occlusion of both the artery and the vein produced a fundus picture entirely characteristic of so-called central retinal vein occlusion.

Histopathological examination revealed no retinal changes on occlusion of the central retinal vein, but haemorrhages with destruction of the inner retinal layers on simultaneous occlusion of the artery and the vein.

The study is very suggestive of the importance of arterial insufficiency in the production of the clinical picture labelled central retinal vein occlusion. The pertinent literature on the subject is reviewed.

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