Brit. J. Ophthal. (1968) **52**, 1

COMMUNICATIONS

FLUORESCEIN STUDIES IN RETINAL VASCULAR OCCLUSION*†

BY

D. W. HILL

Department of Clinical Ophthalmology, Institute of Ophthalmology, University of London

THE clinical entities of retinal artery occlusion and retinal vein thrombosis produce disturbances in vision resulting directly from interference with the retinal circulation. The introduction of fluorescence retinal photography (Novotny and Alvis, 1961) and subsequent technical modifications provide a useful tool for investigating the extent of the circulatory disturbance in these vascular occlusions and correlating it with the clinical signs. This paper reports the results of 39 examinations carried out on patients as soon after diagnosis as possible.

Other investigators have assessed the retinal circulation time by fluorescence photography. Oberhoff, Evans, and Delaney (1965), using cinematographic documentation, judged the first appearance of dye in the arterioles and veins at the disc margin, and found times varying between 1·2 sec. for the macular vessels and 3·0 sec. for vessels related to the upper temporal quadrant beyond the macula. Ferrer (1965) used a modified Zeiss retinal camera to secure photographs at short intervals and measured the disc-to-disc circulation time. In this investigation both macular and peripheral circulation times have been measured and a mean figure calculated.

Method

Clinical.—Each case was seen as soon as possible after the occlusive episode. A case history was compiled, the eyes examined, and where appropriate the fields of vision charted. Retinal photography and fluorescence photography followed. In cases of arterial occlusion, the accepted methods of treatment were employed as soon as the diagnosis was established, before investigation; unfortunately they were largely unsuccessful.

Technical.—Retinal photography was accomplished with the Zeiss retinal camera suitably modified for fluorescence photography in the manner described by Dollery, Hodge, and Engel (1963). Kodachrome II film was used for the colour transparencies of the retina and Ilford H.P.S. for fluorescence photography. Photographs were taken every 2 sec. for 12–14 sec. after the appearance of dye, then less frequently. The timing of retinal photographs was signalled from the power-pack by the recharge switching relay and displayed on a Cambridge single-channel direct-writing recorder; the assistant giving the injection provided a signal at the commencement, using a foot switch. The times of the photographs were estimated to the nearest second after starting the injection.

The fluorescence negatives were mounted and examined by projection. Direct comparisons were made by simultaneous projection of two negatives from matched projectors. Measurements of retinal vessel calibre were made directly on the colour transparencies (occasionally on fluorescence negatives), using a microscope with a low-power objective and screw micrometer eye-piece (Hill and Dollery, 1963). From the measurements the ratio of abnormal to normal venous calibre was

* Received for publication October 24, 1966.
† Address for reprints: Research Department of Ophthalmology, Royal College of Surgeons of England, Lincoln's Inn Fields, London, W.C.2.

calculated. This was termed the venous index. In the case of central occlusions one or two comparable sites were measured in each eye, the veins being selected as draining similar areas. In branch occlusion comparable unaffected veins in the same eye on opposite sides of the horizontal meridian were chosen for comparison.

Estimates of the fluorescein transit time through the retina were obtained by inspection of sequential photographs to determine the times of peak concentration in the arteries and veins at sites close to the optic disc. Since the circulation time close to the disc is fast and that in the periphery slow, two venous estimates were made at different sites: the junction of macular venules with principal temporal veins, and the principal veins close to the disc. The first gave an estimate of the macular transit time, and the second, judging the peak concentration in the centre of the vein, gave the peripheral transit time. The mean of the two values was calculated and used in consideration of the results. In branch vessel occlusion the local transit time was estimated from the times of peak concentration at a site just distal to the block and at a corresponding site on the artery or vein of the affected area. This transit time was compared with that of a healthy area in the same eye in which the time might be expected to be similar.

The duration of the arterial phase of fluorescence was estimated from the first appearance of the dye to the end of the decrescent phase. The delay in the appearance of dye seen in some central artery occlusions was easily estimated from the difference between the appearance time of the dye on the disc and that in the central artery. In branch occlusions the delay in development of the peak fluorescence between the affected vessel and surrounding vessels of similar calibre was estimated.

The transit estimates were all utilized in the form of ratios, expressing the relationship between the patient's affected and unaffected retinal circulation; thus Mean Transit Ratio (M.T.R.), Local to Expected Transit Ratio (L/E.T.R.) in branch occlusions, and Arterial Phase Ratio (A.P.R.) were all calculated.

Material

45 patients were examined by fluorescence retinal photography, following a recent retinal vascular accident, between July, 1964, and March, 1966. As this was an exploratory study a wide range of cases was admitted, but the following criteria were satisfied. All cases of central artery occlusion had a history of sudden loss of vision, often dramatic in onset, accompanied by pallor and opacification of the retina together with a variable degree of collapse of the retinal vessels. Venous occlusion was diagnosed when reduction of visual acuity was accompanied by distension of the retinal veins and scattered haemorrhages extending to the periphery of the fundus. Of the cases examined, six were excluded from the report on account of technical failure of the fluorescence photography because of factors other than the occlusion, leaving 39 cases in the study. In three of the cases of branch vessel occlusion reported, data were obtained from the affected eye only; in all other cases data were obtained from both eyes.

Table I (opposite) gives general information about the 39 patients included. Most cases were investigated for possible aetiological factors; tests included blood count, erythrocyte sedimentation rate, erythrocyte sickling test, plasma protein concentration and electrophoresis, blood pressure estimation, and chest *x* ray. General medical examination by a physician was arranged for the majority of patients. The results were negative apart from a high incidence of hypertension (diastolic pressure over 100 mm./Hg) amongst patients with central artery occlusion. There was direct evidence of embolism in the fundus of a number of the cases of arterial occlusion. All the cases of arterial occlusion showed a dense field loss in the territory of the affected arteriole, but field loss in venous occlusion was variable in extent and severity. This aspect of the investigation will be more fully reported later.

Results

Qualitative

Arterial Occlusion.—The pattern of fluorescence seen in the eyes of patients presenting a picture of central retinal artery occlusion was extremely variable; some showed no detectable

abnormality in comparison with the fellow eye (Case 10), and others showed such a gross disturbance of circulation that no transit of dye was observed. Between these two extremes a variety of appearances was seen. The onset of fluorescence might be delayed, so that the small vessels on the disc, and the choroidal background, were seen to fluoresce before the dye was visible in the branches of the central retinal artery. The rate at which dye passed through the arteriolar branches in the retina might be so slow that successive photographs showed the gradual advance of a diffuse dye front. In many cases the concentration of dye reaching the affected eye was reduced, though surprisingly photographs of reasonable quality were still obtained even when there was considerable delay in the appearance of dye, coupled with a slow transit. In one case of embolic occlusion (Case 8), different filling rates were seen in the upper and lower vessels. The inferior vessels filled very slowly and

TABLE I

PARTICULARS OF 39 PATIENTS STUDIED

No.	Age (yrs)	Sex	Type of Occlusion	Site	Side	Blood Pressure	Aetiology
1	52	M			R	190/120	Hypertension
2	70	F			R	206/110	Hypertension
3	51	M			R	210/110	Hypertension
4	78	M			L	160/100	Hypertension
5	56	M	Arterial	Central	L	170/100	Hypertension
6	37	M			R	136/56	
7	57	M			L	200/120	Embolism
8	63	F			L	210/110	Embolism
9	70	M			L	210/110	Embolism
10	71	M	Arterial	Central	L	175/100	Hypertension
11	63	M			R	116/76	
12	72	F			L	170/80	
13	41	M			R	—	
14	55	M			L	108/76	
15	59	M	Venous	Central	R	160/100	Hypertension
16	53	M			R	150/80	
17	37	M			L	114/64	
18	36	M			L	130/76	
19	54	M		Sup.	R	150/95	Embolism
20	41	F		Mac. br.	L	120/90	
21	61	F		S.T.	R	—	Embolism
22	49	M		Inf.	R	160/90	Embolism
23	51	M	Arterial	Sup.	R	—	Embolism
24	68	M		Cilio. R.	R	160/80	
25	54	M		Inf.	L	180/110	Embolism
26	59	M		Inf. (?)	L	—	
27	54	M		I.T.	R	230/115	Hypertension
28	58	M		I.T.	L	175/100	Hypertension
29	67	M		I.T.	L	170/100	Hypertension
30	60	M		Inf.	L	145/90	
31	60	M		I.T.	R	180/100	Hypertension
32	58	F		S.T.	R	170/98	
33	58	F		I.T.	R	150/76	Hypertension – tr.
34	49	F	Venous	I.T.	R	180/112	Hypertension
35	58	F		I.T.	R	210/130	Hypertension
36	56	F		S.T.	L	158/94	
37	74	F		S.T.	L	180/110	Hypertension
38	60	M		I.T.	R	160/100	Hypertension
39	54	M		S.T.	L	150/90	

the fluorescence was more intense than in the superior vessels (see Fig. 2, below) where circulation was faster. No staining of the vessel walls or leakage of fluorescein occurred apart from the actual site of the embolus.

The vessels were masked where they passed deeply into the oedematous retina, so that the fluorescein column was poorly seen. If the circulation was very slow, demonstrable filling of the veins might be absent during the transit of dye, though residual fluorescence was seen afterwards. No areas of leakage were seen, apart from the sites of recent visible emboli. In two cases in which patches resembling soft exudates occurred they did not fluoresce. The appearances in branch arteriolar occlusion were essentially similar, though the changes relating to the optic disc were not seen.

The changes at the optic disc were of considerable interest. Where the delay between the appearance of the dye in the central retinal artery and disc circulations was sufficient, a separate circulation was observed in the small vessels on the surface of the disc in all but one case. These extended over the surface of the disc and for a short distance, seldom more than half a disc diameter, on to the surface of the retina, obvious cilio-retinal arterioles excepted. The fluorescein from this disc circulation drained into tributaries of the central retinal vein. In two of the three most severely obstructed cases of central retinal artery occlusion there was evidence of retrograde filling (Fig. 1) of branches of the central retinal artery, occurring from the arterioles of the disc circulation. In some cases emboli in the form of bright yellow plaques were observed on the disc in the bifurcation of the central retinal artery, and also more peripherally in the branch arterioles. When fluorescence retinal photography was performed soon after the occlusion, these plaques showed immediate dense fluorescence (Fig. 2), followed by a small area of leakage in late photographs.

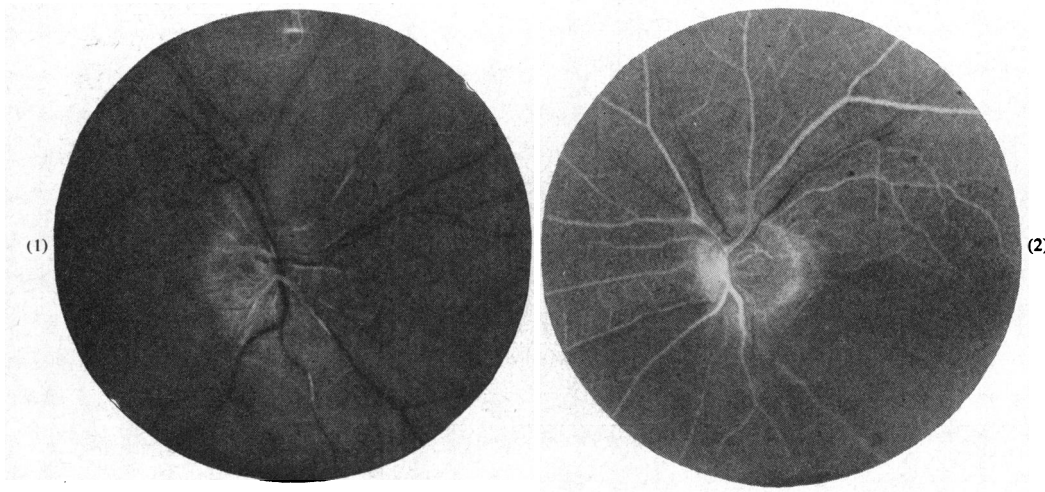

FIG. 1.—Right fundus of Case 3, severe central retinal artery occlusion. Fluorescein photograph 15 sec. after injection, showing separate disc circulation draining into retinal veins. The central retinal vessels remain dark, unfilled with fluorescein apart from the proximal parts of the veins. Below, an area of filled dilated capillary bed can be seen, with retrograde filling of the retinal arteriole.

FIG. 2.—Left fundus of Case 8, central retinal artery occlusion due to a saddle embolus impacted on the disc. Fluorescein photograph taken 13 sec. after injection. Intense fluorescence is seen on the disc at the site of the embolism and the circulation in the lower half of the fundus is delayed as compared with the upper half. Dye beginning to enter the lower vessels is seen more brightly than that in the upper vessels, possibly because only plasma flow is occurring.

Venous Occlusion.—The spectrum of appearances seen in retinal vein occlusion was less extensive than in arterial occlusion, but was complicated by the presence of haemorrhages and retinal oedema. These two factors combined to obscure and distort the pattern of fluorescence, making it difficult to assess the abnormality of circulation. The arterial inflow often showed a fainter fluorescence than in the normal eye, but there was never any delay in its appearance.

Abnormal filling of the dilated retinal veins (Fig. 3) was seen to a varying extent; the centres of the veins were poorly fluorescent whilst the margins showed a marked band of fluorescence as the transit progressed. This was followed by blurring at the edge of the vein as fluorescence was seen in the surrounding tissues. Late pictures taken 5 minutes or more after the last injection of dye showed extensive fluorescence in the tissues around the large veins, as well as leakage in other areas of the fundus.

In the cases of branch retinal vein occlusion included in this series, there was considerable variation of the clinical picture and duration of the occlusion with resultant differences in the pattern of fluorescence. In some the haemorrhages were so extensive as to obscure most of the transit in the affected area, in others the transit could be well seen. The inflow of dye into the arterioles was not delayed. Venous filling was followed by fluorescence spreading in the tissues around the veins, and leakage of dye followed a pattern similar to that seen in central retinal vein occlusion. In long-standing cases microaneurysms and new vessels were seen (Fig. 4).

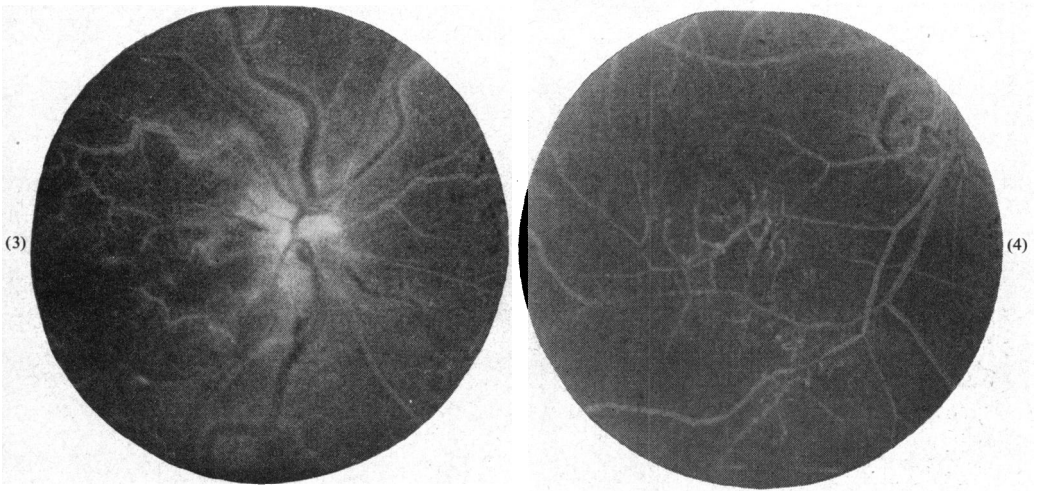

FIG. 3.—Right fundus of Case 11, central retinal vein occlusion. Fluorescein photograph taken 23 sec. after injection, during the venous phase. Defective filling of the large veins, the margins of which are outlined with fluorescein already leaking into the tissues, is seen, together with distension of the small veins and widespread leakage of fluorescein.

FIG. 4.—Right fundus of Case 31, long-standing branch retinal vein occlusion. Fluorescein photograph taken 17 sec. after injection, during the arterio-venous phase. Extensive abnormality of the smaller vessels, both venous and arterial, is seen with microaneurysm formation.

Quantitative

Central Retinal Vessel Occlusion.—Table II (overleaf) sets out the important figures for fluorescein circulation, and for comparison the relevant clinical data.

TABLE II

CENTRAL VASCULAR OCCLUSIONS (CASES 1–18)

Type	General		Clinical				Fluorescence			Notes
	Case No.	Age (yrs)	Duration (days)	Visual Acuity	Venous Index	Collapse of Vessels	Delay (sec.)	M.T.R.	A.P.R.	
"Arterial"	1	52	¼	No PL	0·56	+++	∞	∞	—	No C.R.A. fluorescence Retrograde filling
	2	70	1½	HM	0·34	+++	∞	∞	—	No C.R.A. fluorescence
	3	51	½	HM	0·43	+++	28	∞	∞	Prolonged A. phase, no venous phase Retrograde filling
	4	78	1	CF	0·78	++	12·5	∞	3·3	
	5	56	2	HM	0·70	++	5	9·6	2·0	
	6	37	1	PL	0·58	++	3·5	6·2	4·3	
	7	57	½	HM	0·80	+	0	5·5	1·3	
	8	63	1	HM	0·99	+	2	3·2	1·3	No separate disc circulation seen
	9	70	1	HM	0·98	+	0	(2·1)	2·1	Peripheral transit only
	10	71	4	CF	1·03	0	0	1·25	0·8	
"Venous"	11	63	5	6/36	1·8		0	4·6	1·2	
	12	72	17	3/60	1·5		0	(3·0)	1·3	Macular circulation time only
	13	41	10	6/9	1·5		0	2·3	(1·4)	A. phase approx. estimate
	14	55	1	6/9	1·5		0	1·1	1·0	
	15	59	15	6/9	1·4		0	1·4	(1·0)	A. phase approx. estimate
	16	53	28	6/36	1·2		0	1·5	0·7	
	17	37	28	6/24	1·2		0	—	—	Filling very poor
	18	36	?	6/18	1·1		0	0·7	0·9	Amblyopic eye

Cases 1 to 9 are patients with clinical central retinal artery occlusion listed in order of decreasing severity as evidenced by the degree of collapse of the central retinal vessels and interference with the fluorescein transit. Collapse is assessed qualitatively, + arterioles narrowed, ++ arterioles and venules narrowed, and +++ arterioles and venules narrowed together with lengths of segmented blood column in the vessels.

Cases 11 to 18 are patients with clinical central retinal vein occlusion in order of decreasing severity as judged by the degree of venous dilatation and disturbance of fluorescein transit.

Case 10 stands between these two groups, the patient having sustained a sudden loss of vision, accompanied by oedema of the optic disc and retina without a "cherry spot", full veins, and a few haemorrhages. Subsequently the haemorrhages increased and soft exudates developed to produce a clinical picture of central retinal vein occlusion.

The arterial section of Table II reveals a correlation between collapse of the vessels and slowing of the circulation as represented by the mean transit ratio (M.T.R.); this is seen more clearly in Fig. 5 (opposite). There is a less precise correlation between vessel collapse and two other observations: delay in appearance of fluorescein in the central retinal vessels and venous index (V.I.).

The venous section of Table II shows a relationship between the degree of venous distension, measured by the V.I., and the delay in circulation of fluorescein indicated by the

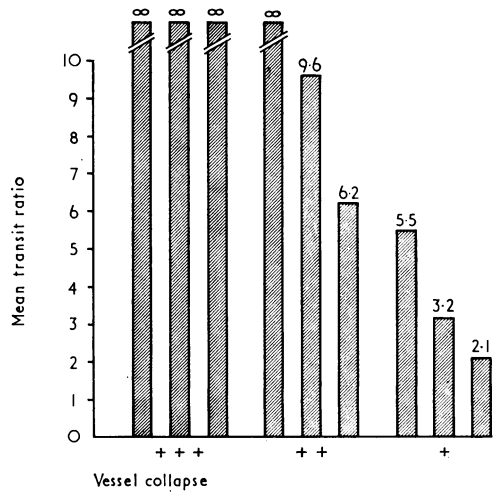

FIG. 5.—Relationship between Mean Transit Ratio and Vessel Collapse in central retinal artery occlusion.

M.T.R. The cases in which distension is greatest showed the slowest circulation. No case in this group showed any delay in the appearance of fluorescein in the retinal arterioles. The last column of the Table shows the arterial phase ratio (A.P.R.); this is seen to be variable in arterial occlusion but approximating to unity in venous occlusion.

Table II demonstrates that there is a close association between the apparent severity of the occlusion, judged by clinical observation and measurement of the blood vessels, and the delay in transit of the fluorescein. The scatter diagram (Fig. 6) of venous indices and M.T.R. for all cases shows a complete break at the unity ratio, with dissimilar trends in venous and arterial occlusion. The figures are insufficiently accurate to plot a graph line with confidence, but two nominal straight lines have been inserted to emphasize the break.

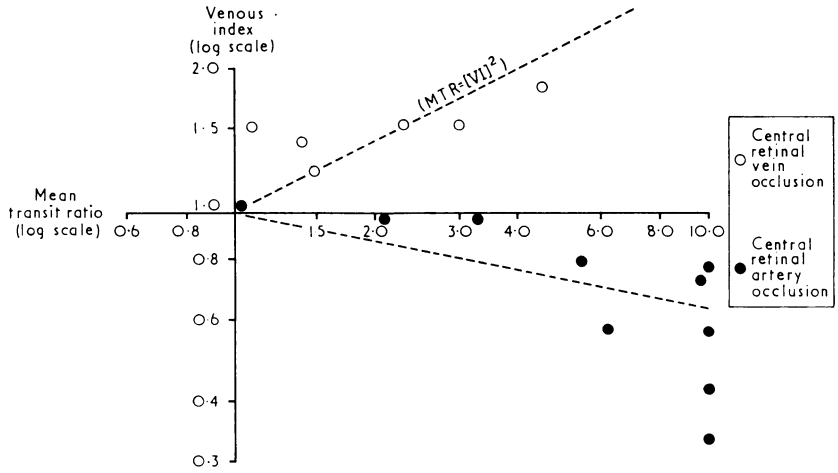

FIG. 6.—Relationship between Mean Transit Ratio and Venous Index in central retinal vessel occlusion (All infinite mean transit ratios are assigned a value 10).

Branch Vessel Occlusion.—Table III sets out in similar fashion the data concerning the branch retinal vessel occlusions. The cases are set out in order of severity of the occlusion, judged as far as possible on transit ratio and clinical criteria. The final column contains comments on the fluorescein transit and site of the occlusion.

TABLE III

BRANCH VESSEL OCCLUSIONS (CASES 19–39)

Type	General		Clinical					Fluorescence		Notes
	Case No.	Age (yrs)	Duration (days)	Site	Order of Branch Occluded	Venous Index	Collapse of Vessels	Local A. Delay (sec.)	Local/Expected Transit Ratio	
"Arterial"	19	54	¼	R. sup.	1	0·47	++	∞	∞	No local filling
	20	41	2	L. mac.	(4)	—	—	∞	∞	Macular arteriole No local filling
	21	61	14	R. ST	3	—	—	4·5	∞	Direct and retrograde filling Dynamics disorganized
	22	49	1	R. inf.	1	0·81	+	6	2·2	
	23	51	42	R. sup.	1	0·64	+	0·5	1·5	
	24	68	10	R. mac.	(3)	—	0	2	3·5	Cilioretinal arteriole
	25	54	¼	L. inf.	1	1·00	0	0·5	2·0	Site of block not seen
	26	59	2	L. ?inf.	(2)	1·07	0	0	1·0	
	27	54	32	R. IT	(2)	0·98	0	0	1·0	
"Venous"	28	58	1	L. IT	2	1·34		0	∞	Slow transit, venous phase not assessable
	29	67	9	L. IT	2	1·22		0	6·5	
	30	60	10	L. inf.	1	1·17		0	3·5	
	31	60	50	R. IT	3	1·72		0	2·3	
	32	58	42	R. ST	3	1·2		0	2·3	
	33	58	60	R. IT	3	1·74		0	2·2	
	34	49	8	R. IT	3	1·66		0	1·7	Multiple small occlusions
	35	58	7	R. IT	3	1·75		0	1·4	
	36	56	13	L. ST	2	1·01		0	1·4	
	37	74	19	L. ST	3	1·95		0	1·0	
	38	60	40	R. IT	3	—		0	1·0	
	39	54	90	L. ST	4	—		0	1·0	

There is a great deal more variation in the duration of the branch occlusions at the time of the examination, and the calibre of vessel occluded also varies from case to case. This latter variation is expressed in the column headed "Order of branch occluded"; the first division into upper and lower vessels on the disc is termed 1 (first order branch), the second division into nasal and temporal vessels 2, and so on. In the higher order of vessels it is often necessary to make an estimate because of the unevenness of branching; these are indicated by placing the number in brackets. In Case 34 several small vessels appeared to be occluded. In several instances it was not possible to measure the venous calibre or assess the degree of collapse of vessels.

Inspection of the branch arterial occlusion data reveals some correlation between the

clinical indications of severity as expressed by the degree of vessel collapse and venous index, and the flow data expressed by local arterial delay and local transit ratio (Figs 7 and 8). This is similar to the experience in central artery occlusion. The cases of branch vein occlusion show a varying degree of delay of circulation through the affected area but no correlation between this delay and the degree of venous dilatation as expressed by the venous index.

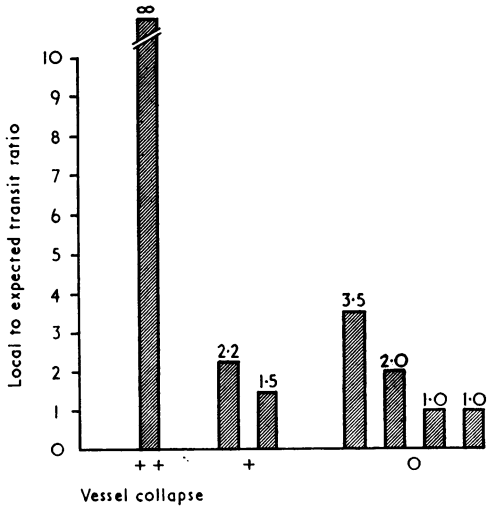

FIG. 7. — Relationship between Local to Expected Transit Ratio and Vessel Collapse in branch retinal artery occlusion.

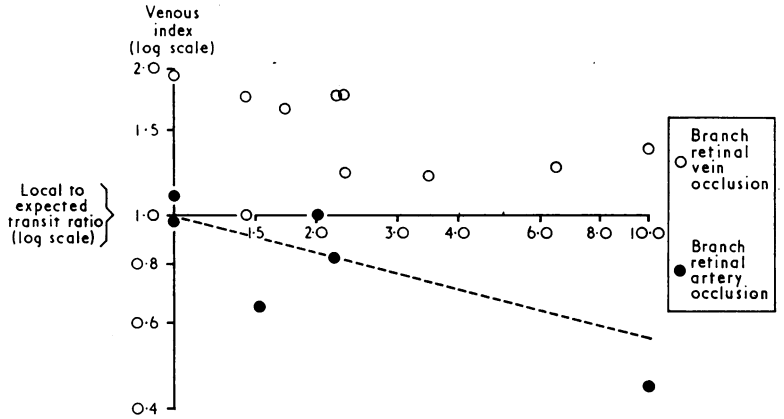

FIG. 8.—Relationship between Local to Expected Transit Ratio and Venous Index in branch retinal vessel occlusion (All infinite local transit ratios are assigned a value 10).

Discussion

Method.—An accurate appreciation of these results must rest on understanding the limitation of the techniques in use. The injection of fluorescein into a systemic vein is followed by circulation of the bolus of dye, which becomes spread out over a column of blood by the time it leaves the left side of the heart. The speed of injection, rate of circulation, and local conditions in the heart and lungs combine to affect the concentration of dye reaching the eye,

and more specifically the form of the time and concentration curve of the dye observed at any particular point during the passage of fluorescein through the eye. Measurement of the rate of circulation through the eye must utilize one identifiable point on the time and concentration curve of the dye and follow this through the retinal vessels. The obvious one would be the appearance of the dye, but unfortunately there is an appreciable and variable period of increasing concentration of the dye so that the exact moment of advent is difficult to detect, especially when there is already residual fluorescence from previous injections. Peak concentration is the only practical alternative and is reasonably easy to determine by direct comparison of sequential negatives; the only disturbing factor, alteration in the optical adjustment of the camera due to patient or observer, is apparent on inspection of the negatives.

The transit ratio has been chosen in preference to absolute circulation time, as this approach reduces the number of assumptions underlying the results, each patient serving as his own control.

The validity of comparisons of vessel calibre have been rightly questioned by Stokoe and Turner (1966), who drew attention to the irregularity of division and distribution of the retinal vessels, and the fact that apparent artery-and-vein pairs near the disc often serve territories of differing size. In this study comparisons were made between veins in affected and normal areas of retina, and care was taken to choose vessels apparently serving similar territories. In comparisons between two eyes, veins draining territories of the same size in the same quadrant, and in comparisons within one eye similar veins above and below the horizontal meridian, were chosen.

It is often argued that oedema or clouding of the retina in arterial obstruction may affect the visibility of the vessels, and in particular their apparent size. This does occur, but it is usually obvious in a well-focused transparency by the localized loss of vascular detail; such areas have been avoided in making comparisons.

Results.—In central retinal artery occlusion the appearance of the retinal vessels is variable, from slight collapse of the arterioles to gross collapse of arterioles and veins with fragmentation of the blood column. Corresponding with this range of clinical appearances, there is a progressive reduction of perfusion revealed by the increasing M.T.R. of the fluorescein studies (Fig. 5), thus demonstrating the validity of the method and showing how variable is the ischaemia which results in loss of vision by arterial occlusion. To what extent the circulation must be reduced before the clinical manifestations of central artery occlusion appear cannot be decided. The data available relate to one point in time and take no account of alterations since the onset of the occlusion, whether spontaneous or induced by treatment. The variability of the ischaemia provides a possible explanation for widely-differing reports on the effects of treatment.

The circulation on the optic disc, seen clearly when the occlusion is severe, is derived from the ciliary arteries, but drains into the central retinal vein. Extension into the retina and retrograde filling of some of the branches of the central retinal artery demonstrate clinically the continuity of the circulation at capillary level. This is of interest in the light of recent experimental work on embolic occlusion (Ashton, Dollery, Henkind, Hill, Paterson, Ramalho, and Shakib, 1966).

The delay in filling the central retinal vessels which occurred in all but two of the milder cases of occlusion can be explained in two ways: either the central artery along all or most of its length is an end artery and the delay occurs because of the slow passage of dye; or, the

actual blockage being complete, the residual circulation results from a long-path anastomosis.

The increased fluorescence in the areas of slowest circulation (Case 8, Fig. 2) suggests that plasma flow only is occurring (Knisely, Warner, and Harding, 1960), allowing the fluorescein to be seen unmasked by the red cells which normally absorb much of the fluorescence.

Before considering central venous occlusion, it is important to differentiate between transit time and perfusion rate, for variations in the volume of the vascular bed will affect the relationship between these two quantities. The volume of the retinal vascular bed has not been considered in relation to central artery occlusion, as its variation is unlikely to be significant at the level of accuracy of these investigations. However, if the traditional view of the mechanism of the fundus changes in central retinal vein occlusion is accepted, namely that they are due to venous occlusion, then a rise in pressure will occur throughout the vascular bed until the perfusion rate is restored almost to its original level. An increased volume of the bed resulting from the raised pressure will prolong the transit time, though the perfusion rate (volume flow per unit time) is unaltered. If the dilatation of the larger veins is accepted as a crude index of this increased volume, then as a first approximation the square of venous calibre will equate with the volume of the retinal vascular bed, and hence with the transit time. In Fig. 6 a line passing through the origin has been plotted to show the relationship M.T.R. $= (V.I.)^2$. Although the scatter of results does not prove the relationship, it is compatible with it, having regard to the inherent errors of the investigation.

The alternative hypothesis that the appearances of central retinal vein occlusion are due to chronic arterial ischaemia (Paton, Rubinstein, and Smith, 1964) poses a number of problems where the present data are concerned. The cases in Table II are arranged in order of descending severity, decreasing arterial occlusion followed by decreasing venous occlusion, yet there is a profound break in the transit data between Cases 9 and 11 (M.T.R. 2·1 to 4·6) which can be explained only by suggesting a secondary anoxic dilatation of the vascular bed in venous obstruction. Case 10 does little to elucidate the problem; at the time of examination 5 days after the sudden loss of vision, the patient was beginning to develop signs of central retinal vein occlusion with haemorrhages and full veins, though the transit data showed only slight delay. Vision never recovered and he later developed the full clinical picture of central retinal venous occlusion. It is easier to orientate this case in the series if two separate vascular accidents (arterial followed by venous) are postulated, than if arterial ischaemia is the sole factor.

Leakage is not seen in central artery occlusion, except in relation to the site of recent emboli; however, in central vein occlusion, it occurs widely in the fundus. Though the ischaemia is more severe in arterial occlusion, the perfusion pressure is low. In venous occlusion the anticipated perfusion pressure will depend on the causative mechanism; if it is partial arterial occlusion, then the pressures will show a steady rise from a low level in severe venous occlusion to near normal in the mildest cases; on the other hand, if it is due to obstruction of the veins, the pressure will reach high levels exceeding normal and these will be greatest in the severe occlusions. Cases 11 and 12 in this series, which have the longest transit times and high venous indices, show the most marked leakage of fluorescein, an observation easier to understand on the basis of venous obstruction than of partial arterial occlusion.

The results in branch occlusions are less consistent than in central occlusions, though the

presence of an inbuilt control in the rest of the fundus helps to eliminate many sources of technical error. Unfortunately the size of vessel occluded varies and this introduces fresh sources of error, while the difficulty of obtaining a satisfactory venous index increases and fluorescence photographic data is less reliable because of the difficulty in making judgements on small vessels and the shorter transit times involved. An additional factor in many cases of branch occlusion was the delay before the patient attended hospital and investigation became possible.

Whilst branch arterial occlusions are fairly consistent and reproduce in miniature the pattern of central artery occlusion (Fig. 7), branch vein occlusions show no correlation between the venous index and local to expected transit ratio (L./E.T.R.) (Fig. 8), which prompts the inquiry whether there is a fundamental difference between branch and central vein occlusion.

Conclusions.—The present studies show that in arterial occlusion there is a variable degree of reduction of blood flow, and in central venous occlusion there is an increase in the fluorescein transit time which may be largely due to increase in the size of the vascular bed. Indirect evidence is in favour of the traditional explanation of central venous occlusion, though as Hayreh (1965) has shown there is experimental evidence to suggest that the state of the arterial part of the circulation may influence the development of physical signs in the fundus. Reduced dynamometry readings have been recorded in cases of central venous occlusion (Paton and others, 1964), suggesting that both arterial and venous factors may contribute to the clinical state.

Summary

(1) 39 patients with recent retinal vascular accidents have been examined by fluorescence retinal photography.

(2) The qualitative and quantitative (transit times) results are recorded and discussed.

(3) A wide range of changes was encountered. In only a few cases of arterial occlusion did retinal circulation appear to be completely arrested.

(4) The relevance of the data to theories of venous occlusion is discussed.

My thanks are due to Mrs. J. M. Moore for processing the fluorescein films, and to Miss G. Tait for painstaking work with the photographic records; I also wish to thank the surgeons and casualty officers of Moorfields Eye Hospital who have referred patients for investigation. The diagrams were prepared in the Department of Medical Illustration, Institute of Ophthalmology.

REFERENCES

ASHTON, N., DOLLERY, C. T., HENKIND, P., HILL, D. W., PATERSON, J. W., RAMALHO, P. S., and SHAKIB, M. (1966). *Brit. J. Ophthal.*, **50**, 286.

DOLLERY, C. T., HODGE, J. V., and ENGEL, M. (1963). *Med. biol. Illus.*, **13**, 4.

FERRER, O. M. (1965). *Amer. J. Ophthal.*, **60**, 587.

HAYREH, S. S. (1965). *Brit. J. Ophthal.*, **49**, 626.

HILL, D. W., and DOLLERY, C. T. (1963). *Trans. ophthal. Soc. U.K.*, **83**, 61.

KNISELY, M. H., WARNER, L., and HARDING, F. (1960). *Angiology*, **11**, 535.

NOVOTNY, H. R., and ALVIS, D. L. (1961). *Circulation*, **24**, 82.

OBERHOFF, P., EVANS, P. Y., and DELANEY, J. F. (1965). *Arch. Ophthal. (Chicago)*, **74**, 77.

PATON, A., RUBINSTEIN, K., and SMITH, V. H. (1964). *Trans. ophthal. Soc. U.K.*, **84**, 559.

STOKOE, N. L., and TURNER, R. W. D. (1966). *Brit. J. Ophthal.*, **50**, 21.