

Emergence point and angulation of disc vessels in the normal eye

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The appearance of vessels in a pathological cup has been described as that of a shift nasally with a "break" of the vessels at the margin of the cup (Duke-Elder, 1959, Adler, 1962). Goldmann (1956) describes two typical forms of *normal* disc appearances, one in which there is a small amount of temporal excavation and the other in which excavation is more extensive, but in both forms the vessels arise at right angles to the cribriform plate at the nasal border of the cup; his first sign of glaucomatous change is the nasal displacement of the blood vessels, *i.e.* their angular deviation from their normal perpendicular ascent along the steep nasal slope of the physiological excavation. Although most observers would agree that this angular deviation is very common in glaucoma, Armaly (1969) has shown that in the normal eye "displacement" of the vessels, *i.e.* the angle between the major trunks and the floor of the cup at their point of entry, is related to the ratio of diameter of the optic cup to diameter of optic disc (the cup-to-disc diameter ratio).

A basis for the present survey was a clear distinction between two characteristics of the emerging disc vessels:

- (a) *Emergence point*, *i.e.* the site at which vessels first became visible to the ophthalmoscopist, or rather to the fundus camera; the point is defined in relation to the margins of the disc and cup;
- (b) *Angulation*, *i.e.* the angle between the emerging vessels and a plane tangential to the cribriform plate or base of the cup itself (see Fig. 1, overleaf).

Figs 4a and b are good examples of discs which differ in these characteristics. The term "bending" has not been used because it implies a change in direction, and we have no definite information about the pathway of the vessel behind the point where it becomes visible; "bending" might be better reserved for the change in direction of the vessel at the edge of the disc.

For a series of "normal" eyes, the following observations were made:

- (1) With reference to the cup:
 - (a) The emergence position of the vessels in relation to:
 - (i) the margins of the cup
 - (ii) the area of disc cupping.
 - (b) The relationship between vessel angulation and emergence position.
- (2) With reference to the disc:
 - (a) The emergence position of the vessels in relation to:
 - (i) the margins of the disc
 - (ii) the area of disc cupping.
 - (b) The relationship between vessel angulation and emergence position.
- (3) The relationship between vessel angulation and the area of disc cupping.

(4) The role of the eccentric position of the cup within the disc area in any relationships found under the above headings.

Subjects

The individuals used for this survey had been studied previously in the determination of the relationship between cup-to-disc ratio and length of eyeball (Tomlinson and Phillips, 1969) and applanation tension and length of eyeball (Tomlinson and Phillips, 1970). These were 75 undergraduates whose ages varied between 18 and 27 years; 26 were female and 49 male. The results from only one eye of each subject were used for statistical purposes; this was randomly selected by the toss of a coin (36 right, 39 left).

Method

Stereoscopic fundus photographs of all subjects were taken with the Zeiss Fundus Camera by the successive photographic technique described previously (Tomlinson and Phillips, 1969). These photographs were mounted on card to form stereo-pairs and viewed through a variable prism stereoscope.

THE EMERGENCE POSITION of the vessels was referred to the horizontal and vertical margins of the cup and disc to give the *nasal/temporal emergence point ratio* (N/T EPR) (distances b/a for the cup in Fig. 2); and the *superior/inferior emergence point ratio* (S/I EPR) (distances c/d in Fig. 2). The point of emergence was taken to correspond to the mid-point of the vessel. Measurements were made on the stereo-pairs by a finely graduated steel rule. The cup-to-disc area ratio had been found in a previous survey by planimetry (Tomlinson and Phillips, 1969).

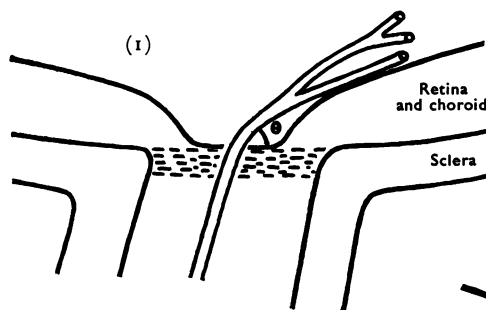


FIG. 1 *Vessel angulation.* The angle ascribed to the vessel is that formed by the wall of the vessel immediately after emergence and the tangent to the lamina cribrosa at that point (angle = θ)

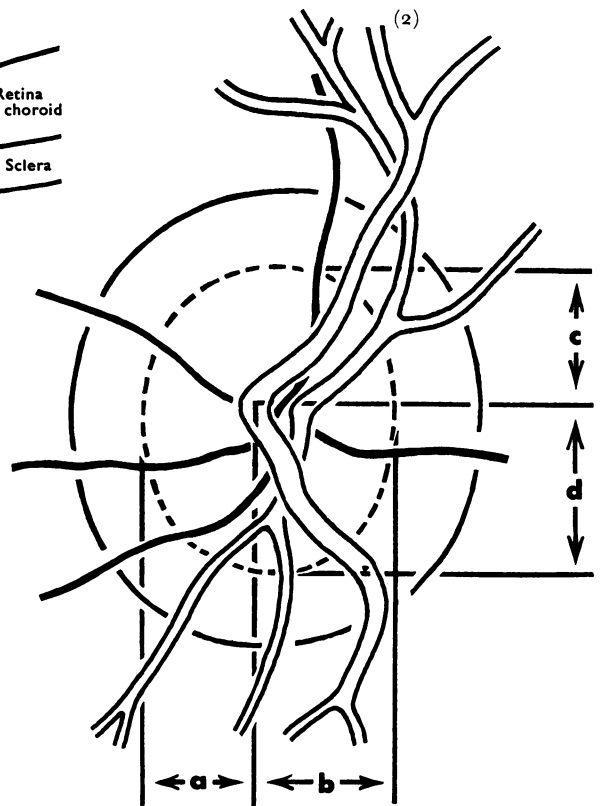


FIG. 2 *Diagram of right optic disc.* Emergence Point Ratio (EPR) for the cup. — The nasal/temporal EPR is given by the ratio b/a ; the superior/inferior EPR by c/d

The DEGREE OF ANGULATION of the vessels was found from the angle formed by the wall of the vessel immediately after emergence in the bottom of the cup and the tangential plane to the lamina cribrosa (plane assumed if lamina not visible) at the emergence point (Fig. 1). The angulation was measured in degrees of arc: if the vessels appeared to leave the base of the cup without bending and came straight towards the observer, the angle was recorded as 90° ; if the vessels' direction on emergence was along the base of the cup, their angulation was 0° .

The emergence point ratios and the degrees of angulation were found separately for the arteries and veins.

The HORIZONTAL ECCENTRICITY of the position of the cup within the disc margins was expressed as the ratio of (i) the horizontal distance from the nasal edge of the cup to the nasal edge of the disc to (ii) the horizontal distance from the temporal edge of the cup to the temporal edge of the disc.

Results

(1a) EMERGENCE POINT RATIO (EPR) OF VESSELS IN THE CUP IN RELATION TO THE CUP-TO-DISC AREA RATIO

The relationship between the EPR (N/T and S/I) for the arteries and veins and the cup-to-disc area ratios were statistically analysed with the Rank Correlation method of Spearman (Table I). Significant relationships were found, for the vein, between the S/I EPR and

Table I Rank correlation test applied to Emergence Point Ratio (EPR as related to the cup margins) compared with cup-to-disc area ratios and angulation of vessels and eccentricity of cup.

Dimensions	Correlation coefficient	Level of significance
C/D area ratio and Artery N/T EPR	-0.090	P < 0.50*
C/D area ratio and Vein N/T EPR	-0.262	P < 0.50†
C/D area ratio and Artery S/I EPR	+0.090	P < 0.05*
C/D area ratio and Vein S/I EPR	+0.233	P < 0.05†
Artery angulation and Artery S/I EPR	+0.232	P < 0.05†
Artery angulation and Artery N/T EPR	-0.226	P < 0.05†
Vein angulation and Vein S/I EPR	+0.070	P < 0.05*
Vein angulation and Vein N/T EPR	-0.257	P < 0.05†
Horizontal cup eccentricity and Artery N/T EPR	-0.480	P < 0.001†
Horizontal cup eccentricity and Vein N/T EPR	-0.328	P < 0.01†

*Not significant

†Significant at the levels stated (<0.05 is the minimum usually required level)

the C/D area ratio and between N/T EPR and C/D area ratio; the larger the C/D area ratio the more inferior and nasal was the emergence position of the vein within the cup. A scattergram of the latter is shown in Fig. 3a (overleaf) together with a regression line of values of C/D area ratio on values of N/T EPR for the vein.

(1b) EMERGENCE POINT RATIO (EPR) OF VESSELS IN THE CUP IN RELATION TO VESSEL ANGULATION

In Table I are listed the significant relationships found between angulation and the EPR (S/I and N/T) for the artery, and between angulation and the N/T EPR for the vein. These indicate that the nearer the angulation of the artery is to 90° the more inferior and nasal is the emergence position of the vessel. The vein is similarly related in its emergence position in the horizontal meridian to vein angulation. A scattergram with a regression

line of values of vein angulation on values of vein N/T EPR for the cup is shown in Fig. 3b.

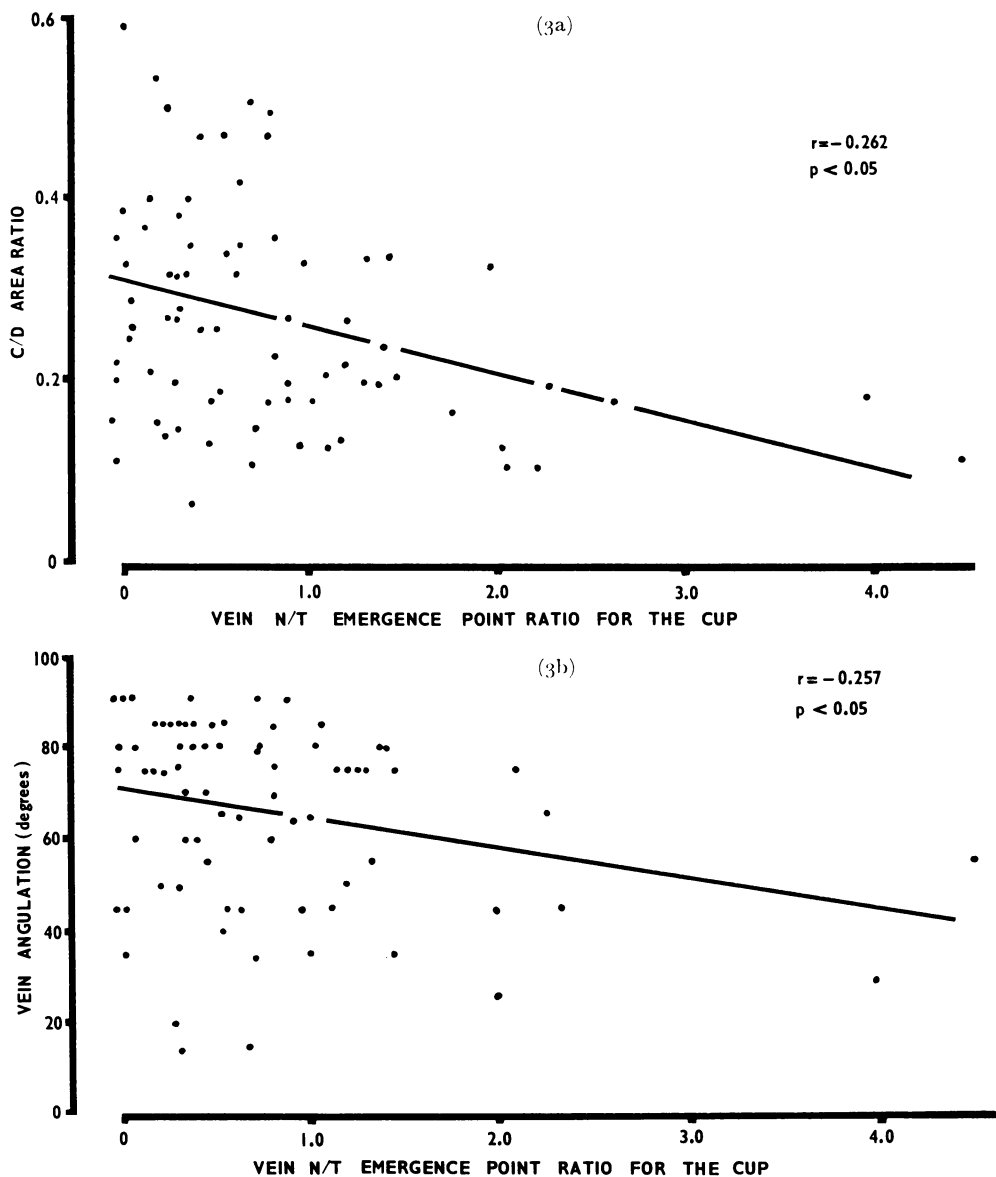


FIG. 3 Scattergrams (with regression lines)

- (a) C/D area ratio on vein N/T emergence point ratios for the cup
 (b) Vein angulation on vein N/T emergence point ratios for the cup

(2a) EMERGENCE POINT RATIO (EPR) OF VESSELS IN THE DISC IN RELATION TO CUP-TO-DISC AREA RATIO

In Table II are listed the significant relationships found between the N/T EPR of the vein and artery and the C/D area ratio; the larger the C/D area ratio the more nasally emergent

are the vessels within the disc area. A scattergram with a regression line of values of C/D area ratio on values of vein N/T EPR for the disc is shown in Fig. 3c.

Table II Rank correlation test applied to Emergence Point Ratio EPR (as related to the disc margins) compared with cup-to-disc area ratios and angulation of vessels and eccentricity of cup. Also eccentricity of cup compared with vessel angulation

Dimensions	Correlation coefficient	Level of significance
C/D area ratio and Artery N/T EPR	-0.503	P < 0.001†
C/D area ratio and Vein N/T EPR	-0.339	P < 0.01†
Artery angulation and Artery N/T EPR	-0.097	P < 0.50*
Vein angulation and Vein N/T EPR	+0.090	P < 0.50*
Artery N/T EPR for Disc and cup	+0.486	P < 0.001†
Vein N/T EPR for Disc and cup	+0.758	P < 0.001†
C/D area ratio and Artery angulation	-0.340	P < 0.01†
C/D area ratio and Vein angulation	-0.430	P < 0.001†
Horizontal cup eccentricity and Artery N/T EPR	-0.094	P < 0.50*
Horizontal cup eccentricity and Vein N/T EPR	-0.043	P < 0.50*
Horizontal cup eccentricity and Artery angulation	+0.042	P < 0.50*
Horizontal cup eccentricity and Vein angulation	-0.089	P < 0.50*
Horizontal cup eccentricity and C/D area ratio	+0.265	P < 0.05†

*Not significant †Significant at the levels stated

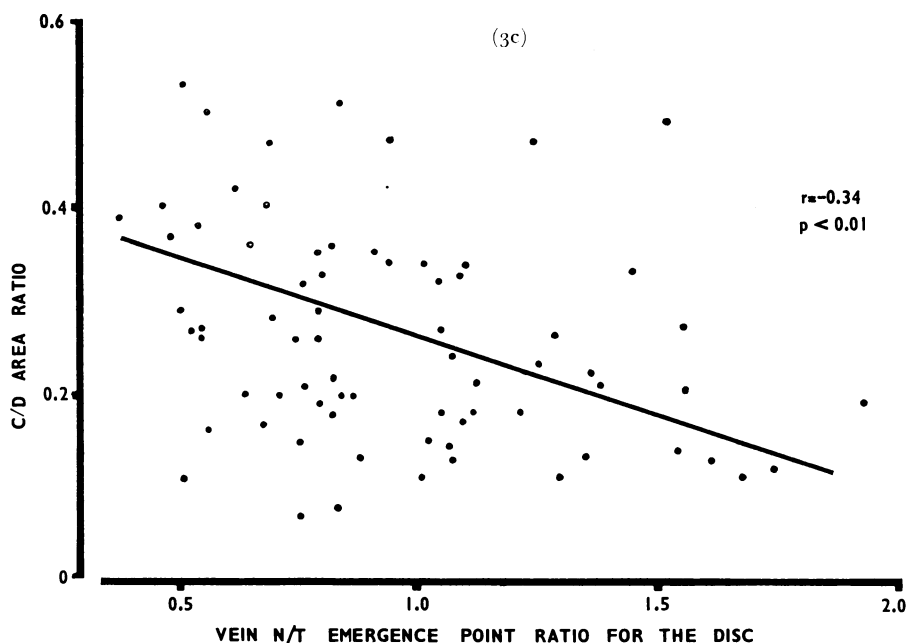


FIG. 3 (c) C/D area ratio on vein N/T emergence point ratios for the disc

(2b) EMERGENCE POINT RATIO (EPR) OF VESSELS IN THE DISC IN RELATION TO ANGULATION
No significant correlation was found for the N/T EPRs of the vein and artery and vessel angulation.

(3) VESSEL ANGLUATION AND AREA OF DISC CUPPING

Highly significant relationships were found between vessel angulation and the C/D area ratio for both the vein and artery; the larger the C/D area ratio the more likely are the vessels to deviate from the 90° direction (Table II).

(4) CUP ECCENTRICITY

The cup was found to be significantly more eccentrically positioned with respect to the disc margins with larger cup-to-disc area ratios. A significant relationship was also found between cup eccentricity and the N/T EPR, with respect to the cup margins, for both veins and arteries; *i.e.* when the cup is eccentrically positioned within the disc area the more likely are the vessels to emerge to the nasal side (Table I). No correlation was found between the N/T EPR for vein or artery referred to the disc margin and cup eccentricity. A similar lack of correlation between vessel angulation and cup eccentricity can be seen in Table II.

Table III shows the mean and standard deviations for the emergence point ratios (in relation to the edges of the cup) and angulations recorded for the arteries and veins. Significant differences were found to exist on the Student's *t* test for the means of N/T EPR, S/I EPR and angulation between the veins and arteries. On the Snedecor *F* test a significant difference between the variances of vein and artery N/T EPR, and vein and artery angulation were found (See Discussion).

Table III Means and standard deviations of vessel relationships to cup margins

<i>Dimension</i>	<i>Mean ± S.D.</i>	<i>Level of significance of difference between means (t test)</i>	<i>Level of significance of difference between variances (F test)</i>
Vein N/T EPR Artery N/T EPR	0.83 ± 0.67 0.34 ± 0.34	} P < 0.001†	} P < 0.01†
Vein angulation Artery angulation (in degrees from "straight ahead")	65.4 ± 19.86 71.93 ± 13.46	} P < 0.05†	} P < 0.05†
Vein S/I EPR Artery S/I EPR	1.067 ± 0.35 1.144 ± 0.38	} P < 0.05†	} P < 0.25*

*Not significant

†Significant at the levels stated

Discussion

The method of measurement of angulation used in this survey may be criticised on the basis of its subjective nature. One observer's impression was used throughout to describe the amount of angulation in degrees of arc. It is likely that this observer's idea of the angles in absolute terms was inexact, but the comparison between one subject and another was probably reasonably accurate. To test this claim, angulation of the vein and artery was assessed on two occasions; the correlation between the results obtained on these two occasions was significant at the 2 per cent. level. Angles were described in degrees of arc rather than by the grades used by Armaly (1969), in order to conform with the principle of using all available gradation of the data; in other words, a value allotted to a reading near one end of a wide group would not be taken as identical with one near the other end. Admittedly in our series in practice the observer described angles in steps of 5°, *e.g.* 40°, 45°. (Another consideration when data are allotted to groups is that a *descriptive* classification is more immediately understandable than a *numerical* grading: for example, in

grading angles of anterior chamber the use of the terms narrow, medium and wide, with narrow-medium and medium-wide to make six groups would be less obscure than, say, "Grades I to VI").

Angulation of both arteries and veins within the cup have been shown in this survey to be related to the amount of disc cupping in "normal" eyes; the larger the area of cupping the greater is the departure of the vessel's path from the "straight-ahead" direction. This is in agreement with the results of Armaly (1969) and casts serious doubt on the value of vessel angulation as an indicator of pathological cupping, because it is found in large cups even when these are not associated with glaucoma.

It has also been demonstrated that the more nasally emergent the vessel is *within the cup* the *less* likely is it to deviate from the 90° direction - see Fig. 4; accordingly, the *absence* of nasal angulation of vessels cannot be accepted as a valid contraindication of pathological cupping. The increased "supporting" effect experienced by the vessels the closer they are to the margin of the cup is presumably the explanation. However, N/T EPR in relation to disc margin is not (significantly) correlated with vessel angulation—the explanation for this is probably that the position of the cup within the disc varies to some extent independently of the position of the vessels.

The point of emergence of the vein (as distinct from its angulation) when related both to the cup and disc margins has been found to be significantly related to the area of disc cupping in that discs with larger amounts of cupping have the point of emergence of the vein more to the nasal side (Fig. 4). Accordingly a nasal point of emergence of the vein should not be a diagnostic feature in pathological cupping, *especially in the absence of nasal angulation*. The vein S/I EPR within the cup is also related to the degree of disc cupping; the larger the area of cupping the more inferior is the emergence position. The emergence

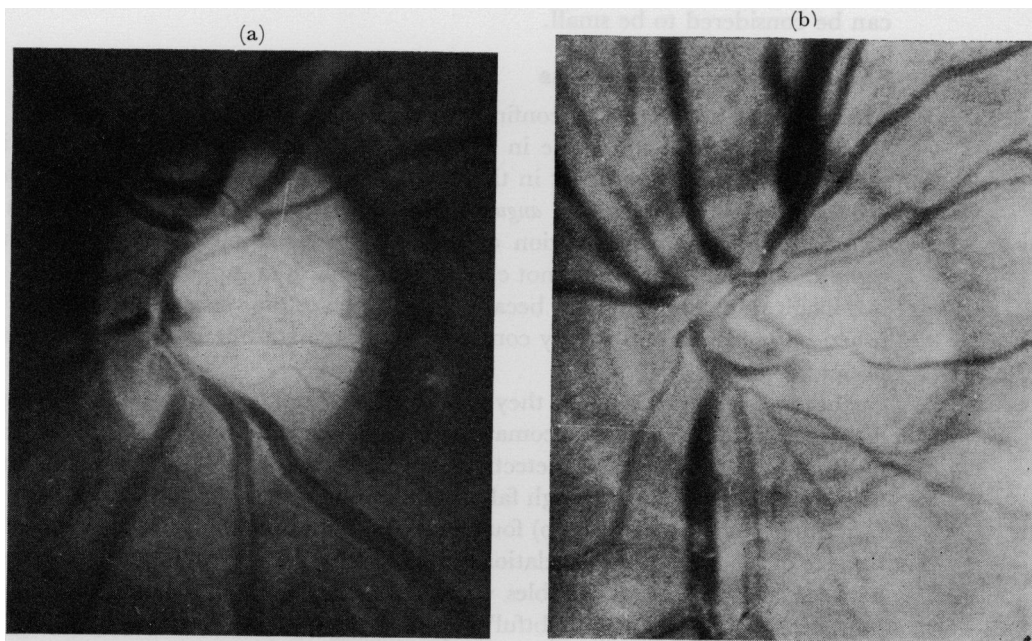


FIG. 4 Photograph of optic disc in two subjects

- (a) The vessels emerge near the nasal edge of the cup and disc, at an angle of 85° ; there is a moderate area of cupping (c/d area ratio = 0.40)
- (b) The vessels emerge centrally within the cup and disc, and are more deviated from the "straight-ahead" direction (angle 15°); the degree of cupping is less (c/d area ratio = 0.32)

ratios of the artery, both S/I and N/T, within the cup are not related to cup/disc ratio; this is consistent with the much smaller variation in artery emergence position in comparison with that of the vein (Table III).

As shown in Table III, the vein was found to emerge significantly more centrally within the cup than the artery, and its emergence position was susceptible to greater variation in emergence position in the horizontal meridian with increased cup/disc ratio. It also shows greater degrees of deviations from 90° than the artery. The vein relative to the artery may generally be described as emerging more temporally and a little superior within the cup and to be more angled in the initial part of its path. The relation between emergence points of vein and artery found in this survey agrees with that shown in diagrams in Wolff (1948) and Hayreh (1970).

An apparently low N/T EPR for a vessel in a cup, indicating nasal emergence of that vessel within the cup, may be due either to the vessel's emerging nasally within the disc area or to the cup's being eccentrically displaced towards the temporal margin. If the latter be true, it might be the reason for the significant correlation found between vein NT/ EPR for the cup and C/D area ratio (cup eccentricity has been shown to be related to cup-to-disc area ratio (Table II) and to vein N/T EPR for the cup). The eccentricity of the cup cannot, however, have any effect on the vein N/T EPR for the *disc*. As a high correlation has been demonstrated at the 0.01 per cent. level of significance between N/T EPRs for the cup *and* disc for both the arteries and vein, we consider that the relationship found between cup-to-disc area ratio and vein N/T EPR for the cup is almost independent of cup eccentricity and instead due almost entirely to the emergence point of the vein. Cup eccentricity is not found to be related to vessel angulation or to the emergence point ratios for the disc, and its importance in the observations listed above can be considered to be small.

Some clinical implications

These observations tend to confirm that the criteria for diagnosis of *early* pathological cupping are difficult to define in an individual case. Emergence point ratios of vessels should probably play no part in the diagnosis, save in the negative sense that *if the emergence point is markedly eccentric, angulation of the vessels should not be expected even if the disc is pathologically cupped*. Angulation of vessels (as well as cup-to-disc ratios) in individual cases at one point in time cannot claim to do more than support suspicion; in other words, it is illogical to conclude that, because angulation of the vessels at the bottom of the established pathological cup is very common, glaucoma is to be diagnosed when angulation is present.

Authors vary in the value they place on the presence of pathological cupping in the diagnosis of open-angle glaucoma. Graham and Hollows (1966) showed that ophthalmoscopy was as efficient in detecting *established* (our italics) glaucoma as tonometry and field screening, although a high false positive rate was noted (no false negatives). Fisher, Carpenter, and Wheeler (1970) found a close relationship between the state of the disc and the size of the field - this correlation was greater, with one exception, than the correlations between any other two variables which included ocular tension and facility of outflow; however, a category of "doubtful" cupping was included. Armaly (1969) would seem to agree with Shutt, Boyd, and Salter (1967) that a fair proportion of cases with glaucomatous field loss exist *without* pathological cupping (34 per cent. according to the latter). In so far as there may be a true difference of opinion between authors (it may be less than appears because some are concerned with early cupping and others with established

glaucoma), differing criteria are probably the explanation. It would probably be common ground, however, that the diagnosis of *early* pathological cupping is often difficult and that tonometry, visual field examination, and careful examination and recording of the appearances of the optic disc, as well as slit-lamp examination and gonioscopy would constitute the minimum criteria for the diagnosis and management of glaucoma.

It seems likely that ophthalmoscopic criteria for early pathological cupping would be best derived in the individual case from serial stereoscopic photographs of the disc – or diagrams made regularly.

We have the clinical impression that sharpness of the disc margin is a good criterion of early as well as of late pathological cupping. Vessels are of little help in this assessment because the points at which they cross the disc margin are affected rather late in the pathological process. Sharpness has to be discounted, however, as of no pathological significance along a temporal crescent or a (minimal) inferior coloboma. Another important characteristic is saucerization of the disc tissue between the physiological cup and the disc margin. Pallor and excavation with undermining of the disc margins are late signs.

Summary

The angulation and site of emergence of the vessels relative to the margins of the cup and disc are considered in relation to the area of disc cupping (the cup-to-disc or C/D area ratio) in a series of 75 normal eyes of subjects whose ages ranged from 18 to 27 years. Significant relationships are found to exist between the “emergence point ratios” for the vein (*i.e.* distance between centre of emerging vein and nasal edge of cup or disc divided by distance from temporal edge) and C/D area ratio; and between the emergence point ratio of the artery when referred to the disc margin only (not cup) and the C/D area ratio. Discs with larger C/D area ratios have vessels which emerge more to the nasal side. Eyes with larger C/D area ratios tend to have vessels which are more angled on emerging into ophthalmoscopic view. A relationship between vessel angulation and emergence position, referred to the cup margin, is also found to exist (*i.e.* vessels which emerge towards the nasal edge do so at angles near to 90° to the base of the cup). The influence of the eccentricity of the cup within the disc margins on the above relationships is probably small. The validity of vessel angulation and nasal emergence point of vessels as diagnostic features in glaucoma and the *absence* of nasal angulation as a contraindication of pathological cupping are brought into question by the results of this survey.

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