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Vertical ovalness of glaucomatous cupping

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The decision whether or not the optic disc shows early glaucomatous changes is one that has to be made frequently in clinical practice, and the importance of this decision is well recognized. The problem is essentially a matter of deciding whether one is looking at a cup which is 'physiological' or 'pathological', and the difficulty is due to the fact that the transition from 'physiological' to 'pathological' is gradual as in chronic disease anywhere in the body. Several recent papers have suggested that extension of a cup upwards or downwards is an early pathological change in glaucomatous excavation of the disc (Kirsch and Anderson, 1973; Weisman, Asseff, Phelps, Podos, and Becker, 1973; Gloster and Parry, 1974) or, in other words, that the early glaucomatous cup is vertically oval. The investigation reported here is concerned mainly with this suggestion.

If one is interested in the shape of a cup in the optic disc then it is clearly important to be able to determine the outline of the cup with precision, and this applies to investigative and clinical work equally. It does not need to be emphasized that, with the ophthalmoscope alone, it is sometimes easy to define the margin of the cup and at other times very difficult. In the present investigation the margin of the cup was defined by combining information from several sources:

1. A special colour photograph was taken of the disc which exaggerated the colour contrast between the floor of the cup and the disc tissue surrounding the cup (Gloster and Parry, 1974).
2. An immediate black-and-white photograph was taken on which the observer marked the margin of the cup as it appeared from (*a*) binocular slit-lamp observation, and (*b*) the ordinary ophthalmoscopic view, paying particular attention to the parallactic movement between the floor and the rim of the cup.
3. Stereoscopic colour photographs of the disc.

It was felt that the combination of all this information yielded the best possible delineation of the area of cupping.

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According to Tomlinson and Phillips (1974), in non-glaucomatous subjects, the shape of the disc influences the shape of a physiological cup within it, a vertically oval cup tending to occur in a vertically oval disc. Therefore it would seem that the shape of the cup should be considered not only in isolation but also in relation to the shape of the disc. This involves the cup: disc ratio—that is, the diameter of the cup divided by the diameter of the disc—and since we are concerning ourselves particularly with the ovalness of the cup, we shall be interested in both the vertical and horizontal cup: disc ratios.

Methods

The subjects of this study were all patients attending the Glaucoma Clinic at the Institute of Ophthalmology, on whom optic disc photography was undertaken either as part of their clinical assessment or to provide a record of the disc appearance to assist in their subsequent management. In the routine of clinical examination, the patients' intraocular pressures (IOP) were measured on several occasions by Goldmann applanation tonometry, and their visual fields were charted on the Goldmann perimeter using stimuli presented as flashes (Gloster, 1970). In addition, provocative tests had been performed when the appropriate indications existed. A full history was taken with special reference to the symptoms of intermittent closed-angle glaucoma and the possible occurrence of glaucoma in relatives. On the basis of the history and examination, eyes were divided into the following groups:

A. *Eyes with full fields:*

1. Non-glaucomatous—in which the IOP was never found to be above 20 mm Hg, provocative tests were negative, and there was no glaucomatous field defect, these conditions being so in both eyes of the same patient.
2. Ocular hypertensives—in which an IOP of more than 20 mm Hg had been recorded at least twice with an open angle, but in which no glaucomatous field defect could be demonstrated.
3. Fellow eyes in cases of 'unilateral simple glaucoma' in which no glaucomatous field defect could be found, although the other eye showed a typical

defect together with an IOP of more than 20 mm Hg with an open angle. The IOP in some fellow eyes was below 20 mm Hg while in others it was above.

B. *Eyes with glaucomatous field defects*

In all these the diagnosis was simple glaucoma, the untreated IOP having been above 20 mm Hg on at least two occasions with an open angle, and typical glaucomatous defects were present in the visual field.

Patients using miotics were instructed to stop using these for periods varying from 2 to 7 days before photography, acetazolamide being prescribed when necessary to prevent a large rise in IOP. The pupils were dilated with 2 per cent homatropin and cocaine drops, supplemented sometimes with 10 per cent phenylephrine or 1 per cent mydrilate, good pupillary dilatation being required for stereoscopic photography of the discs.

A Kowa RC fundus camera with a Polaroid attachment was used to give an immediate positive black-and-white print of the disc. The disc was examined ophthalmoscopically, and then with a Haag-Streit 900 slit lamp and binocular microscope in conjunction with either a Hruby lens or a Goldmann fundus contact lens. In defining the margin of the cup it was found useful sometimes to use a very narrow slit, or to vary the angulation between the lines of observation and of illumination, or to interpose a green filter in the illuminating beam. The observer then marked what he considered to be the margins of the cup on the Polaroid print, on the basis of his ophthalmoscopic and slit-lamp observations.

The West German Zeiss fundus camera was used to take plain colour photographs of the disc, using a $\times 2$ converter to obtain increased magnification and a special fixation device (Parry, 1975). Further photographs were taken using a cyan ring or 80B filter (Gloster and Parry, 1974). Lastly, stereoscopic photographs of the disc were taken, either successively after altering the angle of the camera, or simultaneously using a twin prism mounted on the objective of the camera (Saheb, Drance, and Nelson, 1972).

After photography the patients' IOPs were measured with the Goldmann applanation tonometer, a miotic was usually instilled, and in all cases the pupils and IOPs were checked before the patient was allowed to leave the clinic.

The basis for the cup and disc measurements was provided either by the cyan ring or the 80B photographs (that is, those in which the colour contrast of the cup and disc was exaggerated). These transparencies were back-projected on tracing paper and the outline of the disc was drawn together with those parts of the margin of the cup which could be determined with certainty. In order to complete the outline of the cup, the stereoscopic photographs were observed in a viewer and reference was made to the slit-lamp drawing on the Polaroid print. By using all this information it was usually possible to be reasonably sure of the margins of the cup, especially above and below, although there was sometimes doubt as to exactly how far the cup extended towards the temporal border of the disc. If there was considerable doubt, measurement was not attempted.

The following measurements were made as described by Gloster and Parry (1974):

(i) Cv, vertical diameter of the cup;
(ii) Ch, horizontal diameter of the cup;
(iii) Dv, vertical diameter of the disc;
(iv) Dh, horizontal diameter of the disc.

From these, the following ratios were calculated:

(i) Cv/Ch, ovalness ratio (Tomlinson and Phillips, 1974) of the cup;
(ii) Dv/Dh, ovalness ratio of the disc;
(iii) Cv/Dv, vertical cup: disc ratio;
(iv) Ch/Dh, horizontal cup: disc ratio.

The ability of the various ratios to differentiate between eyes with full fields and eyes with glaucomatous defects was determined as described by Gloster and Parry (1974).

Results

Table I is concerned with the ovalness of the cup and the disc; a ratio of less than 1·0 means that there is horizontal ovalness, while a ratio greater than 1·0 means vertical ovalness. It is clear that, on the average, the optic disc is vertically oval in all categories of eyes examined. With regard to the cup, it can be seen that the ratio changes from being less than unity in non-glaucomatous eyes, to slightly above unity in ocular hypertensives and fellow eyes in 'unilateral simple glaucoma', and to well above unity in glaucomatous eyes with associated field defects. If eyes with full fields are compared with those with defective fields, there is a significant difference ($t = 7{\cdot}52$; $0{\cdot}001 > P > 0$) between the two groups in the values obtained for Cv/Ch, the ovalness ratio of the cup. Unexpectedly, there is also a difference between these two groups of eyes for Dv/Dh, the ratio expressing the ovalness of the disc; although small this difference is nevertheless significant ($t = 2{\cdot}49$; $0{\cdot}02 > P > 0{\cdot}01$).

Table II shows the vertical and horizontal cup: disc ratios. As one passes from non-glaucomatous eyes to ocular hypertensives and fellow eyes and finally to eyes with established glaucoma, there is a progressive increase in both the vertical (Cv/Dv) and horizontal (Ch/Dh) cup: disc ratios, but the change in the former is greater than in the latter. The differences between Groups A and B were very highly significant ($0{\cdot}001 > P > 0$) for both ratios.

The means and standard deviations of the various ratios and their ability to differentiate between eyes with full fields and those with glaucomatous defects are shown in Table III. Remembering that pure chance would give a 50 per cent correct differentiation, it can be seen that in this respect Dv/Dh was almost valueless and that the vertical cup: disc ratio (Cv/Dv) was the most useful. The vertical ovalness of the cup was some guide to the presence or absence of a field defect, but was

Table I *Ovalness of cup and disc*

Group	*Diagnosis*	*No. of eyes*	*Ovalness of cup (mean Cv/Ch)*	*Ovalness of disc (mean Dv/Dh)*
A. Eyes with full fields	Non-glaucomatous	31	0·96	1·05
	Ocular hypertension	78 (138)	1·06 (1·03)	1·06 (1·06)
	Fellow eyes of 'unilateral simple glaucoma'	29	1·05	1·09
B. Eyes with glaucomatous field defects	Simple glaucoma	86	1·20	1·10

not as good as the horizontal cup:disc ratio (Ch/Dh), and certainly not as effective as the vertical cup:disc ratio.

Discussion

Although it might be difficult to define precisely the clinical condition of any individual eye, the four sub-groups of patients—non-glaucomatous, ocular hypertensives, 'unilateral simple glaucoma', and established glaucoma with field defects—provide, in that order, a series in which the incidence of glaucoma may be considered to increase progressively, and any clear variation through the series in the ratios measured may be related to the severity of glaucoma.

Cv/Ch, the ratio expressing ovalness of the cup, was less than 1·0 in the non-glaucomatous eyes, indicating that the physiological cup is, on the average, horizontally oval. The ratio slightly exceeds 1·0 in eyes with raised tension but no field defects, whether these are in patients with ocular hypertension or are the fellow eyes of patients with 'unilateral simple glaucoma'. When a field defect could be established the mean ratio increased to 1·20. These results thus strongly support the view that an early change in the glaucomatous disc is vertical elongation of the cup. There was also a very much smaller increase in the ratio Dv/Dh, expressing the ovalness of the disc, and this difference was significant, although at a much lower level of confidence; it is not clear why the disc itself should appear slightly more oval vertically in eyes with field defects than in those with full fields, and this requires further investigation.

Table II shows that the vertical and horizontal cup:disc ratios increased, as would be expected, from low values in the non-glaucomatous patients to high values in the patients who had field defects. It can be seen, however, that the vertical ratio increased more than the horizontal ratio, and this accords with the increasing vertical ovalness of the cup.

The question then arises which observation made on the disc offers the most help in deciding whether or not one is dealing with an eye in which glaucoma has advanced to the stage of producing a field defect. Table III answers this question, showing clearly that the vertical cup:disc ratio is the most useful in this respect.

The practical clinical points to be made are:

1. When there is doubt whether cupping in the disc is physiological or glaucomatous, stereophotography and binocular slit-lamp examination of the disc may be extremely helpful.
2. A relatively small cup which is vertically oval

Table II: *Cup : disc ratios*

Group	*Diagnosis*	*No. of eyes*	*Vertical cup : disc ratio (mean Cv/Dv)*	*Horizontal cup : disc ratio (mean Ch/Dh)*
A. Eyes with full fields	Non-glaucomatous	31	0·46	0·51
	Ocular hypertension	78 (138)	0·55 (0·54)	0·56 (0·56)
	Fellow eyes of 'unilateral simple glaucoma'	29	0·60	0·61
B. Eyes with glaucomatous field defects	Simple glaucoma	86	0·80	0·74

Table III *Ability of various ratios to differentiate between eyes with full fields and those with glaucomatous defects*

Ratio	Eyes with full fields			Eyes with glaucomatous field defects			Eyes correctly differentiated (per cent)
	Mean	SD*	n†	Mean	SD*	n†	
Cv/Ch	1·03	0·17	138	1·20	0·15	86	70
Dv/Dh	1·06	0·09	138	1·10	0·10	86	55
Cv/Dv	0·54	0·14	138	0·80	0·09	86	90
Ch/Dh	0·56	0·13	138	0·74	0·11	86	76

*Standard deviation †Number of observations

should raise the suspicion of glaucoma.

3. The vertical cup: disc ratio is the most reliable indicator of glaucomatous change.

Summary

Slit-lamp examination and stereoscopic fundus photography were found to be helpful in differentiating between physiological and glaucomatous cupping of the disc.

Vertical ovalness of any cup in the disc should raise the suspicion of glaucoma, and the magnitude of the vertical cup: disc ratio is of particular significance.

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