A METHOD OF RECORDING DISC ALTERATIONS AND A STUDY OF THE GROWTH OF NORMAL AND ABNORMAL DISC CUPS*

BY

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EXETER

IN a paper read by me in 1921 to the Royal Society of Medicine⁽¹⁾ I endeavoured to establish the following conclusions drawn from a series of curves and frequency polygons constructed from a series of cases:—

(a) There is a tendency in some cases for the cup to enlarge, so that the curves showing variations at different ages are higher with advancing years, and frequency polygons show a shifting of the highest block away from the smaller discs.

(b) That this tendency begins in childhood, is not marked in early adult life, and is most marked after that time.

(c) While, in later adult life, the proportion of large cups increases, the number of the largest cups decreases coincident with the occurrence of chronic glaucoma in the same series of cases.

(d) The inference drawn from these conclusions was that the enlargement of the cup in adult life without symptoms of glaucoma must be regarded with suspicion and considered as an effect of pressure, and that such cases require careful watching for the development of glaucoma.

In an addendum to that paper two cases in which enlargement had been observed were recorded; but further investigation having been made to prove more completely the occurrence of these changes in individual cases in normal and glaucomatous eyes, it is proposed to deal with these in the present paper.

The method of recording adopted in my work since the paper mentioned above has been to draw the disc and the surface edge of the cup of the same apparent size as observed with the ophthalmoscope, and then to indicate any alterations from cylindrical shape in the cup by an inner curve representing the outline of the base of the cup, radiating lines being drawn between that and the cup margin. The depth of the cup was estimated as nearly as possible in dioptries. It should be noted that normal or abnormal cups more than 3 dioptries in depth are rare. These particulars are sufficient for nearly every purpose. In the case of steps a note is made at the side of the disc, a bracket showing its extent.

In some discs the surface of the disc is above the level of the retina. This may be indicated by curved lines passing from the edge of the cup to the edge of the disc in the parts that are so

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raised, the height of the curve suggesting the degree of elevation. A note is added, "surface of disc +2" or whatever figure the estimation may give. (Fig. 1.)

The estimations of depth or projection would be added in the notes of the cases to complete the description, e.g., "c," "cup depth—2 D.," "c," "cup depth—0.5 D. Surface of disc +1."

The method of estimating the percentage area by graph paper is described in my paper previously referred to⁽¹⁾. A more convenient method is by superposing a transparent celluloid plate marked off into 1/10 inch squares, measuring the areas of the disc and cup, and reducing that of the cup to a percentage of the disc area.

It will be useful to compare the degree of accuracy of the surface and depth measurements. The real diameter of the optic disc is

FIG. 1.—Method of construction of disc diagram.

- (a) Outlines of disc and cup edge (drawn for clearness of illustration, $\times 2$ diameters apparent size).
- (b) Junction of slope and base of cup or extent of step added to "a."
- (c) Radiating lines to show extent of slope.
- (d) Bracket marking step. (Note—No radiating lines here.)
- (e) Curved lines to show extent of disc area projecting above surface of retina.

about 1.5 mm.; as seen by the ophthalmoscope it appears to vary, but as a rough average 11 mm. horizontally and 12 mm. vertically may be taken as the apparent diameters. Most observers could work with fair accuracy up to a tenth of these surface dimensions. In estimating depths by the ophthalmoscope, few observers would be accurate enough to divide a 3-dioptre depth into any more than six parts of 0.5 dioptre each. If these statements are true, the surface measurements are more accurate than are the vertical. But the importance of the surface area of the cup is that in all cases of increase, except those of very advanced glaucoma or those exceptional cases of large physiological cups such as are illustrated in Mr. Hugh Thompson's paper⁽²⁾, the increase of size is nowhere larger than at the surface, and usually smaller. This will become more apparent when the various shapes met with are considered.

The special exceptions mentioned are those in which the retinal vessels are seen in the bottom of the cup, then disappear, and

finally emerge round the edge of the cup, indicating that the middle dimensions of the cup are larger than the surface or the bottom. So far there has not been found any way of indicating by a diagram the actual size of a dimension which can neither be measured nor inferred, so we may leave these cases to be described by words. The word "bulbous" will describe such cups fairly well, and is proposed as a tentative description.

A few words must be said upon the various shapes of the cups. These are :—

"Conical," in which the base of the cup is smaller than the surface area, so that part or the whole of the side is sloping. Usually this is confined to the outer half or two-thirds of the cup. About 6 in 7 normal cases have this shape.

The term "cylindrical" is used in the ordinary mathematical sense. About one-seventh of normal cases have cups of this description. They do not often exceed in area 25 per cent. of the disc, but I have seen one in a boy of 16 years which was 75 per cent. If severe accuracy were used the proportion would be less than 1 in 7, for some of the cylindrical cups have a slight bevel along their outer margin.

The third variety will be called the "stepped cup," for it has a step or ledge between the cup and the surface of the disc. A ledge completely surrounding the cup in a normal case has not been seen by me; in 708 normal cups in my private practice I have seen 4 with a ledge partly surrounding the cup, passing usually at one or both ends into a smooth slope. In the same series, in 22 eyes having chronic glaucoma, there was one with a partial step. In my out-patients I have noted this year 7 cases in which small steps have existed, and it may be taken that incomplete steps are commoner in glaucomatous than in normal cups.

The fourth variety is the "bulbous" cup, which has been already described. It is not common except in very advanced cases of chronic glaucoma, and does not come within the purview of this paper, because its largest dimensions cannot be ascertained.

Methods of increase

Normal cups.—The number of eyes in which an increase has been observed is 11; Fig. 2 and Table II show these in detail.

The amount of increase observed has varied from 6 per cent. to 18 per cent. of the disc surface area. From Table II it is obvious that the rate of increase varies much, e.g., in one case in 14 months the increase was 6 per cent., in another 17 per cent. in 12 months. The uncertainty of the time element is much increased in observations of this kind by the irregular attendance of patients; in what part of the interval between the two observations the growth occurred cannot be stated. It is significant that

the two oldest cases showed the increase in comparatively short times, $4\frac{1}{2}$ months and 4 months respectively.

The direction of the enlargement in all the cases except J was towards the temporal side, but usually asymmetrically relative to the horizontal diameter, the enlargement being generally greater

FIG. 2.—Growth of normal cups.

TABLE II.—Details of cases in Fig. 1.

Age at first observation.	Right Eye.	Left Eye.	Percentage increase.		No. of months between observations.
			R	L	
8 years	A	B	17	16	12 months
10 "	C	D	14	12	19 "
14 "	E	F	11	17	11 "
14 "	G		6	nil	14 "
44 "		H	nil	16	$10\frac{1}{2}$ "
48 "	I		6	nil	18 "
52 "		J	nil	14	$4\frac{1}{2}$ "
68 "	K		18	nil	4 "

in the lower temporal than in the upper temporal quadrant. But C has an enlargement equal in the two temporal quadrants, while J has a nearly concentric enlargement in all directions.

In A and B the surface areas only are recorded. In the remaining cases the shapes are indicated. It will be seen that in most the enlargements are conical, being greatest at the surface of the

discs. In 3 cases, E, H and K, the cylindrical parts of the cups are also enlarged, indicating a much greater increase in the capacity of the cups than if the enlargement were merely sloping.

These observations are in accord with the explanation given in my paper before mentioned, that in early life the increase can be explained as the result of growth, but that in adult life it is probably the result of pressure—the vitreous acting in the cup as a viscous fluid, conveying to it the general intraocular pressure in all directions, which acts upon the nerve head because this is the weakest part of the ocular coat. Thus eccentric growth is more marked in cases A to G than in H to K.

Abnormal cases.—My experience in cases of primary optic atrophy during the time in which drawings of the optic disc have been made is too small for me to draw any generalization; most advanced cases show some cupping, but it is not usually of great depth, though occasionally very marked.

In chronic glaucoma the enlargement is nearly always in all directions, as would be the case in a fluid pressure. And, as the great majority of cups are conical, with the outer side sloping and the inner more steep, or quite vertical, this general shape remains in the early stage. Again, most cups are eccentrically placed in the disc, their centres are nearly always in the temporal halves of the discs; therefore, a general enlargement will reach the temporal side of the disc earlier than it does the inner side.

The pressure acting in all directions, there is a deepening and widening going on at the same time. The former is limited by the lamina cribrosa, the widening by the lateral resistance of the nerve head tissues. The resultant of the contest between the latter and the intraocular tension depends upon the varying anatomical conditions.⁽³⁾ What is generally seen is that the enlargement begins at the surface of the disc, usually as a slope in the temporal half, the nasal half remaining vertical (e.g., Fig. 3, Nos. 5 and 6A). Sometimes a steep slope forms on the nasal side (Fig. 3, No. 6B). In other cases the slope is more symmetrical (Fig. 3, Nos. 1, 2, 3, 4 and 7). In most of these cases the record is incomplete, as the earlier record was made before the present method of recording the shape of the cup was completely evolved; but, as the slope goes in nearly all these in all directions beyond the original record of the cup surface area, it is obvious that these have extended more or less symmetrically by a slope. And this last group is especially interesting because it contains most of the smallest cups (Nos. 1, 2, 3 and 4). Now in recording cases the observer is hampered by the varying stages in the illness at which the patient comes under observation; and because of its insidious onset, it usually happens that the cup in glaucoma cases is fairly large when first seen. Most patients are soon operated upon and

FIG. 3.—Cups enlarging in Glaucoma.

No. of Case.	RIGHT EYES.		LEFT EYES.		Remarks.
	First observation.	Second observation.	First observation.	Second observation.	
1*
2*					Choroidal atrophy around discs in second observation.
3*					Ditto.
4*
5					Ditto at both observations.
6					Ditto.
7*

*Only surface area of cup shown in first observation.

TABLE III.—Details of cases in Fig. 3.

No. of Case.	Age.	Size of Cups—percentages.				Time between Observations.
		Right Eye.		Left Eye.		
		First Note.	Second Note.	First Note.	Second Note	
1 <i>a</i> {	68 years	23	36			6½ months
<i>b</i> {	68 "			24	50	4 "
2	60 "	41	62	33	100	11 "
3	55 "	29	53	46	66	12 "
4	59 "	34	57	42	42	4 "
5	68 "	35	50	49	49	5 "
6 <i>a</i> {	58 "	50	55			3 "
<i>b</i> {				48	63	6 "
7	59 "	53	65	51	59	7½ years

the balance of forces at work disturbed; so that these operated cases have to be excluded from the present paper. It is for that reason that Fig. 3 contains so small a proportion of large cups, and so many small cups. But the latter are most valuable as showing the earliest stages of enlargement and their origin in cups quite indistinguishable in size from physiological cups. So that a general conical enlargement in all directions in the earliest stages is at least frequent. It is usually steeper in the nasal half, probably because the fibrous tissue surrounding the retinal vessels offers a strong antero-posterior resistance; it is easier to push this to one side than to push it backwards.

It should be observed that Fig. 4, containing cups showing steps, has only one (Fig. 4, I), which shows a step and no slope, and that this only surrounds half of the cup. So that the cases dealt with in this paper are decidedly against the view that the stepped cup is the usual method by which the glaucomatous cup is evolved. On the other hand, it would appear that steps are more usually minor incidents in the general enlargement of the cup.

The exceptional case of the stepped cup may be explained by the occurrence of a weak superficial layer behind which is a decidedly stronger layer, so that there is a condition analagous to strata of rocks unequal in resistance, in which the soft rocks are worn away and a ledge is formed by the remaining harder layer.

In only one case have I been able to observe the formation of the step; the case is worth mentioning in detail. When first seen, its cup area was 63 per cent., which decreased to 31 per cent. after the use of eserine, and increased to 50 per cent. after a subsequent slight rise of pressure, these alterations being accompanied by corresponding alterations in vision. The 31 per cent. cup was cylindrical, the 50 per cent. cup (seen 8 months later) had a slight

FIG. 4—Glaucoma cases showing steps.

FIG. 5—Chronic glaucoma—Alterations after eserine—step formation.

slope on its inner side, which 5 months later still existed and was prolonged by a narrow step occupying the upper quarter of the cup edge. In this case part of the step formed at a place where there was no slope, either in the 63 per cent. or 31 per cent. cup. But a single observation cannot be made into a rule. Moreover, the 50 per cent. cup has not reached the boundaries of the 63 per cent. cup first observed.

Only once have I seen a ledge completely surrounding a glaucomatous cup; it was observed before the series dealt with in this paper, and must be regarded as exceptional. Direct observation in this supports deduction, for the surface exposed to pressure in the disc cup being greater than the cross section of the cup at the disc surface, the lateral effect is greater than the vertical; therefore it would be unlikely that a ledge would be formed.

Value of cupping in diagnosis

No consideration of the value of a diagnostic sign is complete without both its negative and positive value being considered. Here, as in every other sign, there are limitations both ways. I have seen glaucoma with a 22 per cent. cup, and normal field and vision in an adult with a 70 per cent. cup. Obviously this sign must be taken in conjunction with the other signs of glaucoma, a fate it shares with every other sign of disease, for the pathognomonic sign is merely a snare to catch the feet of the unwary. But, when this is admitted, an enlarged cup in adult life should always arouse suspicion; an enlargement actually observed to occur in cases with no other disease of the disc should be interpreted as the result of pressure, though this may not have affected central vision or the field of vision. It may never go far enough to do this or require treatment, but it should always be taken as a warning.

The cases of glaucoma occurring in cases with comparatively small cups are interesting and merit consideration. Some of the cases shown in Fig. 3 have small cups, but have been chosen because they show growth, not because of their smallness. Reviewing these and other cases, it appears that some are small merely because they are in an early stage. But a large proportion of the cases with small cups seem to have more pain than most chronic glaucoma patients. Sufficient time has not elapsed to follow their course, but these are apparently an intermediate group between chronic and subacute glaucoma. My impression is that they tend to subside quickly after operation, and some to make a complete recovery. It appears to me that these cases which recover may be due to a temporary increase in the viscosity of the ciliary region secretion, which tends to spontaneous recovery.

If relief to the pressure is not given, such cases pass into the group of cases in which the cups are large.

There are two other considerations to which I cannot give an answer :—

(a) Do normal cups ever decrease?

There is no *a priori* reason why they should not in early life, when alterations are questions of growth; but it would not be likely to occur in adult life if the theory advanced in this paper is correct—that the alterations then are due to pressure, for this generally increases or remains stationary at this time. It does not often decrease in cases such as are dealt with in this paper, except under artificial conditions such as operation, or the use of miotics.

(b) Does the possession of a large cup in childhood or youth predicate a larger cup in later life, and, particularly, does it predispose to glaucoma?

Answers to these questions would require observation of particular cases over many years, especially that of the predisposition to glaucoma. But these questions are important when we are dealing with individual cases.

In conclusion I would strongly recommend the drawing of the disc cup being made a routine part of the note-taking of eye cases. Cups vary so much in cross section and depth that it would be possible to arrange a continuous series from a cup hardly recognizable to the largest and deepest, so that terms such as "cupped disc" are vague and meaningless when an attempt is made to translate them into accurate ideas. Doubtless the method suggested in this paper has its limitations, particularly in that it presupposes the ability to draw a simple diagram; but, granted that ability, it is a concise way of expressing the main variations in disc cups and a step in the direction of that exact expression of our observations which should be our constant aim.

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