The optic disc in glaucoma, II: Correlation of the appearance of the optic disc with the visual field

R. A. HITCHINGS

*Department of Clinical Ophthalmology, Institute of Ophthalmology,
Moorfields Eye Hospital, City Road, London, EC1*

G. L. SPAETH

Wills Eye Hospital, Philadelphia, Pa, USA

SUMMARY Examination of stereoscopic optic disc photographs allowed accurate prediction of glaucomatous and normal fields to be made in 82 and 95% of eyes respectively and for visual field loss to be correctly located in upper and lower half in 83 and 91% of cases respectively. Despite this high correlation the existence of false positive and false negative predictions means that the total reliance on optic nerve examination without visual field estimation in the evaluation of the glaucoma patient should *not* be made. Optic disc examination is too insensitive for long-term follow-up of visual function in a glaucoma patient.

The high correlation between the state of the visual field and the optic disc means that, in the evaluation of the visual functions of a glaucoma patient, the appearance of the optic disc and the visual field should be in agreement.

All therapy for glaucoma is directed against visual loss as that aspect of glaucomatous disease which is functionally incapacitating. Sophisticated methods of assessing the field of vision have allowed recognition of the characteristic scotomata that are the early signs of visual damage. Correct evaluation of visual field defects, however, is time consuming and of necessity subjective. Much recent attention has been directed towards the optic disc because of the more objective nature of the observation. As a result attempts have been made to correlate glaucomatous damage visible on the optic disc with change in the visual field in the hope of increasing the understanding of the disease and improving the care of the patient.

In one recent study, using monocular disc photographs, a series of changes at the optic disc were described which were quite reliably associated with visual field loss (Read and Spaeth, 1974). In other studies, where stereoscopic disc photographs (Douglas *et al.*, 1974) or a combination of stereoscopic funduscopy and monocular disc photographs were used (Hoskins and Gelber, 1975), correct pre-

diction of visual field loss was achieved in 85 and 84% of cases respectively.

This paper reports the accuracy of predicting visual field loss from an analysis of stereoscopic disc photographs of 504 eyes from 252 patients. This material has been used as a basis for a previous report (Hitchings and Spaeth, 1976a), where the optic discs were categorised on the basis of their morphological appearance. This report looks at the accuracy of the disc-field correlation for each optic disc category and shows that prediction of the visual field is considerably more accurate for some of these categories than others. Reasons for incorrect visual field prediction are analysed. It is concluded that disc-field correlation is insufficient to allow reliance on examination of the optic disc alone in the management of glaucoma, but when visual function of a glaucoma patient is being evaluated the appearance of the optic disc and visual field should be in agreement.

Materials and Methods

The stereo photographs from 252 patients (504 eyes) were used. The population comprised 227 patients whose intraocular pressure was consistently greater than 21 mmHg and 25 patients ophthalmologically normal. The stereo pairs were examined without the

This investigation was supported by the National Institute of Health Research Grant No. EY0067704 from the National Eye Institute

Address for reprints: Mr R. A. Hitchings, Moorfields Eye Hospital, City Road, London EC1V 2PD

diagnosis being known. The opposite eye of the same patient was available for comparison, providing a test not dissimilar from routine clinical evaluation. Visual field loss was predicted when marked thinning, total absence, or localised pallor of the neuroretinal rim was observed. A fuller analysis of these features has already been discussed (Hitchings and Spaeth, 1976a). The location of visual field defects was based on the known spatial localisation of nerve fibres in the retina and optic papilla (Traquair, 1944; Hoyt and Luis, 1962; Wolff, 1968; Read and Spaeth, 1974; Lynn, 1975). Visual field defects were placed in the upper or lower half of the visual field by observing those signs suggesting field loss on the corresponding lower or upper half of the optic disc.

The predicted field was compared with the actual

Table 1 *Correlation of visual field with optic disc type: (a) Eye with visual field loss*

<i>Optic disc type</i>	<i>Total no. eyes</i>	<i>Actual no. with field loss</i>	<i>No. of eyes correctly predicted to have visual field loss</i>	<i>False - ve</i>
Cupping without neuroretinal rim pallor	124	22	12	2
Overpass	44	14	11	1
Cupping with neuroretinal rim pallor	68	60	58	6
Focal notching of the neuroretinal rim	23	23	23	0
Bean-pot	14	13	13	0
Total no. eyes with visual field loss		132	117	82%

Table 2 *Correlation of visual field with optic disc type: (b) Eye with a normal visual field*

<i>Optic disc type</i>	<i>Total no. eyes</i>	<i>No. with normal field</i>	<i>No. of eyes correctly predicted to have a normal field</i>	<i>False + ve</i>
Normal	231	231	231	0
Cupping without neuroretinal rim pallor	124	102	102	8
Overpass	44	30	29	3
Cupping with neuroretinal rim pallor	68	8	2	4
Bean-pot	14	1	1	0
Total no. eyes with normal field		372	365	95%

field obtained on the same day as the photographs. The actual field was plotted on a Goldmann perimeter, 3 isopters being measured in a standardised fashion. The method has been fully described elsewhere (Spaeth, 1975) and is based on that described by Rock *et al.* (1973).

Results

82% of eyes with visual field loss and 95% of eyes with normal fields were correctly identified. Correct location of a visual field defect to the upper or lower half of the field was achieved in 83.5 and 91% of eyes respectively. The results of comparing eyes with and without visual field loss with optic disc 'types' may be seen in Tables 1 and 2 respectively. It will be seen that 'focal notching' in the neuroretinal rim was always associated with visual field loss. Fig. 1 is a

Fig. 1 *Stereophotograph illustrating 'focal notching', an inferotemporal notch, or extension of the cup, is present (arrowed). Adequate visualisation of these stereo-pairs may be obtained by holding a suitable convex sphere in front of each eye, de-centred sufficiently to give fusion*

Fig. 2 Stereophotograph illustrating 'cupping with pallor' (arrowed) in a patient with an inferior arcuate scotoma

stereophotograph of an optic disc with focal notching that had a corresponding upper arcuate scotoma. The detection of 'pallor' on the neuroretinal rim in conjunction with glaucomatous cupping was also a good indicator of visual field loss. 58 of the 60 eyes classes as 'cupping with pallor' were correctly predicted to have visual field loss. Fig. 2 is a stereophotograph of an eye demonstrating cupping with pallor that had visual field loss. The prediction of visual field defects was less accurate in those eyes with 'cupping without pallor'; whereas glaucomatous cupping with localised absence of the neuroretinal rim would always be associated with a corresponding field defect, thinning of the neuroretinal rim without obvious pallor was often seen without field loss. (Fig 3 is a stereophotograph of an eye with localised absence of the neuroretinal rim at the upper pole and thinning of the neuroretinal rim without pallor at the lower pole.) Out of 22 eyes demonstrating cupping without pallor only 12 were correctly stated to have field loss.

Table 3 correlates the predicted location of field defects in the upper and lower halves of the visual field with optic disc type. It may be seen that most errors occurred with the optic discs designated 'cupping with' and 'cupping without pallor' of the neuroretinal rim.

Discussion

It is proposed to look at features in the optic disc suggesting visual field loss and discuss possible sources of error.

FEATURES SUGGESTING VISUAL FIELD LOSS

Glaucomatous enlargement of the optic cup frequently follows a pattern of vertical extension of the orifice of the cup (Chandler and Grant, 1965; Kronfield, 1967; Kirsch and Anderson, 1973; Wiseman *et al.*, 1973). Deepening of the cup (Portnoy, 1975) with an increase in the steepness of the walls may also be present. All these factors con-

Fig. 3 Stereophotograph illustrating localised absence of the neuroretinal rim at the upper pole (white arrows) and localised thinning of the neuroretinal rim at the lower pole (dark arrows) in an eye with upper and lower scotomata

Table 3 Correlation of location of visual field loss with optic disc type

Optic disc type	Upper half field loss			Lower half field loss		
	Actual field loss (103 eyes)	No. of eyes correctly predicted to have field loss (89 eyes, 83.3%)	False + ve	Actual field loss (68 eyes)	No. of eyes correctly predicted to have field loss (62 eyes, 91%)	False + ve
Cupping without pallor of the neuroretinal rim	16	12	0	14	8	0
Overpass cupping	7	7	1	9	8	0
Cupping with pallor of the neuroretinal rim	48	38	13	40	40	6
Focal notching	23	23	0	0	0	0
Bean-pot cupping	9	9	0	5	6	1

tribute to an increase in the total volume of the cup (Portnoy, 1975) without there necessarily being extensive loss of neuroretinal rim. Such changes are recognisable before detectable field loss (Kronfeld, 1967; Fishmann, 1970; Kolker and Hetherington, 1970; Portnoy, 1975). The prediction of field loss in a glaucomatous eye was based on identifying sites from which neuroretinal rim tissue had been lost. This was seen as thinning, absence, or pallor of the neuroretinal rim tissue.

The results obtained in this study show a very high correlation between observation of these signs on the neuroretinal rim of the optic disc and visual field loss. The figures of 82% of discs with and 95% without field loss are in general agreement with studies carried out by Douglas *et al.* (1974) and Hoskins and Gelber (1975), who correctly forecast 85 and 84% of discs with field loss and 80 and 97% without field loss respectively. These figures are *not* good enough to place total reliance on optic disc examination to the exclusion of visual field testing when evaluating a glaucoma patient.

The correct location of field defects in upper and lower halves of the visual field was achieved in 83.5 and 91% of eyes respectively. More precise location of defects within the visual field based on optic disc examination would be subject to far greater error, because of the difficulty in equating small field defects with a specific area on the neuroretinal rim. Reliance on optic disc morphology alone for long-term management would be quite insufficient, as minor changes in the visual field would not be likely to cause visible change on the neuroretinal rim of the optic disc; the false positive and negative readings could induce overtreatment and the withholding of treatment respectively in some cases.

SOURCES OF ERROR

The accuracy of spotting visual defects by evaluation

of the optic disc is sufficiently high to warrant a closer look at the sources of error. Evaluation of possible errors point to three major sources. Firstly, errors inherent in the methods used to examine the visual field and optic disc. Secondly, non-glaucomatous causes for visual field loss. Thirdly, the variable response of the optic nerve in glaucoma.

Errors in clinical examination

Errors inherent in visual field examination are notorious. This is particularly important with the early isolated scotomata that occur in glaucoma, and may have contributed to some of the incorrect predictions in this series. Visual field testing is an art, 'requiring a degree of psychic evaluation that will determine the validity of its findings' (Harrington, 1975).

Magnified stereophotographs of the optic disc provide a good and accurate method of recording detail. However, some detail is lost. The photographs are not true stereoscopic photographs, as they are taken consecutively, and an erroneous impression of the shape of the optic cup may occur because of eye movements and/or variations in the separation of the camera angle.

Examination of the stereo pairs is open to human error with subtle glaucomatous changes being overlooked. In several instances, repeat examination of the optic disc, on this occasion with knowledge of the visual field, allowed recognition of those signs described above that suggest visual field loss.

The wide field of illumination that occurs with fundus photography allows light from the peripapillary choroid to 'colour' adjacent disc tissue (Gloster and Parry, 1974). In a few eyes where the neuroretinal rim appeared pink on the fundus photograph slit-lamp examination of the optic disc using a narrow light beam revealed localised pallor. These instances accounted for some of the failures to predict the existence of a field defect in this study.

Fig. 4a Stereophotograph illustrating 'bean-pot' cupping. Notice relative thickness of neuroretinal rim at upper and lower poles (arrowed).

Fig. 4b Corresponding visual field

Non-glaucomatous causes for visual field loss

Coexistent chorioretinal and neurological disease may cause visual field defects. Three such cases were present in the series where the defects in the visual field were not reflected by concomitant glaucomatous changes at the optic disc.

Variations in the response of the optic nerve in glaucoma

In this series the eyes observed to have 'focal notching' (Hitchings and Spaeth, 1976a) in the neuroretinal rim were always found to have an associated defect in the visual field. In these eyes the neuroretinal rim appeared normal except in the affected sector, where it was considerably thinned. The discovery of a localised notch despite a 'normal' field merits searching the visual field until the glaucomatous defect is found.

In the eyes with evidence of a more generalised enlargement of the optic cup associated with a region of pallor on the neuroretinal rim ('cupping with pallor') a defect could usually be found in that part of the visual field corresponding with the pale sector of the rim. However, a small proportion of eyes in this group did *not* have a recordable field defect to correspond with the pale sector. This may reflect inadequate visual field testing, itself a coarse method for assessing visual function or an incorrect assumption that pallor always means atrophy. Neuroretinal rim pallor is commonly associated with hypofluorescence, but small areas of hypofluorescence of the neuroretinal rim do not always have an associated visual field defect. (Hitchings and Spaeth, 1976b).

The greatest difficulty in predicting the state of the visual field from examination of the optic disc came

from the group entitled 'cupping without pallor.' This group is important because it contains optic discs similar in appearance to the optic discs whose optic cups decreased in volume following control of intraocular pressure (Kolker and Hetherington, 1970; Armaly, 1975), suggesting 'regression' of the optic nerve disease.

As has already been discussed, a proportion of optic discs demonstrating cupping without pallor may be seen on slit-lamp examination to have sector pallor of the neuroretinal rim to correspond with the visual field defect. This is one reason why slit-lamp examination is an essential part of the glaucoma examination. Even with slit-lamp examination difficulty arises in recognising morphological changes in the pink neuroretinal rim that are of sufficient severity to be associated with loss of visual field.

In an individual case a large optic cup is not necessarily a sign of visual field loss. A large optic cup may be developmental and reflect a greater than usual diameter of the optic disc. Because the neurones comprising the neuroretinal rim are relatively constant in number, they have a constant cross-sectional area. The greater the optic disc diameter the larger the cup and proportionately smaller the neuroretinal rim.

In normal individuals a large optic cup in one eye is mirrored by a similarly sized cup in the fellow eye (Hitchings and Spaeth, 1976a). Acquired enlargement of the optic cup (Hitchings and Spaeth, 1976a) may be detected before visual field loss and may simultaneously affect the orifice, walls, and floor. The optic cup can form a large proportion of the volume of the intraocular part of the optic nerve before field loss is demonstrated. The most extreme example is seen in eyes with 'bean pot' cupping, where, although the cup may be very large, the amount of visual field loss appears disproportionately small (Fig. 4). In these cases such localised thinning or absence of the neuroretinal rim

provides a clue to possible field loss. In the one eye within the series reported with a normal field despite 'bean pot' cupping the neuroretinal rim appeared of similar thickness and uniform colour throughout. The 'undermining' of the neuroretinal rim that exists in these optic nerves is not an indicator of visual field loss. At what stage it is associated with field loss cannot be ascertained as it is hidden behind the neuroretinal rim.

In eyes with 'cupping without pallor' the optic disc will show acquired enlargement of the cup. Clues to the state of the visual field are found in variations in neuroretinal rim thickness rather than the slope of the walls or the depth of the optic cup. Careful examination of the contours of the neuroretinal rim will suggest the presence or absence of visual field loss. If there is no visual field defect the neuroretinal rim will appear to be of equal thickness throughout or show gradual variations rather than abrupt changes in thickness when passing from one part of the rim to another (Fig. 5). When a visual field defect is present, the neuroretinal rim will often demonstrate abrupt changes in thickness when passing from one part of the rim to the next. In this instance it is the thin neuroretinal rim, sharply demarcated from adjacent, thicker rim, that has a corresponding visual field defect. (Fig. 6). Despite recognition of these sources of error there remain a few optic discs in eyes with visual field defects that do not show clear-cut changes suggesting visual field loss.

Ancillary evidence comes from examination of the nerve fibre layer. When the layer is visibly intact, the field is normal. When it is possible to detect localised defect in the reflexes arising from the nerve fibre layer, a corresponding defect in the visual field can frequently be detected. Many eyes with glaucoma, however, will have complete depression of reflexes arising from the nerve fibre layer despite full field or localised defects (Hitchings and Spaeth, 1976a).

Fig. 5 Stereophotograph illustrating cupping without pallor. In this case the visual field was normal, the neuroretinal rim shows gradual variations in thickness only

Fig. 6 Stereophotograph illustrating cupping without pallor, in this case the neuroretinal rim shows sudden thinning at the lower pole (arrowed) corresponding with the upper half visual field defect

Conclusion

Careful examination of magnified stereo-pair photographs of the glaucomatous disc allows accurate prediction of the presence and absence of visual field loss. The error rate was too high to permit exclusion of visual field examination in the evaluation of a patient with glaucoma, and insufficiently sensitive for long-term follow-up. However, the existence of a good disc-field correlation means that the evaluation of the glaucoma patient is incomplete without ensuring agreement between the appearance of the optic disc and state of the visual field.

References

- Armaly, M. (1975). In *Proceedings of an International Glaucoma Symposium*, p. 155, ed. R. Etienne and G. L. Paterson. Lyon, Vaulx-en-Valin.
- Chandler, P. A., and Grant, W. M. (1965). *Lectures on Glaucoma*, ch. 1. London, Kimpton.
- Douglas, G. R., Drance, S. M., and Schulzer, M. (1974). *Canadian Journal of Ophthalmology*, **9**, 391.
- Fishmann, R. S. (1970). *Archives of Ophthalmology*, **84**, 590.
- Gloster, J. G., and Parry, G. (1974). *British Journal of Ophthalmology*, **58**, 50.
- Harrington, D. O. (1975). *American Journal of Ophthalmology*, **80**, 414.
- Hitchings, R. A., and Spaeth, G. L. (1976a). *British Journal of Ophthalmology*, **60**, 778.
- Hitchings, R. A., and Spaeth, G. L. (1976b). *British Journal of Ophthalmology* (in press).
- Hoskins, H. D., and Gelber, E. C. (1975). *American Journal of Ophthalmology*, **80**, 284.
- Hoyt, W. F., and Luis, O. (1962). *Archives of Ophthalmology*, **68**, 94.
- Kirsch, R. F., and Anderson, D. R. (1973). *American Journal of Ophthalmology*, **75**, 42.
- Kolker, A. E., and Hetherington, J. (1970). *The Diagnosis and Therapy of Glaucoma*, p. 131. St Louis, Mosby.
- Kronfeld, P. C. (1967). In *Proceedings of a Symposium on Glaucoma*, p. 62. St Louis, Mosby.
- Lynn, J. R. (1975). In *Proceedings of a Symposium on Glaucoma*, p. 151. St Louis, Mosby.
- Portnoy, G. L. (1975). *American Journal of Ophthalmology*, **80**, 51.
- Read, R. H., and Spaeth, G. L. (1974). *Transactions of the American Academy of Ophthalmology and Otolaryngology*, **73**, 225.
- Rock, W. J., Drance, S. M., and Morgan, R. W. (1973). *Archives of Ophthalmology*, **89**, 287.
- Spaeth, G. L. (1975). *Transaction of the American Ophthalmological Society*, **63**, 491.
- Traquair, H. M. (1944). *Transactions of the Ophthalmological Society of the United Kingdom*, **64**, 3.
- Wiseman, R. L., et al. (1973). *Transactions of the American Academy of Ophthalmology and Otolaryngology*, **77**, 157.
- Wolff, E. (1968). *The Anatomy of the Eye and Orbit*, p. 130. London, Lewis.