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The Bedford Glaucoma Survey

I. Long-term follow-up of borderline cases

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In a survey carried out between 1964 and 1966, 5,941 persons over the age of forty living in Bedford were screened for glaucoma. The ocular tensions were measured with the Goldmann applanation tonometer by a technician and the subjects were then seen by an ophthalmologist, who took a brief ocular history and family history and carried out an external examination and ophthalmoscopy. Subjects were referred for more detailed examination if the tension was 21 mm. Hg or more, if the optic discs appeared abnormal, and if there was a history of haloes or a family history of glaucoma. 55 cases of primary glaucoma (0·93 per cent.) were detected as a result of the survey and a further 212 persons were advised to return annually for further examination (Bankes, Perkins, Tsolakis, and Wright, 1968). 190 of these attended on more than one occasion, and this paper presents our findings after following 141 subjects for a period of 5 to 7 years.

The reasons for follow-up were ocular hypertension, suspicious optic discs, a family history of glaucoma, symptoms of haloes, or a combination of these factors. The diagnostic categories were defined as follows:

OCULAR HYPERTENSION

An ocular tension of 21 mm. Hg or above by applanation tonometry, in the absence of glaucomatous field defects and with no evidence of angle closure.

CHRONIC SIMPLE GLAUCOMA

An ocular tension of 21 mm. Hg or above by applanation tonometry on two or more occasions, glaucomatous cupping of the disc, and visual field defects typical of glaucoma, and with no evidence of angle closure.

LOW TENSION GLAUCOMA

As for chronic simple glaucoma, except that the ocular tension is persistently less than 21 mm. Hg by applanation tonometry.

CLOSED-ANGLE GLAUCOMA

A clear history of haloes typical of corneal oedema with gonioscopic evidence of a narrow angle capable of closure; *or* an ocular tension of 21 mm. Hg or above in the presence of obstruction of the angle by the root of the iris.

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Methods

At each annual examination the ocular tension was measured by applanation tonometry, the peripheral fields were assessed using a perimeter, and the central fields were plotted using the Globuck apparatus (Buchanan and Gloster, 1965). These tests were performed by glaucoma technicians and the results inspected by an ophthalmologist.

Any person who developed ocular symptoms, a field defect, or a rise in tension, was examined by an ophthalmologist and, if this was indicated, referred for a complete investigation in the Glaucoma Clinic at the Institute of Ophthalmology. If the reason for follow-up was a suspicious disc the follow-up examination was carried out by an ophthalmologist.

Results

The present situation is shown in Table I, from which it can be seen that over half have been discharged, one-quarter have failed to complete the follow-up, five cases of primary glaucoma and four cases of secondary glaucoma have been diagnosed, and thirty persons are still being followed up.

Table I *Follow-up of* 190 *borderline cases*

Follow-up	*No. of cases*	*Per cent. of total*
Discharged	102	53·68
Follow-up incomplete	49	25·79
Primary glaucoma	5	2·63
Secondary glaucoma	4	2·11
Follow-up continuing	30	14·74
Total	190	—

DISCHARGES

After some 3 years of the follow-up study, it became apparent that there was a marked tendency for the ocular tension to be slightly lower at each annual examination, and many people in whom the tension in one or both eyes had been 21 mm. Hg or more now had tensions of less than 21 mm. Hg with no other signs of glaucoma. It was decided therefore that, if the ocular tensions remained below 21 mm. Hg at two or more annual examinations, further follow-up was unnecessary. Similarly, subjects who were being followed up only because of a family history of glaucoma were discharged after a period of 3 years if there had been no change in ocular tension, visual fields, or the appearance of the disc.

Details of the reason for follow-up in cases discharged are shown in Table II. The ocular hypertensives who were discharged had had tensions below 21 mm. Hg for more than 2 years (mean 2·65 years). The mean tension reading from the eyes with the highest tension on screening in this group had been 22·93 mm. Hg (S.E. = 0·643). The highest tension was 30 mm. Hg. The distribution of tensions is shown in Fig. 1.

The patient with the highest tension had thyrotoxicosis with exophthalmos at the time of screening and also complained of intermittent vertical diplopia. After treatment of the thyrotoxicosis the tensions remained below 21 mm. Hg.

INCOMPLETE FOLLOW-UP

In most cases it was not possible to ascertain why follow-up appointments were not kept, but three people were known to have died, two were too ill to attend, and at least five

Table II *Reason for follow-up in cases discharged*

Findings	*No. of cases*	*Per cent. of total*
Ocular hypertension	81	79·41
Ocular hypertension and family history	5	4·90
Ocular hypertension and suspicious disc	1	0·98
Suspicious disc	7	6·86
Family history	4	3·92
Haloes	2	1·96
Other*	1	0·98
Total	102	

*This patient was discharged although the tensions were 24 mm. Hg because she was old and disabled.

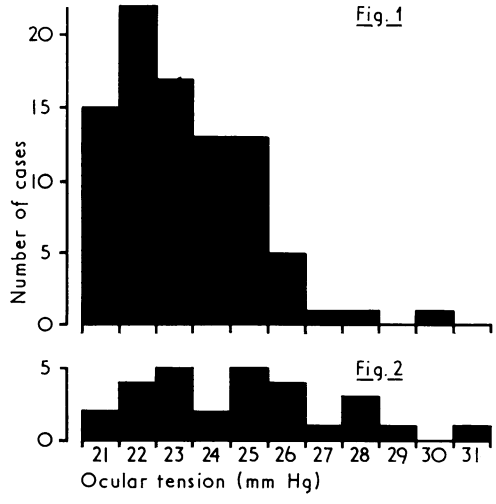

FIG. 1 *Distribution of initial tensions of cases discharged from follow-up*

FIG. 2 *Distribution of initial tensions of cases still being followed up*

Table III *Reason for follow-up where this was not completed*

Findings	*No. of cases*	*Per cent. of total*
Ocular hypertension	43	87·76
Ocular hypertension and suspicious disc	3	6·12
Ocular hypertension and family history	2	4·08
Family history	1	2·04
Total	49	

had moved to an unknown address. The reasons for follow-up in this group are shown in Table III.

PRIMARY GLAUCOMA

Details of these five cases are shown in Table IV (overleaf). No. 2931 represents a mistake in assessment during the original survey. The patient was noted to have a suspicious disc

Table IV *Five cases of primary glaucoma*

Case no.	*Age at first examination (yrs)*	*Sex*	*Presenting features*	*Length of follow-up*	*Further course*
1788	57	M	Tension R. 23, L. 23 mm. Hg Discs normal Tonography (C) R. 0·16, L. 0·10	7 yrs 7 mths	Tension readings between 20 and 23 mm. Hg Slight changes R. disc with early field defect Positive water-drinking test R
2931	78	F	Tension R. 18, L. 17 mm. Hg Suspicious L. disc Lens changes Field defects ? defects due to poor concentration Tonography (C) R. 0·29, L. 0·24	3 yrs	Tensions R. 25, L. 22 mm. Hg Definite glaucomatous cupping with field loss
4692	64	M	Tensions R. 26, L. 24 mm. Hg Discs normal No field defect Tonography (C) R. 0·22, L. 0·19	4 yrs 9 mths	Tensions R. 22, L. 22 mm. Hg Early cupping of discs ? Small arcuate scotoma
5063	59	F	Tensions R. 27, L. 28 mm. Hg Discs normal No field defect Tonography (C) R. 0·24, L. 0·25	6 yrs	Tensions R. 22, L. 20 mm. Hg Early cupping R. disc with early field defect
90109	51	F	Tensions R. 23, L. 23 mm. Hg Suspicious discs No field defect demonstrated Tonography (C) R. 0·16, L. 0·12	4 yrs 1 mth	Tensions R. 22, L. 20 mm. Hg Early cupping with field defects

in the left eye, but the ocular tensions were R. 18, L. 17 mm. Hg. Her age was 78 years and field tests suggested some defect, but her concentration was poor and she had senile lens changes which were thought to explain the field defects. Tonography revealed coefficients of outflow of R. 0·29, L. 0·24. She was referred back to the clinic 3 years later by an ophthalmologist and at this time her tensions were R. 25, L. 22 mm. Hg, both discs showed pathological cupping, and there were definite glaucomatous field defects in both eyes.

Three of the other four cases of chronic simple glaucoma had presented with ocular hypertension only, and one had ocular hypertension with suspicious discs. Definite glaucoma, as evidenced by cupping of the disc and field defects, developed over periods of 4 to 7 years. The coefficient of outflow was normal in two cases and borderline in the other two at the commencement of follow-up.

It is interesting that the sporadic tonometric readings showed no tendency to rise during the follow-up period (except in No. 2931), and yet disc and field changes developed. No. 2931, who almost certainly had glaucoma at the time of screening, did not show a raised tension at that time and should have been classified as having low tension glaucoma; 3 years later the tensions were over 21 mm. Hg. The overall incidence of chronic simple glaucoma in the 141 subjects followed up satisfactorily was five (3·54 per cent.). No cases of closed-angle glaucoma have been diagnosed.

SECONDARY GLAUCOMA

Details of the four cases classified as having secondary glaucoma are shown in Table V. It was not possible to exclude an element of chronic simple glaucoma in No. 5160, but in view of his age, and his poor central vision but full peripheral fields, treatment was not advised.

Table V *Secondary glaucoma*

Case no.	*Age at first examination (yrs)*	*Sex*	*Presenting features*	*Length of follow-up*	*Further course*
5160	74	M	Tensions R. 23, L. 23 mm. Hg Suspicious discs Central field defects Macular degeneration History neuro-syphilis	1 yr 3 mths	No change Peripheral fields full
4872	62	F	Tensions R. 22, L. 22 mm. Hg Widespread old disseminated chorioretinitis ? Congenital syphilis	4 yrs 4 mths	No change
930	63	F	Tensions R. 34, L. 23 mm. Hg Bilateral uveitis	2 yrs 11 mths	Tensions reduced below 21 mm. Hg after course of treatment for uveitis
1055	45	M	Tensions R. 20, L. 23 mm. Hg Old injury left eye with iridodialysis	7 yrs 3 mths	Tensions R. 20, L. 21 mm. Hg No field defect

CONTINUING FOLLOW-UP

The reasons for follow-up in these thirty cases are shown in Table VI. All are being seen in the Glaucoma Clinic at the Institute of Ophthalmology. Two of the patients who

Table VI *Reason for follow-up where this is being continued*

Findings	*No. of cases*	*Per cent. of total*
Ocular hypertension	23	76·67
Ocular hypertension and suspicious disc	3	10·00
Ocular hypertension and family history	2	6·67
Family history	2	6·67
Total	30	

presented with ocular hypertension are thought to have early chronic simple glaucoma; one has a positive water-drinking test and the discs are thought to show early cupping, but no field defect can be demonstrated. The other developed a partial retinal vein thrombosis in one eye and is being treated with miotics, although no definite glaucomatous field defect has been demonstrated.

The mean tension from the eyes with the highest tension on screening in this group had been 24·75 mm. Hg (S.E. = 0·48). The highest tension was 31 mm. Hg and the distribu-

tion of tensions is shown in Fig. 2 (see p. 181). The patient with the initial tension of 31 mm. Hg has a positive water-drinking test and early cupping. The other patient with probable early chronic simple glaucoma had a tension of 25 mm. Hg on initial examination.

Discussion

One of the main purposes of this follow-up study has been to see whether ocular hypertension is a precursor of chronic simple glaucoma. In any screening in which tonometry is used, some 5 per cent. of the population will be found to have tensions of 21 mm. Hg or more. The follow-up of these cases is time-consuming and expensive in terms of skilled personnel and it is therefore important to know whether they are likely to develop glaucoma and after what time interval.

Linnér and Strömberg (1967) re-examined 152 people with ocular hypertension 5 years after their original survey, and found that three had developed field loss and cupping of the disc—an incidence of glaucoma of 2 per cent. Leydhecker (1967) found that 26 of fifty ocular hypertensives developed field defects after 7 years, but there is some doubt whether the field defects were glaucomatous in character. Graham (1968) re-examined 195 ocular hypertensives after nearly 4 years and found only one with a glaucomatous field defect (0·5 per cent.). Armaly (1969) similarly found that, of 198 individuals with an initial tension of more than 23 mm. Hg, only one developed a glaucomatous field defect.

In the present study 124 ocular hypertensives have been followed up for 5 to 7 years, and four have developed chronic simple glaucoma (3·23 per cent.). This is a higher incidence than that found in the original population screened (42 out of 5,941 : 0·71 per cent.), and the difference is statistically significant ($\chi^2 = 10{\cdot}2$; $P<0{\cdot}0025$). If the two cases still under observation who are thought to have early chronic simple glaucoma without definite field loss are included, the incidence rises to six out of 124 (4·84 per cent.; $\chi^2 = 26{\cdot}2$; $P<0{\cdot}00025$). One further case of chronic simple glaucoma diagnosed on follow-up did not have ocular hypertension on screening but was noted to have suspicious discs.

If the ocular hypertension is associated with suspicious signs at the optic disc there is a greater likelihood that glaucoma will develop. Of six cases of ocular hypertension with suspicious discs followed up, one developed chronic simple glaucoma; one further case of glaucoma, as mentioned above, was diagnosed from nine followed up with suspicious discs, but without ocular hypertension, on screening. Thus two out of fifteen persons found to have suspicious discs on screening later developed chronic simple glaucoma (13·3 per cent.).

In the original survey, twenty of the 45 cases of open-angle glaucoma diagnosed were thought to have suspicious discs on screening. However, the remaining 25 cases would not have been detected by ophthalmoscopy alone. It could be argued that as all these cases were judged to have cupping of the disc on more careful examination, all 45 could have been detected at the screening stage by ophthalmoscopy alone, and Walker (1967) has used this successfully as a screening method. The recognition of early glaucomatous cupping demands considerable experience, however, and unless reliable objective methods can be developed it is not a screening technique which could be used by a glaucoma technician.

The height of the tension on screening bears some relationship to the development of glaucoma; the higher the tension the greater the probability of glaucoma (Perkins, 1967).

In the present study, two of the cases of glaucoma had tensions over 25 mm. Hg and in the original survey 58 per cent. of all glaucoma cases diagnosed had tensions above 25 mm. Hg on screening. The two patients still on follow-up as suspected early chronic simple glaucoma also had initial tensions of 25 mm. Hg or more. However, two of the patients with glaucoma had tensions below 25 mm. Hg on screening.

The three glaucoma patients whose only abnormality on screening was ocular hypertension developed field changes 5, 6, and 7 years respectively after screening, so that it is probably not necessary to re-examine ocular hypertensives at yearly intervals. None of the fifteen with a family history of glaucoma has so far developed the disease.

The results of this follow-up study suggest that the risk of field defects developing over a 5-year period in patients with moderate degrees of ocular hypertension is small; it seems justifiable therefore to withhold anti-glaucomatous therapy until field defects can be demonstrated.

Summary

A 5 to 7-year follow-up of 141 persons referred from a glaucoma survey because of ocular hypertension, suspicious discs, or a family history of glaucoma, showed that only five (3·54 per cent.) developed glaucoma. Three had presented with ocular hypertension alone, one with ocular hypertension and a suspicious disc, and one with a suspicious disc without hypertension. Two further cases of chronic simple glaucoma are still being investigated, and if these cases are included the probable incidence of glaucoma in this series is 4·39 per cent.

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