Detection of Undiagnosed Glaucoma by Eye Health Professionals

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Purpose: To examine the clinical features of undiagnosed open-angle glaucoma (OAG) in people who have attended an eye care provider within the previous 12 months and to suggest strategies to assist in the early detection of glaucoma.

Design: Population based cross-sectional study.

Participants: Permanent residents aged 40 years and older at recruitment during 1992 through 1996.

Methods: A cluster-stratified random sample of 4744 participants from the urban and rural cohorts was studied. Structured standardized interviews and dilated ocular examinations were conducted in all eligible participants. Data on demographic characteristics, prior knowledge of eye disease, use of eye care services, intraocular pressures, cup-to-disc ratios, visual fields, and photography of optic discs were obtained. All suspected glaucoma cases were submitted to a panel of 6 ophthalmologists to determine glaucoma diagnosis.

Main Outcome Measures: Clinical features of participants seen by eye health professionals within the previous 12 months who have previously undiagnosed OAG, previously diagnosed OAG, and no glaucoma.

Results: Thirty-five previously undiagnosed and 43 previously diagnosed participants had visited an optometrist or ophthalmologist or both in the previous 12 months. Age and gender were not significantly different between the undiagnosed and diagnosed glaucoma cases. After logistic regression, the type of eye professional seen (odds ratio [OR], 45.17; 95% confidence interval [95% CI], 5.89–346.17; $P = 0.0002$) and the presence of visual field defects (OR, 0.06; 95% CI, 0.01–0.69, $P = 0.020$) were the only statistically significant variables between the diagnosed and undiagnosed glaucoma groups.

Conclusions: Raised intraocular pressure should not be relied on as the only triggering factor in glaucoma investigations. *Ophthalmology 2004;111:1508–1514 © 2004 by the American Academy of Ophthalmology.*

Open-angle glaucoma (POAG) is one of the leading causes of irreversible visual loss[1–5] in Western society, with a prevalence of 1.1% to 3.0%.[3,6–12] The number of people with glaucoma in the world is estimated to be 67 million, of whom 7 million were bilaterally blind in year 2000.[2] However, more than 50% of those in developed countries with glaucoma are unaware of their disease.[2] To reduce visual impairment and thus loss of independence in the aging population, detection of OAG is of utmost importance.

As in many other published studies,[2,6,13] the Visual Impairment Project (VIP) found a large proportion of previously undiagnosed cases of glaucoma.[12,14] Of concern though is the presence of undiagnosed OAG in people who had visited an eye care provider in the previous year. The aim of this study was to examine, from a population-based sample, the factors that may contribute to the failure of glaucoma detection by eye health professionals.

Materials and Methods

The VIP was a population-based study of the prevalence, cause, and impact of eye diseases in adults age 40 years and older, who had resided at their current address for more than 6 months at the time of recruitment. It used a cluster-stratified sampling technique in which participants were drawn from 9 randomly selected pairs of adjacent census collector districts in urban Melbourne and 4 rural communities in Victoria. A door-to-door private census identified all residents eligible to participate in the study, and all eligible individuals were invited to complete an interview and examination at a local center. Interpreters were used when participants did not speak English, and home visits were conducted when participants were unable to attend the local examination center. The Royal Victorian Eye and Ear Hospital Human Research and Ethics Committee approved the study in accordance with the Declaration of Helsinki for research involving human subjects. All participants gave informed consent before interview and examination. A detailed description of the methodology of this study was reported elsewhere.[15]

In a structured interview, data regarding the participant's demographic characteristics, medical history, medication use, history

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of eye disease, visual symptoms, and use of optometry and ophthalmology services were elicited. Slit-lamp examination was performed to screen for eye diseases, including pseudoexfoliation syndrome. Dilated ocular examination by a trained clinician using a standardized protocol, with 1 drop of tropicamide (0.5%) and 1 drop of phenylephrine hydrochloride (10%), was performed in all participants. Fundus examination was then carried out with a slit lamp and a +90 diopter lens, measuring the vertical cup-to-disc (C/D) ratio. Paired stereo photographs of the optic disc and macula were taken with a Topcon TRC FET retinal camera (Topcon Corporation, Tokyo, Japan).

Visual field testing was performed with a Humphrey Field Analyzer with the 24-2 Fastpac statistical package (Humphrey Instruments Inc., San Leandro, CA). If the participant was unable to complete threshold visual field testing, a Bjerrum tangent screen visual field test was performed. When this was unobtainable, a confrontation field was used. The results of Humphrey visual field testing were inspected for reliability at the time of examination, and unreliable tests were repeated or alternative visual field tests were done. Test results on the Humphrey Field Analyzer were considered inadequate for use in data analysis if there were >20% of fixation losses or >33% of either false-positive or false-negative errors. All participants with diagnosed and undiagnosed glaucoma had Humphrey visual field testing.

Intraocular pressure (IOP) was measured with the Tono-Pen (Oculab, Calendale, CA) after the instillation of oxybuprocaine hydrochloride (0.4%) in each eye. When the confirmed result was 21 mmHg or more, a Goldmann applanation tonometer was used. The IOP obtained by Goldmann applanation tonometer was then recorded. Pachymetry was not included as part of glaucoma assessment, because its significance was unknown at the time of study (1992 to 1996).

Glaucoma suspects were defined as participants who had one or more increased IOPs of >21 mmHg, a glaucomatous visual field defect, vertical C/D ratio of more than 0.7 in either eye, C/D ratio asymmetry of more than 0.3, or anyone who reported a history of glaucoma. Photographs of optic disc and examination records of glaucoma suspects were submitted to a panel of 6 ophthalmologists, 2 of whom were glaucoma subspecialists, for evaluation. Initially, members of the panel individually appraised all the masked optic disc photographs and then the masked visual field printouts for the likelihood of glaucoma. Once completed, all the optic disc photographs and visual field printouts were unmasked, and each ophthalmologist was subsequently provided with the relevant history and the results of full ocular examination to reevaluate and determine the presence of OAG on the basis of all the presented clinical features.

Suspected glaucoma cases were classified as definite, probable, or possible OAG, ocular hypertension, primary angle-closure glaucoma, secondary glaucoma, and no glaucoma. Each ophthalmologist used his or her own clinical judgment to classify each eye of each case. Cases with significant discrepancies between panel members were resolved in open discussion. Definition of glaucoma was by the worse eye. The use of 3 grades of glaucoma definitions in this study was to allow for some of the difficulties faced in the diagnosis of glaucoma. We believe that few eye health practitioners would argue with the diagnosis of glaucoma in the definite glaucoma category, whereas some inconsistency in diagnosis might be observed in probable cases. Large discrepancies in diagnosis might exist in possible cases and were thus not included in the analysis of this study.

Participants with probable or definite glaucoma, either previously diagnosed or undiagnosed, and those with no glaucoma who had been seen by eye care professionals within the last 12 months were included in this study. All statistical analyses were performed with Statistical Analysis Software version 6.10.[16] Explanatory variables considered in the analyses were age, gender, visual acuity, visual field defects, IOP, vertical C/D ratio, disc asymmetry, family history, residences, and type of eye care provider seen. Three different outcomes were considered: previously diagnosed versus previously undiagnosed glaucoma, previously undiagnosed glaucoma versus no glaucoma, and all glaucoma versus no glaucoma. *T*-tests were performed for the differences of age, IOP, and vertical C/D ratio in the worst eye between 2 values for each outcome and between rural and urban residences, and the *P* values under the assumption of unequal variances were reported. The *P* values for Fisher exact tests obtained from the contingency tables between gender and residences and between each outcome and gender, visual field defect, or visual acuity were then examined. Logistic regressions were used to perform the univariate and multivariate analyses. Univariate analyses were adjusted for age and gender for each outcome and each explanatory variable. For each outcome, the best model was presented by use of the backward stepwise selection. The odds ratios, 95% confidence intervals, and *P* values were derived from Wald statistics. A *P* value of less than 0.05 was considered statistically significant.

Table 1. Glaucoma Cases—Years Since Last Seen by Eye Care Professional

Years Since Last Seen by Eye Health Professionals	Undiagnosed Probable or Definite Glaucoma Cases	Diagnosed Probable or Definite Glaucoma Cases	No Glaucoma
1	35	37	1898
2	14	1	793
3	8	0	391
4	2	2	220
5	2	1	178
>5	9	1	497
Never	2	0	404
Total	72	42	4381

Results

A total of 4744 of 5520 of eligible people (86%) participated in interviews and examinations in the VIP. Ages ranged from 40 to 103 years, with a mean of 59 (standard deviation [SD], 12) years. Of these, 53% (2530 of 4744) were female, and 31% (1473 of 4744) resided in rural areas. There were no significant age or gender differences between urban and rural participants. However, urban participants were more likely to be born overseas (45% vs. 13%, $P = 0.001$) and to speak a language other than English in their homes (17% vs. 2%, $P = 0.001$).

Ninety-five percent (4495 of 4744) of participants had complete data for IOP, C/D ratios, visual fields and type of eye care professionals seen. Possible, probable, or definite OAG was found in 187 persons. Eighty-one percent (58 of 72) of possible cases, 72% (23 of 32) of probable cases, and 59% (49 of83) of definite cases were previously undiagnosed at the time of the study.

Of the 115 participants with probable or definite OAG, 72 (63%) were previously undiagnosed. Of these undiagnosed probable and definite cases, 35 (49%) had visited an eye care provider within the previous 12-month period. In contrast, of the 43 participants with previously diagnosed probable or definite glaucoma, 37 (86%) had seen either an ophthalmologist or optometrist or both over the last year (Table 1). Another 1898 participants had visited an eye health professional in the previous year but were nonglau-

comatous (Table 2). Thirty-five participants classified as "no glaucoma" but were previously diagnosed with glaucoma were excluded. In addition, no "possible glaucoma" cases were included in this study. Four previously diagnosed glaucoma cases had pseudoexfoliation syndrome, whereas none were found in the group with undiagnosed glaucoma.

Within the undiagnosed glaucoma group, there were 20 (57%) females, and the mean age was 71 years (range, 51–88; SD, 10). Age and gender were not significantly different compared with the previously diagnosed glaucoma group (age: $P = 0.67$, gender: $P = 1.00$). However, when evaluated against participants with no glaucoma (age: mean, 60; range, 10–95; SD, 11; gender, 56% female), there were no gender differences; undiagnosed glaucoma participants were significantly older ($P<0.0001$).

In the 35 recently examined cases of undiagnosed glaucoma, the mean IOP in the worse eye was 19 mmHg (range, 10–45 mmHg; SD, 7 mmHg), which was significantly higher than the 15 mmHg (range, 6–52 mmHg; SD, 3 mmHg) found in subjects with no glaucoma ($P = 0.002$). Ten (29%) undiagnosed glaucoma, 8 previously diagnosed glaucoma (23%), and 67 nonglaucomatous (3.5%) individuals had an IOP of ≥21 mmHg. Most undiagnosed glaucoma cases do not have a high IOP. Although multivariate analysis shows that IOP was significantly higher in undiagnosed glaucoma than in people without glaucoma ($P<0.0001$, Table 4), no significant differences were found compared with those with diagnosed glaucoma in univariate analysis ($P = 0.58$, Table 3).

The mean vertical C/D ratio in the worse eye was 0.71 (range, 0–1.0; SD, 0.25) in the undiagnosed glaucoma group and 0.79 (range, 0.2–1.0; SD, 0.20) in the diagnosed glaucoma group. Sixty-six percent (23 of 35) of those with undiagnosed glaucoma had a vertical C/D ratio ≥0.7, whereas 75% of diagnosed glaucoma subjects had this feature. However, univariate analysis suggested that these did not reach statistical significance ($P = 0.37$, Table 3). However, compared with those without glaucoma, vertical C/D ratio is a significant clinical feature ($P<0.0001$, Table 4). In addition, a vertical C/D ratio asymmetry of more than 0.3 was not statistically significant between the undiagnosed and diagnosed glaucoma groups ($P = 0.64$, Table 3).

Best-corrected visual acuity was a poor predictor of the presence of glaucoma. All except 3 (8.6%) undiagnosed glaucoma participants and 4 (11%) diagnosed glaucoma cases had a visual acuity of 6/6. Although only 1.2% (22 of 1863) of nonglaucomatous participants had a visual acuity worse than 6/6, the difference in the proportion of subjects with reduced vision was not significant ($P = 0.13$, Table 3).

Twenty-nine of the 35 (83%) undiagnosed cases of glaucoma had knowledge of their family history of eye diseases. Of these, only 5 (17%) reported a family history of glaucoma. In comparison, of those who responded, 28% of the previously diagnosed glaucoma cases ($P = 0.35$) and 7.5% of no glaucoma cases ($P = 0.07$) reported having a family history of glaucoma (Tables 3, 4). In addition, there were no significant differences between undiagnosed and diagnosed glaucoma when comparing location of residence after logistic regression ($P = 0.15$, Table 3).

Because 1 of the undiagnosed glaucoma participants had preexisting cortical blindness, Humphrey visual field data were analyzed in 34 of the 35 participants. Visual field defects were present in all undiagnosed cases of probable glaucoma but were absent in 1 of the 26 (3.8%) undiagnosed cases of definite glaucoma. A total of 97% (33 of 34) of participants with undiagnosed glaucoma had visual field abnormalities. In addition, visual field abnormalities were the only presenting signs in 7 (20%) cases of undiagnosed glaucoma (Table 5). Of the 33 abnormal visual fields, 14 (42%) had paracentral arcuate or sectoral defects, 11 (33%) had nonspecific abnormalities, 5 (15%) had visual field constrictions, and 3 (9%) had quadrant defects. In contrast, only 69% (25 of 36) of the diagnosed glaucoma and 23% (432 of 1842) of no glaucoma cases had visual field abnormalities. After multivariate analysis, the odds of having visual field defects among those with diagnosed glaucoma were lower than those with undiagnosed glaucoma (odds ratio [OR], 0.06; 95% confidence interval [95% CI], 0.01–0.69; $P = 0.02$, Table 3). In addition, the odds of undiagnosed glaucoma were 14 times higher (OR, 14.10; 95% CI, 2.83–7.08; $P<0.0001$) in participants with visual field defects compared with those without glaucoma (Table 4).

One of the undiagnosed definite glaucoma cases (Table 5, patient no. 2) had a vertical C/D ratio of <0.7, a C/D ratio asymmetry of less than 0.3, no visual field defects, but a raised IOP of 24 mmHg. The diagnosis of definite glaucoma, rather than ocular hypertension, was made because the optic discs showed excavation of the neuroretinal rim and a nerve fiber layer defect.

For most undiagnosed glaucoma participants, there were usually multiple clinical signs to suggest the presence of glaucoma. As seen in Table 5, 80% (28 of 35) of participants had at least 2 positive indicators of glaucoma with either reduced visual acuity, abnormal visual fields, raised IOP, large vertical C/D ratio, asymmetry between eyes, or positive family history. Of these, 23 participants (66%) had both visual field defects and a raised vertical C/D ratio.

The principal reasons to visit an eye care provider in the previous year were mainly for renewal of reading or distance vision glasses, review of diabetic retinopathy, age-related macular degeneration, or postcataract extraction assessment. It was not known whether these visits included ocular examination with dilatation of pupils, measurements of IOP, or visual field testing. However, multivariate logistic regression showed that diagnosed glaucoma cases were more likely to have been seen by both an ophthalmologist and an optometrist (OR, 45.17; 95% CI, 5.89–346.17; $P = 0.002$) or ophthalmologist alone (OR, 13.56; 95% CI, 2.16–85.15; $P = 0.005$) than by an optometrist alone in the previous 12 months (Table 3).

In summary, when comparing the previously undiagnosed glaucoma and diagnosed glaucoma cases, visual field defects and the type of eye care provider seen were the only statistically significant variables (Table 3). In addition to raised vertical C/D ratio and IOP, Humphrey visual field abnormalities were the important clinical factors when comparing participants with undiagnosed glaucoma with those without glaucoma and those with previously diagnosed glaucoma (Tables 3, 4).

Table 2. Demographic Features of Participants with Previously Undiagnosed, Previously Diagnosed Probable and Definite Glaucoma, and No Glaucoma Who Had Visited an Eye Care Professional within the Last 12 Months

	Undiagnosed Probable and Definite Glaucoma (%)	Diagnosed Probable and Definite Glaucoma (%)	No. Glaucoma (%)
Total (%)	35	37	1898
Probable	9 (26)	9 (24)	
Definite	26 (74)	28 (76)	
Age (yrs)			
40–49	0 (0)	0 (0)	421 (22)
50–59	7 (20)	4 (11)	566 (30)
60–69	6 (17)	13 (35)	498 (26)
70–79	15 (43)	10 (27)	306 (16)
>80	7 (20)	10 (27)	107 (6)
Gender			
Male	15 (43)	15 (41)	837 (44)
Residence			
Rural	13 (37)	8 (22)	584 (31)

Table 3. Comparison of Clinical Features of Participants with Previously Diagnosed Glaucoma to Those with Previously Undiagnosed Glaucoma Who Had Been Seen by an Eye Care Provider in the Last 12 Months

	Diagnosed Glaucoma (%)	Undiagnosed Glaucoma (%)	Odds Ratio (95% Confidence Interval)*	P Value	Odds Ratio (95% Confidence Interval)†	P Value
Best corrected visual acuity <6/12	4/37 (11)	3/35 (9)	1.23 (0.24–6.29)	0.802		
Presence of visual field defect	25/36 (69)	33/34 (97)	0.06 (0.01–0.54)	0.011	0.06 (0.01–0.69)	0.020
IOP ≥ 21 mmHg	8/35 (23)	10/35 (29)	0.73 (0.25–2.16)	0.576		
VCDR≥0.7	27/36 (75)	23/35 (66)	1.60 (0.57–4.52)	0.375		
Asymmetry≥0.3	3/34 (9)	4/34 (12)	0.67 (0.13–3.58)	0.640		
Family history of glaucoma	7/25 (28)	5/29 (17)	1.90 (0.50–7.14)	0.348		
Residence						
Urban	29 (78)	22 (63)	1.00			
Rural	8 (22)	13 (37)	0.47 (0.16–1.33)	0.15		
Type of eye caregiver seen						
Optometrist only	3/37 (8)	18/35 (51)	1.00		1.00	
Ophthalmologist	14/37 (38)	12/35 (34)	11.30 (2.25–56.69)	0.003	13.56 (2.16–85.15)	0.005
Both	20/37 (54)	5/35 (14)	52.93 (7.84–365.37)	<0.0001	45.17 (5.89–346.17)	0.0002

*Adjusted for age and gender.
†Adjusted for age, gender, visual field defects, and type of eye caregiver seen.
IOP = intraocular pressure; VCDR = vertical cup-to-disc ratio.

Discussion

In any clinical practice or epidemiology study, it is fundamental to be consistent in the definition of the disease to reliably diagnose that disease or to compare research conclusions. Because there is a lack of a universal consensus in the diagnostic criteria of OAG,[17–19] the study and the diagnosis of this disease remain difficult.

The diagnostic criteria for OAG have varied between different centers and studies. Indeed, as discussed by Lee et al[18] and Bathija et al,[19] there has been a change in the definition of OAG over the years. More recently, high IOP has been identified as a risk factor for glaucoma rather than a definitional factor. Therefore, there has been a shift toward the importance of the optic disc and the presence of visual field defects in the diagnosis of OAG. Recent studies[9,10,13,17] have provided more specific criteria, but there still remains a lack of consistency in glaucoma definition in current clinical research.

Most recent studies[7–9,11] have required the presence of visual field defects; however, the cutoff points for vertical C/D ratio and asymmetry between eyes have differed slightly. The Blue Mountains,[9] Baltimore,[10] Barbados,[13] and Rotterdam[17] Eye Studies had no IOP criterion, whereas a raised IOP was the prerequisite for the Beaver Dam[7] and Egna-Neumarkt[8] studies. Because of diverse opinions in glaucoma definition, in our study there were no specific diagnostic criteria for the diagnosis of glaucoma. Rather, a panel of 6 ophthalmologists, 2 of whom were glaucoma subspecialists, was asked to make a clinical diagnosis based

Table 4. Comparison of Clinical Features of Participants with Previously Undiagnosed Glaucoma to Those without Glaucoma Who Had Been Seen by an Eye Care Provider in the Last 12 Months

	Undiagnosed Glaucoma (%)	No Glaucoma	Odds Ratio (95% Confidence Interval)*	P Value	Odds Ratio (95% Confidence Interval)†	P Value
Best corrected visual acuity <6/12	3/35 (9)	22/1863 (1)	2.77 (0.73–10.45)	0.133		
Presence of visual field defect	33/34 (97)	432/1842 (23)	81.74 (10.92–611.98)	<0.0001	14.11 (6.39–31.13)	<0.0001
IOP ≥ 21 mmHg	10/35 (29)	67/1845 (4)	10.58 (4.72–23.72)	<0.0001	11.68 (5.10–26.78)	<0.0001
VCDR≥0.7	23/35 (66)	164/1893 (9)	21.09 (10.01–44.42)	<0.0001	32.89 (16.89–64.05)	<0.0001
Asymmetry≥0.3	4/34 (12)	68/1826 (4)	2.92 (0.98–8.71)	0.055		
Family history of glaucoma	5/29 (17)	124/1644 (8)	2.57 (0.94–7.00)	0.065		
Residence						
Urban	22 (63)	1279 (69)	1.00			
Rural	13 (37)	584 (31)	1.17 (0.58–2.36)	0.66		
Type of eye caregiver seen						
Optometrist only	18/35 (51)	1204/1863 (65)	1.00			
Ophthalmologist	12/35 (34)	413/1863 (22)	1.18 (0.55–2.57)	0.668		
Both	5/35 (14)	246/1863 (13)	0.87 (0.31–2.42)	0.785		

*Adjusted for age and gender.
†Adjusted for age, gender, visual field defects, intraocular pressure, and vertical cup-to-disc ratio.
IOP = intraocular pressure; VCDR = vertical cup-to-disc ratio.

Table 5. Summary of Clinical Features in Undiagnosed Glaucoma Cases

			Recent Examinations by			Abnormal					
	Age	Gender	*Ophthalmologists*	*Optometrists*	Glaucoma	*Impaired Best-Corrected Visual Acuity (<6/12)*	*Presence of Visual Field Defect*	*Intraocular Pressure ≥21 mmHg in the Worse Eye*	*Presence of Vertical Cup-to-Disc Ratio ≥0.7 in the Worse Eye*	*Presence of Cup-to-Disc Asymmetry ≥0.3 between the Two Eyes*	*Family History*
1	80	M	+	+	Probable	−	+	−	+	−	−
2	87	F	+	+	Definite	−	−	+	−	−	−
3	78	F	+	+	Definite	−	+	−	+	−	+
4	82	F	+	+	Definite	−	+	−	+	−	−
5	81	M	+	+	Definite	−	+	−	−	−	−
6	83	F	+	−	Probable	−	+	−	−	−	−
7	79	F	+	−	Probable	−	+	−	+	−	−
8	84	F	+	−	Definite	−	+	−	−	−	−
9	73	F	+	−	Definite	−	+	−	+	−	−
10	57	F	+	−	Definite	−	+	+	−	−	−
11	71	F	+	−	Definite	−	+	−	+	−	+
12	75	M	+	−	Definite	−	+	−	+	−	−
13	52	M	+	−	Definite	−	+	−	+	+	−
14	74	M	+	−	Definite	−	+	+	−	−	−
15	88	M	+	−	Definite	+	?	−	+	+	−
16	75	M	+	−	Definite	+	+	−	+	−	−
17	69	M	+	−	Definite	−	+	+	+	−	+
18	73	F	−	+	Probable	−	+	−	+	−	−
19	73	F	−	+	Probable	−	+	−	+	−	−
20	51	F	−	+	Probable	−	+	+	−	−	−
21	52	M	−	+	Probable	−	+	−	+	−	+
22	66	M	−	+	Probable	+	+	−	+	−	−
23	57	M	−	+	Probable	−	+	+	+	+	−
24	63	F	−	+	Definite	−	+	−	+	−	−
25	55	F	−	+	Definite	−	+	−	−	+	−
26	73	F	−	+	Definite	−	+	−	−	−	−
27	61	F	−	+	Definite	−	+	−	+	−	−
28	78	F	−	+	Definite	−	+	−	+	−	−
29	76	F	−	+	Definite	−	+	−	−	−	−
30	57	F	−	+	Definite	−	+	+	−	−	−
31	76	F	−	+	Definite	−	+	+	+	−	+
32	70	M	−	+	Definite	−	+	−	+	−	−
33	76	M	−	+	Definite	−	+	+	+	−	−
34	62	M	−	+	Definite	−	+	−	−	−	−
35	66	M	−	+	Definite	−	+	+	+	−	−

F = female; M = male.

on IOP, C/D ratio, visual field, optic disc appearance, and history. In our study, undiagnosed glaucoma cases may have an IOP of <21 mmHg (71%), vertical C/D ratio <0.7 (34%), asymmetry between eyes <0.3 (89%), or have no visual field defects (3%). We acknowledged that depending on the diagnostic criteria used by eye health professionals, some participants that were diagnosed in this study as having glaucoma may have been considered normal by others. In fact, Wolfs et al[17] had estimated that the overall prevalence of OAG may vary up to 12-fold with different criteria and screening algorithms. Although our diagnoses of glaucoma were not made on the basis of specific criteria, clinical features such as visual field defect, IOP, and vertical C/D ratio were significant factors in differentiating glaucoma and no glaucoma cases (Table 4).

It is generally accepted that the predisposing factors for glaucoma are elevated IOP,[13,20] presence of first-degree relative with glaucoma,[21–24] increasing age,[6,13,25] and African ethnicity.[14,24,26] Other risk factors subject to dispute include hypertension,[13] diabetes mellitus,[13,27] myopia,[24,28] and cataract.[13] Despite extensive worldwide epidemiology surveys and well-recognized association factors, in the developed world more than 50% of glaucoma cases remained undiagnosed.[2,6,8,9,14,17] Of particular concern was the presence of undiagnosed glaucoma in participants who had actually visited an eye care provider in the previous 12 months.

People with undiagnosed OAG who had been seen by an eye health practitioner in the last year had a mean age of 71 years, whereas the mean age of nonglaucomatous participants in the VIP study was 60 years. This was consistent with the widely accepted proposal of increasing risk of glaucoma with increasing age. Although 21% of nonglaucomatous VIP participants were between 40 and 49 years old,[12] all undiagnosed patients with glaucoma who had been seen by an eye health professional in the previous year were

50 years or older. This suggests that any diagnostic measures to assist in early detection of glaucoma should target the age group of 50 years or older.

In addition, only 14% of participants had a known family history of glaucoma, which is comparable to the Baltimore Eye Survey (16%)[21] and Barbados Eye Study (17%).[13] Although a positive family history had been a well-established risk factor of OAG, our results suggested that it was not a significant factor in the diagnosis of glaucoma. Conversely, McNaught et al[29] had found that 27% of patients with OAG who had an established family history were unaware of their positive family history; thus, the proportion of participants with a positive history may be higher than reported. Unless we have widespread recognition of the importance of family history and emphasize the need to inform immediate family, the reported rate of positive family history would remain low and continue to be an unhelpful clinical feature.

Although the presence of glaucoma was positively correlated with IOP,[13,20] we found that 71% of undiagnosed glaucoma cases and 77% of diagnosed glaucoma participants had an IOP of <21 mmHg. The reason for such high proportion in the latter group could be explained by the use of antiglaucoma medication in diagnosed cases. However, these results suggested that the use of IOP as a tool for case detection of glaucoma would be grossly insufficient. Furthermore, it had been estimated that 20% to 30% of patients[7,8,30] with glaucoma had normal-tension glaucoma, and 89% of previously undiagnosed glaucoma cases in The Rotterdam Study had an IOP of <21 mmHg.[17] In addition, normal-tension glaucoma was 4 times as common in patients identified through population screening as in self-selected patients[31] who are easily overlooked in clinical practice. Thus, an isolated level of IOP was not of great importance in the diagnosis of glaucoma. Eye care professionals should not rely on an elevated IOP to trigger them to perform necessary investigations.

Among people with undiagnosed glaucoma who had been seen by eye health practitioners, a large proportion (97%) were found to have visual field abnormalities, compared with 69% found in the diagnosed group. This was the only clinical feature that was statistically significantly different ($P = 0.011$) between the diagnosed and undiagnosed glaucoma participants who had been seen by eye health professionals in the previous 12 months (Table 3). This showed that the odds of picking up undiagnosed glaucoma increased considerably with Humphrey visual field testing. Thus, Humphrey visual field with correlation of clinical findings might be a useful tool in case detection of glaucoma for people age 50 or older who were seen by an ophthalmologist or optometrist and had not had mass screening within the community. However, Humphrey visual field testing was time consuming and expensive, rendering its use less desirable in ophthalmic practices. Faster and cheaper modalities such as frequency-doubling technology perimetry might be useful alternatives[32,33]; however, further studies would also be required to assess its sensitivity and specificity and cost-effectiveness in routine clinical settings.

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Erratum

With apologies, the authorship on "The COMS Randomized Trial of Iodine 125 Brachytherapy for Choroidal Melanoma. IV. Local Treatment Failure and Enucleation in the First 5 Years after Brachytherapy. COMS Report No. 19" (Ophthalmology 2002;109:2197–206) should have been the Collaborative Ocular Melanoma Study Group* (COMS Group).

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