Original Investigation

The Prevalence and Types of Glaucoma in an Urban Chinese Population
The Singapore Chinese Eye Study

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IMPORTANCE Glaucoma represents a major public health challenge in an aging population. The Tanjong Pagar Eye Study reported the prevalence and risk factors of glaucoma in a Singapore Chinese population in 1997, which established the higher rates of blindness in this population.

OBJECTIVES To determine the prevalence and associated risk factors for glaucoma among Chinese adults in Singapore and to compare the results with those of the 1997 study.

DESIGN, SETTING, AND PARTICIPANTS In a population-based survey of 4605 eligible individuals, we selected 3353 Chinese adults 40 years or older from the southwestern part of Singapore. Participants underwent examination at a single tertiary care research institute from February 9, 2009, through December 19, 2011.

EXPOSURES All participants underwent slitlamp ophthalmic examination, applanation tonometry, measurement of central corneal thickness, gonioscopy, and a dilated fundus examination.

MAIN OUTCOMES AND MEASURES Glaucoma as defined by the International Society of Geographical and Epidemiological Ophthalmology guidelines and age-standardized prevalence estimates computed as per the 2010 Singapore Chinese census. Blindness was defined as logMAR visual acuity of 1.00 (Snellen equivalent, 20/200 or worse).

RESULTS Of the 3353 respondents, 134 (4.0%) had glaucoma, including primary open-angle glaucoma (POAG) in 57 (1.7%), primary angle-closure glaucoma (PACG) in 49 (1.5%), and secondary glaucoma in 28 (0.8%). The age-standardized prevalence (95% CI) of glaucoma was 3.2% (2.7%-3.9%); POAG, 1.4% (1.1%-1.9%); and PACG, 1.2% (0.9%-1.6%). In a multivariate model, POAG was associated with being older and male and having a higher intraocular pressure. Of the 134 participants with glaucoma, 114 (85.1%; 95% CI, 78.1%-90.1%) were not aware of their diagnosis. Prevalence (95% CI) of blindness caused by secondary glaucoma was 14.3% (5.7%-31.5%), followed by 10.2% (4.4%-21.8%) for PACG and 8.8% (3.8%-18.9%) for POAG. We could not identify a difference in the prevalence of glaucoma compared with the 3.2% reported in 1997 (difference, −0.04%; 95% CI, −1.2 to 1.2; $P = .97$).

CONCLUSIONS AND RELEVANCE The prevalence of glaucoma among Singapore Chinese likely ranges from 2.7% to 3.9%, with secondary glaucoma being the most visually debilitating type. We could not identify a difference compared with previous studies approximately 12 years earlier. We report a high proportion of previously undiagnosed disease, suggesting the need to increase public awareness of this potentially blinding condition.

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Despite multiple studies, the prevalence of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) remain disputed among Chinese populations because the results differed greatly between studies and between rural[1-8] and urban[9,10] populations. Such differences could be attributed to geographic, climatic, and genetic factors. In addition, the various studies used dissimilar criteria to define glaucoma, which may lead to conflicting rates of prevalence of the condition.

Singapore has a heterogeneous population consisting of 3 major ethnicities, of which the Chinese predominate. A population-based cross-sectional survey, the Tanjong Pagar Eye Study (TPS),[11] was conducted from October 10, 1997, through August 14, 1998, to examine the prevalence of glaucoma in the Singapore Chinese population. The key findings indicated an age-standardized glaucoma prevalence of 3.2% in this population, with POAG representing 49% of glaucoma and PACG and secondary glaucoma being the most visually debilitative glaucoma types. The findings suggested that glaucoma is an underdiagnosed ocular condition, and public health initiatives were recommended for raising awareness.[11] Although we expect this awareness to improve surveillance for and early treatment of glaucoma among the elderly, an aging population may change the prevalence estimates over time.[1] This change establishes a need for ongoing surveys to monitor the prevalence of glaucoma and related morbidity.

In the present Singapore Chinese Eye Study (SCES) conducted from February 9, 2009, through December 19, 2011, we report the prevalence of glaucoma in Singapore Chinese 12 to 14 years after the TPS findings were published. This comparison will provide new understanding of the trends in the epidemiology of glaucoma observed during more than a decade in the Chinese population living in Singapore.

At a Glance

- The age-standardized prevalence of glaucoma among the Singapore Chinese population was 3.2% (95% CI, 2.7%-3.9%). We could not identify a difference from a previous study 12 years earlier.
- The age-standardized prevalence of primary open-angle glaucoma (POAG) was 1.4% (95% CI, 1.1%-1.9%) and of primary angle-closure glaucoma (PACG), 1.2% (95% CI, 0.9%-1.6%). In a multivariate model, POAG was associated with being older and male and having a higher intraocular pressure.
- Secondary glaucoma was the most visually debilitating type followed by PACG.
- We report a high proportion of undiagnosed disease (85.1% [95% CI, 78.1%-90.1%]), suggesting the need to increase public awareness about glaucoma.

Methods

Study Design

The SCES was a population-based, cross-sectional study of 3353 Chinese adults 40 years or older conducted from February 9, 2009, through December 19, 2011, with data analysis performed on September 9, 2013. Details of the study design, sampling plan, and methods have been reported. In brief, the study was conducted in the southwestern part of Singapore, using the same study protocol as the Singapore Malay Eye Study[12] and the Singapore Indian Eye Study.[13] The Chinese ethnicity of the participants was established from a census list provided by the Ministry of Home Affairs and subsequently verified using national identification cards and a questionnaire. On the basis of an age-stratified random sampling strategy, we selected 6752 names. Of these, 4605 individuals were deemed eligible to participate, and we subsequently recruited 3353 participants (response rate, 72.8%). The study adhered to the Declaration of Helsinki. Ethics approval was obtained from the institutional review board of the Singapore Eye Research Institute, Singapore, and written informed consent was obtained from all participants.

Clinical Assessment

All participants were examined at the Singapore Eye Research Institute. We used an interviewer-administered questionnaire to collect demographic data, socioeconomic information, lifestyle factors, and medical, ophthalmic, and family history. The presenting visual acuity with habitual correction and best-corrected visual acuity with subjective refraction were recorded using an Early Treatment of Diabetic Retinopathy Study logMAR number chart (Lighthouse International) at a distance of 4 m.[12] Central corneal thickness (CCT) was measured using ultrasonographic pachymetry (Echoscan model US-1800; Nidek Co, Ltd). Ocular assessment was performed by 2 ophthalmologists (Y.-F.Z. and R.W.) with experience in population-based studies. Slitlamp biomicroscopy (model BQ-900; Haag-Streit Diagnostics) was performed to identify signs of secondary glaucoma. Peripheral anterior chamber depth was determined by using the modified technique of Van Herick et al,[14] with the temporal peripheral anterior chamber examined under optical section at ×16 magnification. Intraocular pressure (IOP) was measured with a Goldmann applanation tonometer (Haag-Streit Diagnostics) before pupil dilation. One reading was taken from each eye. If the IOP reading was greater than 21 mm Hg, a second reading was used for analysis.

Gonioscopy was performed with a Goldmann 2-mirror lens (Ocular Instruments, Inc) under standard dark illumination in all participants. A narrow, vertical, 1-mm beam was offset vertically for superior and inferior quadrants and horizontally for nasal and temporal quadrants. Dynamic indentation gonioscopy with a 4-mirror gonioscope (Sussman; Ocular Instruments, Inc) was used to determine the presence of peripheral anterior synechiae. We used the gonioscopy classification systems of Spaeth[15] and Scheie.[16]

The optic disc was evaluated with a 78-diopter (D) lens at ×16 magnification with a measuring graticule during dilated ophthalmoscopy. We calculated the vertical cup-disc ratio (VCDR) and documented disc hemorrhage, notching of the neuroretinal rim, and retinal nerve fiber layer defects. Finally, automated perimetry (24-2 Swedish Interactive Thresholding Algorithm, Humphrey Visual Field Analyzer II; Carl Zeiss Meditec Inc) was performed with near refractive correction in 1 in 10 participants and in participants with suspected glaucoma. The

visual field test was repeated if the test reliability was not satisfactory (fixation loss, >20%; false-positive rate, >33%; and/or false-negative rate, >33%) or if a glaucomatous visual field defect was present. We used data from participants with perimetry findings within the reference range (n = 438) to define normative values for VCDR and IOP for the population.

Diagnostic Definitions

We defined *suspected glaucoma* as (1) IOP of greater than 21 mm Hg, (2) VCDR of greater than 0.6 or VCDR asymmetry of greater than 0.2, (3) abnormal anterior segment deposit consistent with pseudoexfoliation or pigment dispersion syndrome, (4) narrow anterior chamber angle, (5) peripheral anterior synechiae, (6) other findings consistent with secondary glaucoma, and (7) a known history of glaucoma. Participants with suspected glaucoma underwent perimetry, gonioscopy, and a second IOP measurement on another day.

Glaucoma cases were defined according to the criteria of the International Society for Geographical and Epidemiological Ophthalmology (ISGEO) based on 3 categories.[11] Category 1 was defined as an optic disc abnormality (VCDR or VCDR asymmetry at ≥97.5th percentile of the healthy population or a neuroretinal rim width between the 11- and 1-o'clock positions or the 5- and 7-o'clock positions reduced to a VCDR of ≤0.1) with a corresponding glaucomatous visual field defect. Category 2 was defined as a severely damaged optic disc (VCDR or VCDR asymmetry at ≥99.5th percentile of the healthy population) in the absence of adequate performance in a visual field test. For a diagnosis of category 1 or 2 glaucoma, we required a lack of any other explanation for the VCDR finding (dysplastic disc or marked anisometropia) or a visual field defect caused by retinal or neurologic diseases. Participants with no visual field or optic disc data who were blind (corrected visual acuity, <3/60) and who had undergone previous glaucoma surgery or with an IOP at the 99.5th percentile or greater were classified as having category 3 glaucoma. A glaucomatous visual field defect was considered to be present if the following were found: (1) a glaucoma hemifield test result outside reference limits and (2) a cluster of 3 or more nonedge contiguous points not crossing the horizontal meridian, with a probability of less than 5% of the age-matched reference data on the pattern deviation plot on 2 separate occasions. A narrow anterior chamber angle was diagnosed if the posterior trabecular meshwork was seen for 180° or less during static gonioscopy.[16] Primary angle-closure glaucoma was defined as glaucoma in the presence of narrow angles and features of trabecular obstruction by peripheral anterior synechiae, elevated IOP, iris whorling, glaukomflecken lens opacities,[17] or excessive pigment deposition on the trabecular surface. Participants with glaucoma and an open, normal drainage angle with no identifiable secondary pathologic processes were said to have POAG. Those participants in whom accurate assessment of the cause of the glaucoma was difficult were considered to have unclassifiable glaucoma. Final identification, adjudication, and classification of glaucoma cases were reviewed by the one of us (T.A.) and 2 glaucoma fellowship-trained ophthalmologists (M.B. and A.K.N.).

Other Variables

Systolic and diastolic blood pressures were measured using an automated sphygmomanometer (Dinamap Pro 100V2; GE Health Care). We drew nonfasting blood samples from all participants to determine levels of serum glucose and glycosylated hemoglobin. A participant was considered to have hypertension if the systolic blood pressure was 140 mm Hg or greater or the diastolic blood pressure was 90 mm Hg or greater, if a physician diagnosis was present, or if the participant self-reported a history of hypertension. Type 2 diabetes mellitus was diagnosed in any participant with a nonfasting glucose level of 200 mg/dL or higher (to convert to millimoles per liter, multiply by 0.0555) at examination or a physician diagnosis of diabetes mellitus and the use of antidiabetics. Low visual acuity was defined as a best-corrected logMAR visual acuity (Snellen visual acuity) of greater than 0.30 (20/40) to less than 1.00 (better than 20/200), and blindness was defined as a logMAR visual acuity of 1.00 or greater (20/200 or worse).[12] Myopia was defined as a spherical equivalent refraction of at least −0.5 D.

Statistical Analysis

Statistical analysis was performed with commercially available software (SPSS, version 20; SPSS, Inc). We performed a prevalence estimate of glaucoma for the whole cohort and in age- and sex-stratified groups. Prevalence rates were standardized to the population distribution from the 2010 Singapore Chinese Census[18] using the direct method of adjustment. The observed prevalence of glaucoma from the TPS was stratified as per age and sex and compared with SCES data after similar standardization. We used the unpaired independent *t* test for comparison of means and the χ^2 test or the Fisher exact test for comparison of proportions between groups. Multiple logistic regression analysis was used to assess the association of POAG with risk factors such as age, sex, IOP, CCT, myopia, hypertension, and diabetes mellitus. $P < .05$ was considered statistically significant.

Results

Of the sample population of 4605 individuals identified, 1252 (27.2%) declined the invitation to participate. Nonparticipants were older, with less participation among those 70 years or older (eTable 1 in the Supplement). The mean (SD) age of the study population was 59.7 (9.9) years, and 50.4% were women. Mean (SD) IOP (in the right eye) was 14.3 (3.2) mm Hg, with 97.5th and 99.5th percentiles of 21 and 25 mm Hg, respectively. Mean VCDR in the healthy participants (right eye) was 0.41, with 97.5th and 99.5th percentiles of 0.71 and 0.87, respectively. Mean (SD) VCDR asymmetry was 0.001 (0.07) with 97.5th and 99.5th percentiles of 0.15 and 0.29, respectively. Of the 3353 participants, 691 (20.6%) were identified as having suspected glaucoma. Of these, 134 (4.0%) had glaucoma, including POAG in 57 (1.7%), PACG in 49 (1.5%), and secondary glaucoma in 28 (0.8%).

Table 1 shows the overall crude and age-standardized prevalence of glaucoma, POAG, and PACG. The age-standardized prevalence (95% CI) rate of glaucoma was 3.2% (2.7%-3.9%); of POAG, 1.4% (1.1%-1.9%); and of PACG, 1.2%

Table 1. Prevalence of Glaucoma by Age and Sex in the Singapore Chinese Eye Study Population

Glaucoma Type	Participants[a]		
	All	Men	Women
All			
Age, y			
40-49	5/705 (0.7)	3/347 (0.9)	2/358 (0.6)
50-59	28/1113 (2.5)	17/504 (3.4)	11/609 (1.8)
60-69	37/896 (4.1)	28/472 (5.9)	9/424 (2.1)
≥70	64/639 (10.0)	41/339 (12.1)	23/300 (7.7)
P for trend	<.001	<.001	<.001
Crude total	134/3353 (4.0)	89/1662 (5.4)	45/1691 (2.7)
Adjusted total (95% CI)[b]	3.2 (2.7-3.9)	4.0 (3.2-5.18)	2.4 (1.7-3.2)
POAG			
Age, y			
40-49	3/705 (0.4)	2/347 (0.6)	1/358 (0.3)
50-59	17/1113 (1.5)	13/504 (2.6)	4/609 (0.7)
60-69	18/896 (2.0)	15/472 (3.2)	3/424 (0.7)
≥70	19/639 (3.0)	11/339 (3.2)	8/300 (2.7)
P for trend	<.001	.02	.004
Crude total	57/3353 (1.7)	41/1662 (2.5)	16/1691 (1.0)
Adjusted total (95% CI)[b]	1.4 (1.1-1.9)	2.1 (1.4-2.9)	0.9 (0.5-1.5)
PACG			
Age, y			
40-49	2/705 (0.3)	1/347 (0.3)	1/358 (0.3)
50-59	7/1113 (0.6)	2/504 (0.4)	5/609 (0.8)
60-69	13/896 (1.4)	9/472 (1.9)	4/424 (0.9)
≥70	27/639 (4.2)	18/339 (5.3)	9/300 (3.0)
P for trend	<.001	<.001	.002
Crude total	49/3353 (1.5)	30/1662 (1.8)	19/1691 (1.1)
Adjusted total (95% CI)[b]	1.2 (0.9-1.6)	1.2 (0.8-1.9)	1.0 (0.6-1.6)
Secondary			
Age, y			
40-49	0/705	0/347	0/358
50-59	4/1113 (0.4)	2/504 (0.4)	2/609 (0.3)
60-69	6/896 (0.7)	4/472 (0.8)	2/424 (0.5)
≥70	18/639 (2.8)	12/339 (3.5)	6/300 (2.0)
P for trend	<.001	<.001	.002
Crude total	28/3353 (0.8)	18/1662 (1.1)	10/1691 (0.6)
Adjusted total (95% CI)[b]	0.6 (0.4-1.0)	0.7 (0.4-1.3)	0.5 (0.2-1.0)

Abbreviations: PACG, primary angle-closure glaucoma; POAG, primary open-angle glaucoma.

[a] Unless otherwise indicated, data are expressed as number/total number of participants (percentage).

[b] Age-standardized rates (95% CI) are based on the 2010 Singapore Census of Population (Chinese).[18]

(0.9%-1.6%). The prevalence of glaucoma increased with age (*P* < .001 for trend) and was higher in participants aged 60 to 69 years (odds ratio, 3.7 [95% CI, 1.0-13.0]; *P* = .04) and 70 to 80 years or older (odds ratio, 4.6 [95% CI, 1.3-16.6]; *P* = .02) compared with those aged 40 to 49 years. The standardized prevalence of secondary glaucoma was 0.6% (95% CI, 0.4%-1.0%). The mean (SD) IOP among the participants without glaucoma in the study population was 14.2 (3.1) mm Hg and, among those with glaucoma, 16.7 (5.7) mm Hg (*P* < .001). Of the 57 participants with POAG, 43 (75.4%) had an IOP of no greater than 21.0 mm Hg; of the 49 with PACG, 35 (71.4%) had an IOP of no greater than 21.0 mm Hg. The mean (SD) CCT in the study population without glaucoma was 552 (34) µm. The mean (SD) CCT in participants with POAG (541 [30] µm) was statistically lower than that of the reference study group (*P* = .02).

Table 2 shows the characteristics of participants with specific types of glaucoma. Glaucoma with pseudophakia (0.72%) was the most common diagnosis in the subgroup with secondary glaucoma (84%). The ISGEO categorization of the glaucoma types (**Table 3**) revealed predominance of categories 1 (73.1%) and 2 (26.9%) in this population. Of the 134 participants with glaucoma, 30 (22.4% [95% CI, 16.2%-30.6%]) had low visual acuity (logMAR visual acuity, >0.30 to <1.00 [Snellen equivalent, 20/40 to no worse than 20/200]) and 14 (10.4% [95% CI, 6.3%-16.8%]) were blind (logMAR visual acuity, >1.00 [Snellen equivalent, 20/200 or worse]) according to the primary definition. Blindness due to glaucoma was noted with POAG in 5 of 57 participants (8.8% [95% CI, 3.8%-18.9%]), with PACG in 5 of 49 participants (10.2% [95% CI, 4.4%-21.8%]) and with secondary glaucoma in 4 of 28 participants (14.3% [95%

Table 2. Characteristics and Subtypes of Glaucoma in the Singapore Chinese Eye Study Population [a]

Glaucoma Type	All Participants		Participants by Sex		
	All, No. (%)	Median Age, y	Men, No. (%)	Women, No. (%)	M:F Ratio
Any	134 (4.0)	69.3	89 (5.4)	45 (2.7)	89:45
Primary	106 (3.2)	67.8	71 (4.3)	35 (2.1)	71:35
Secondary	28 (0.8)	71.8	18 (1.1)	10 (0.6)	9:5
Classification					
POAG	57 (1.7)	64.7	41 (2.5)	16 (1.0)	41:16
PACG	49 (1.5)	70.8	30 (1.8)	19 (1.1)	30:19
Neovascular	1 (0.03)	78.7	1 (0.1)	0	1:0
With pseudophakia	24 (0.7)	73.9	15 (0.9)	9 (0.5)	5:3
Postoperative retinal detachment	2 (0.1)	68.6	2 (0.1)	0	1:0
Unspecified glaucoma	1 (0.03)	71.6	0	1 (0.1)	0:1

Abbreviations: PACG, primary angle-closure glaucoma; POAG, primary open-angle glaucoma.

[a] Includes 1691 women and 1662 men (n = 3353).

CI, 5.7%-31.5%]). The proportion of participants with low visual acuity was slightly lower (17.5% vs 30.6%; $P = .18$) among those with POAG vs those with PACG.

The distribution of men compared with women was higher (53.0% vs 26.1%; $P < .01$) among participants with primary glaucoma, and men were 1.6 times more likely to have PACG. The association of clinical variables with POAG was evaluated by logistic regression, and the data are presented in **Table 4**. Primary open-angle glaucoma was associated with being older and male and having a higher IOP, whereas CCT, myopia, diabetes mellitus, and hypertension were not associated with a diagnosis of POAG. Of the 134 participants with glaucoma, 114 (85.1% [95% CI, 78.1%-90.1%]) were not aware of their diagnosis.

The age- and sex-standardized overall prevalence rate (95% CI) of glaucoma in the TPS projected as per the 2010 Singapore census was 3.5% (2.5%-4.9%). The age-standardized rate for men was 3.9% (2.4%-6.3%) and for women, 3.2% (2.0%-5.2%). **Table 5** summarizes the comparison of adjusted and unadjusted prevalence of glaucoma in the TPS and the SCES. We could not identify a difference in the prevalence of glaucoma compared with the 3.2% reported in 1997 (difference, −0.04% [95% CI, −1.2 to 1.2]; $P = .97$). eTable 2 in the Supplement summarizes the comparison of reported prevalence of glaucoma and subtypes of primary glaucoma in various population-based studies conducted in Chinese populations.

Discussion

The age-standardized prevalence of POAG in our study was 1.4% (95% CI, 1.1%-1.9%). This rate was higher than the mean prevalence rates in rural Chinese population studies, such as the Yunnan Minority Eye Study[2] (1.1%) and the Bin County study[3] (0.71% [95% CI, 0.5%-0.9%]); comparable to those of the Kailu County study[8] (1.42% [95% CI, 0.8%-2.0%]); but lower than those found in urban Chinese population studies, such as the Liwan District study[9] (1.8%) and the Beijing Eye Study[10] (2.6% [95% CI, 2.1%-3.0%]), and in rural Chinese populations, such as the Handan Eye Study[7] (2.3% [95% CI, 1.9%-2.7%]).

When we compared our study results with those of the TPS[11] projected to the 2010 Singapore census, the prevalence rate of glaucoma remained similar for both sexes, although a tendency for lower prevalence (95% CI) was seen for women (2.4% [1.7%-3.3%] vs 3.2% [2.0%-5.2%]). For men, we also found a tendency toward a decrease in the prevalence (95% CI) of POAG (1.4% [1.1%-1.2%] vs 2.4% [1.6%-3.2%] previously, with the latter unadjusted to the 2010 census) but a trend toward an increase in the prevalence of PACG (1.2% [0.9%-1.6%] vs 0.8% [0.4%-1.3%] previously, with the latter unadjusted to the 2010 Singapore census). However, this trend is difficult to prove because the methods used for adjusting prevalence in the TPS (owing to incomplete visual field test results) were different from those of the present study. On the contrary, a higher prevalence of POAG is expected because of an increase of myopia prevalence in Singapore.[19] One possibility could be the disproportionate rates of cataract surgery among the 2 primary glaucoma groups in the population sample. We reclassified a few participants as having PACG or POAG based on findings from the phakic eye, whereas the fellow pseudophakic eye remained classified as having glaucoma or suspected glaucoma. However, we assigned the classification of glaucoma with pseudophakia to those eyes with bilateral pseudophakia and glaucomatous changes in one or both eyes. Furthermore, the definition of angle-closure glaucoma in the TPS was based on a 3-quadrant closure, whereas we used a 2-quadrant closure definition in the SCES.

We found that PACG was more visually debilitating compared with POAG, with a higher proportion of low visual acuity (30.6% vs 17.5%) and blindness (10.2% vs 8.8%). These results concurred with those of most other studies.[3,6,7,9-11,20,21] Secondary glaucoma was the most debilitating condition, with 14.3% of these participants being blind.

We found that the prevalence of POAG was higher in our survey population compared with PACG (1.4% vs 1.2%). This finding concurred with results found in most other studies of Chinese people that used the ISGEO criteria for defining glaucoma, except for the Bin County study,[3] which found the converse (1.6% vs 0.7%). In a pooled meta-analysis of epidemiologic studies of glaucoma performed in mainland China,[22] the prevalence of POAG was much lower than that of PACG (0.7% vs 1.4%). Most of those studies (10 of 12) defined glaucoma using elevated IOP on 3 occasions with glaucomatous disc damage, glaucomatous field damage, and water-drinking provocative test results. This method could have led to inaccurate underestimates of POAG prevalence.

Table 3. Glaucoma Diagnosis Based on ISGEO Categorization[a]

Glaucoma Subtype	No. (%) of Participants	
	Category 1	Category 2
POAG	42 (31.3)	15 (11.2)
PACG	36 (26.9)	13 (9.7)
Neovascular	0	1 (0.7)
With pseudophakia	20 (14.9)	4 (3.0)
Postoperative retinal detachment	0	2 (1.5)
Unspecified	0	1 (0.7)
Total	**98** (73.1)	**36** (26.9)

Abbreviations: ISGEO, International Society of Geographical and Epidemiologic Ophthalmology; PACG, primary angle-closure glaucoma; POAG, primary open-angle glaucoma.

[a] Includes 134 participants in the Singapore Chinese Eye Study population with glaucoma. None had category 3 glaucoma. The glaucoma categories are explained in the Diagnostic Definitions subsection of the Methods section.

Table 4. Multiple Logistic Regressions for Risk Factors for POAG in the Singapore Chinese Eye Study Population

Risk Factor	No. of Participants[a]	Odds Ratio (95% CI)	*P* Value
Age group, y			
40-49	686	1 [Reference]	
50-59	1058	3.66 (1.06-12.69)	.04
60-69	840	3.68 (1.04-13.04)	.04
≥70	570	4.57 (1.26-16.58)	.02
Sex			
Male	1572	1 [Reference]	
Female	1582	0.42 (0.23-0.78)	.006
IOP, mm Hg[b]	3154	1.14 (1.07-1.22)	<.001
CCT, μm[b]	3154	0.99 (0.98-1.00)	.06
Myopia[b]			
No	1874	1 [Reference]	
Yes	1280	1.57 (0.89-2.74)	.12
Hypertension			
No	1313	1 [Reference]	
Yes	1841	1.74 (0.85-3.55)	.13
Type 2 diabetes mellitus			
No	2681	1 [Reference]	
Yes	473	0.93 (0.45-1.93)	.84

Abbreviations: CCT, central corneal thickness; IOP, intraocular pressure; POAG, primary open-angle glaucoma.

[a] Complete data were available for 3154 of 3353 participants included in the multivariate model.

[b] Based on the eye with glaucoma; for bilateral cases or participants without glaucoma, based on right eye data or on the left eye data used if the right eye data were not available.

Table 5. Comparison of Prevalence Rates in TPS and SCES

Study (Census Year)	Prevalence, % (95% CI)		
	Overall	Men	Women
TPS (1998, observed)	2.2 (1.4-2.9)	NA	NA
TPS (1998, adjusted for incomplete visual fields)[a]	3.2 (2.3-4.1)	NA	NA
TPS (2010, adjusted)	3.5 (2.5-4.9)	3.9 (2.4-6.3)	3.2 (2.0-5.2)
SCES (2010, adjusted)	3.2 (2.7-3.9)	4.0 (3.2-5.1)	2.4 (1.7-3.3)

Abbreviations: NA, not available; SCES, Singapore Chinese Eye Study; TPS, Tanjong Pagar Eye Study.

[a] Adjusted rate assumes 28% of the participants with a category 1 eye and incomplete field testing had glaucoma. The glaucoma categories are explained in the Diagnostic Definitions subsection of the Methods section.

We also found that men were 1.6 times more likely to have PACG than women. This prevalence was significantly different from that of the meta-analysis, which showed that women had a 75% higher point estimate of PACG prevalence than men in the Chinese population.[22] This aberrant association could be explained by preferentially higher cataract surgery rates among women compared with men in Singapore (relative risk, 1.14 from 1991 to 1996).[23] We speculate that this preferential rate could have led to an actual decrease in the prevalence of PACG or to its reclassification as secondary glaucoma, which would alter the sex-specific prevalence of PACG. This unexpected finding needs confirmation. Some studies[6,7,10,24-27] have suggested an association between myopia and an increased risk for POAG. In our study, we found no association between myopia and POAG. The overall prevalence of POAG was similar despite the increasing prevalence of myopia from 32.0% (349 of 1090 cases in the TPS) to 40.6% (1280 of 3154 cases in whom complete data were available in the SCES).

The strengths of our study include a large sample size with relatively high response rates and the use of standardized ISGEO criteria. Limitations include the absence of optic disc stereophotographs, which could have reduced reproducibility in the determination of the VCDR. Second, the role of newer technologies, such as optical coherence tomographic imaging and novel perimetric techniques, were not explored in this study, which is not mandatory for prevalence studies. Third, nonparticipants were slightly older and mostly older than 70 years, as seen in most prevalence surveys. In addition, the prevalence estimates of POAG and PACG could have been affected by sex differences in the rates of cataract surgery. Finally, comparison between the TPS and the present study differed by sampling strategies, study area, response rates, examiners, reliability issues with visual fields, and gonioscopic criteria. Thus, the present study provides only an approximate trend in glaucoma prevalence after a decade.

Screening for glaucoma remains an important public health issue because the problems caused by this asymptomatic yet visually debilitating disease will only increase over time. Furthermore, 85.1% of participants with glaucoma were not aware of their diagnosis. The possibility of increasing public awareness should be explored, especially in the elderly.

Conclusions

The age-standardized glaucoma prevalence in the Singapore Chinese population was 3.2%. Overall, we found a higher ratio of POAG to PACG. Old age, male sex, and increased IOP were independently associated with the diagnosis of POAG. Secondary glaucoma was the most visually debilitating, followed by PACG and POAG. Compared with the TPS, we could not identify a significant change in the prevalence of glaucoma or the subtypes. Furthermore, the proportion of the population with undiagnosed glaucoma remains high despite improvements in health care access.

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