

Glaucoma in Zulus

A Population-Based Cross-sectional Survey in a Rural District in South Africa

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Objectives: To determine the prevalence and the main types of glaucoma in a representative adult population in rural Zululand, and to describe the distribution of glaucoma-related variables in healthy subjects and those with glaucoma.

Design: A population-based, cross-sectional study.

Setting: Hlabisa district, Northern KwaZulu-Natal Province, South Africa.

Participants: Resident individuals of Zulu ethnic origin, 40 years or older.

Main Outcome Measures: Glaucoma was diagnosed by means of strict objective criteria, based on binocular indirect ophthalmoscopic optic disc appearances validated by results of disc photography and threshold visual field testing.

Results: From an eligible sample of 1115 subjects, 1005 (90.1%) were examined in the survey. The adjusted prevalence of glaucoma of all types was 4.5%, and primary open-angle glaucoma accounted for 2.7%. Secondary glaucoma occurred with an adjusted prevalence of 1.7%, of which the principal contributors were exfoliative and aphakic glaucoma. The prevalence of primary angle-closure glaucoma was low. Normal tension (intraocular pressure, ≤ 21 mm Hg) was measured in 16 (57.1%) of 28 cases of primary open-angle glaucoma. Age- and sex-adjusted prevalence of bilateral blindness was 3.2%, which was exclusively due to glaucoma in 9 (22.0%) of 41 cases.

Conclusions: Primary and secondary glaucoma constitute a significant public health problem in rural Zululand. The prevalence and types of glaucoma vary among different black populations.

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EVIDENCE IS EMERGING that the prevalence and the proportions of different types of glaucoma vary widely between ethnic groups and geographical areas throughout the world. Considerable data have been collected among white subjects and increasingly in those of East Asian origin. However, studies of the distribution of glaucoma in subjects of African derivation have focused mostly on island populations in the Caribbean, where prevalence rates are extremely high, and on the genetically heterogeneous population of the United States. A recent population-based study in rural Tanzania¹ reported an age-adjusted prevalence of primary glaucoma very close to that in African Americans, and with a similar preponderance of the open-angle type. Given the genetic diversity that exists among African ethnic groups^{2,3} and the exclusion of the population of East Africa from the transportation of slaves to the New World, this consistency is surprising. It cannot yet be assumed that these

findings will be consistent across the whole continent of Africa.

Previous work among the indigenous populations of South Africa has, in contrast, given rise to inconsistent results, and their interpretation is hampered by the lack of random sampling methods.^{4,5} Uncertainty remains concerning the prevalence of glaucoma and the distribution of its various forms in black South Africans. In this study, our primary aim was to determine the prevalence of glaucoma in a representative indigenous population in rural Zululand. A secondary goal was to describe the distribution of glaucoma-related variables in healthy subjects and those with untreated glaucoma.

RESULTS

Of a selected sample of 1115 subjects, 1005 (90.1%) completed the examination. The numbers of participants and recruitment proportions categorized for age and sex are shown in **Table 1**. Participation was above

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SUBJECTS AND METHODS

SETTING

The study was performed in Hlabisa, a typical rural district in Northern KwaZulu-Natal Province, South Africa, with an estimated population of 200 000. The population is almost exclusively Zulu, an anthropologically homogeneous Bantu tribe that constitutes the country's largest single ethnic group. Approximately 17% of the population are 40 years or older.⁶ In most of the district, the population lives in scattered homesteads rather than villages, although there is a small urban center. Health care is provided at a number of fixed and mobile clinic points and a 300-bed hospital that has had a resident ophthalmic surgical service since 1997. Unemployment levels are very high, and a significant proportion of the adult population of Hlabisa migrate outside the district to work, often living away from home for months at a time.

POPULATION SAMPLING

We used a 2-stage, nonstratified, cluster-based, random-sampling technique to select a sample of 1115 residents 40 years or older of the Hlabisa district. Sample size was based on a mean (SD) predicted prevalence of primary open-angle glaucoma (POAG) of $2.5\% \pm 1.0\%$.

No detailed census mapping information was available for this age group. Since more than 90% of children in the district enter first grade,⁷ the local education department register was used as a sampling frame. This approach had been successfully used in earlier cross-sectional work in this district.⁷ In the first sampling stage, a list of all registered first-grade students ($n=9296$) was used to randomly select 27 children. In stage 2, for each of the 27 pupils, a randomly selected third-grade student at the same school was chosen from the register. Third-grade children were used as secondary sampling units because they were old enough to direct the fieldworker to their homes. They were not used in the primary sampling stage in an attempt to minimize the selection bias that might have resulted from the fact that a far smaller proportion of children enter third than first grade. The selected child's house was taken as the index point for each cluster. Starting at the physically nearest household to the index house, a census was performed of residents 40 years or older who were then invited to undergo examination. The next physically nearest household was approached until 40 subjects had been selected. Information on the residents of empty households was gathered from the neighbors and, where necessary, each house was visited on at least 3 separate days to identify and to recruit the residents. Given the mobility of the population of Hlabisa, for the purposes of this study, residents were defined as household members who normally spent at least 1 night in 2 weeks in the house.

We examined documentary evidence to confirm the age of a subject when possible. Most of the population has identity documents. When this method failed, an interview using a calendar of locally significant events was performed.

In this way, 27 clusters of approximately 40 subjects were selected.

CLINICAL ASSESSMENT

Participants were examined at their local primary care clinic between April 28, 1998, and March 18, 1999. A series of questions was put to each subject to elicit a family history of blindness or glaucoma or a previous diagnosis of glaucoma.

Visual acuity was measured using a tumbling E chart at 6 m in ambient illumination, with distance correction if normally worn and with a pinhole if the acuity was less than 20/40 (6/12). Objective refraction was measured by means of retinoscopy in subjects in whom the visual acuity ranged from 6/18 to 6/60 and improved by 2 lines or more with the pinhole. Monocular central visual field was assessed in every eye with a visual acuity of 20/200 (6/60) or better using a computerized field analyzer (Henson CFA3000; Tinsley Medical Instruments, Newbury, Berks, England). This central 25° static, semiautomated visual field analyzer has been reported to be sensitive and specific for detection of moderate and advanced glaucomatous visual field loss.⁸ All visual field testing was performed in accordance with a standard protocol by a trained Zulu-speaking technician. Appropriate spherical near correction was worn according to age and adjusted for distance refraction if determined. Threshold sensitivity was determined by repeated testing until 2 identical results were obtained for each eye in an attempt to minimize the learning effect. A 66-point threshold-related suprathreshold test was then performed on the right eye first.

Subjects with an equivocal or abnormal suprathreshold visual field result (false-positive rate in a healthy population, $<1.0\%$ in age-matched healthy subjects) were re-examined using a 52-point threshold test, with automatic retesting of any retinal locations at which the threshold was found to be more than 4 dB below the expected age-matched value. Subjects with a normal suprathreshold test result but with a vertical cup-disc ratio (CDR) of at least 0.7 or a CDR asymmetry of at least 0.3 between their 2 discs also underwent threshold visual field analysis.

The remainder of the examination was performed by a single ophthalmologist (A.P.R.). All subjects underwent slit-lamp anterior-segment assessment for media opacities and signs of secondary glaucoma. Goldmann applanation tonometry was performed with the subject under topical anesthesia with benoxinate hydrochloride, and 2% fluorescein sodium was used to obtain a single reading at the midpoint of the pulse for each eye. Only readings where minimal force was necessary to widen the palpebral aperture

85% in all categories, with the exception of men aged 40 to 49 years. The mean age of the sample was 59.5 ± 12.1 years (men, 60.5 ± 12.3 years; women, 58.9 ± 12.0 years). There was a considerable female preponderance (72.1%), which was most marked in younger participants and reflects sex differences in recruitment rates and the demographic impact of labor migrancy.

OPTIC DISCS

Disc images of sufficient quality for assessing CDR stereoscopically were obtained in 90 participants in the subgroup undergoing optic disc photography (78.9%). The CDRs represented in this sample ranged from 0.15 to 0.68. Vertical CDR was underestimated by indirect ophthal-

sufficiently were recorded as valid. The intraocular pressure (IOP) was also measured by means of a Tono-Pen XL (Mentor Ophthalmics, Santa Barbara, Calif). The result of a single automatic series of readings was recorded, but the test was repeated if the SEM was greater than 5%. Both tonometry instruments were calibrated daily.

Gonioscopy was performed in all subjects using a Goldmann 2-mirror lens. Angle grading was modified from the method described by Spaeth⁹ to include the angle of approach, the level of iris insertion, and the iris profile in each quadrant. Indentation with a Sussman 4-mirror lens was performed if necessary to examine the trabecular meshwork and to detect synechiae. If the drainage angle was judged to be not occludable, the pupils were dilated with 1% tropicamide and 2.5% phenylephrine hydrochloride.

The optic disc was assessed stereoscopically for vertical CDR, rim notching, defects of the nerve fiber layer, and marginal hemorrhages using a Volk +78-diopter lens (Volk Optical Inc, Mentor, Ohio). In the case of the CDR, the largest value from the 11- to 1-o'clock and the 5- to 7-o'clock positions was recorded.

In a subgroup of 114 consecutive participants examined at the most easily accessible clinic, stereoscopic optic disc photography was attempted to validate the assessment of disc cupping. Using the 30° field setting of a fundus camera (Nikon Retinapan 45-II; Nikon Corp, Tokyo, Japan), 2 photographs were taken through dilated pupils for each eye, rotating the camera through 15° between the shots to allow stereoscopic examination. Pairs of transparencies were examined stereoscopically, and the CDR was measured at its widest point from a projected image. The photographic assessment was performed with the assessors unaware of the ophthalmoscopic measurements. Validation was performed for only 1 eye of each subject.

DIAGNOSTIC CRITERIA AND DEFINITIONS

A scheme based on evidence of end-organ damage (ie, damage to the structure and function of the optic nerve) was adopted to diagnose all forms of glaucoma. This scheme was based on a prototype diagnostic scheme developed specifically for cross-sectional prevalence surveys by the Working Group for Defining Glaucoma of the International Society of Geographical and Epidemiological Ophthalmology.¹⁰

Definite glaucoma was diagnosed if the eye fell into 1 of the following 3 categories: (1) Structural and functional evidence of a definite and reliable glaucomatous visual field defect was found in the presence of a CDR of at least 0.7 or CDR asymmetry between fellow eyes of at least 0.2. These values represented the 97.5th percentiles in this population. (2) Advanced structural damage was found on a threshold visual field test result that was not completed satisfactorily or that indicated a suspicious field defect but with a CDR of at least 0.9 or a CDR asymmetry of at least 0.3. These values represented the 99.5th percentiles

in this population. (3) Assessment of the optic disc was not possible because of media opacity. The visual acuity was light perception or worse, with an IOP of at least 30 mm Hg and an afferent defect (if the pupil was visible). Only in these cases of end-stage glaucoma was IOP included as a diagnostic criterion.

A threshold visual field test was defined as definitely glaucomatous if a defect at least 12° wide (2 adjacent points) and 5 dB below threshold sensitivity, adjusted for the expected hill of vision, in a nerve fiber bundle pattern was detected and confirmed on results of retesting. Visual field defects were not attributed to glaucoma in the presence of media opacification or a nonglaucomatous optic nerve lesion that would explain the field abnormality. If a less dense defect was found in a still-typical distribution, the visual field test result was defined as a suspicious field defect. A test result was considered reliable if less than 33% false-positive responses, less than 33% false-negative responses, and less than 25% fixation losses were found. Defective points adjacent to the blind spot were ignored.

Glaucomatous eyes were categorized as having open-angle glaucoma (OAG) or angle-closure glaucoma (ACG) on the basis of gonioscopy findings. A drainage angle was defined as narrow (occludable) when the pigmented trabecular meshwork was visible on gonioscopy with the eye in the primary position for less than 90° of the circumference without indentation. The same diagnostic criteria were applied for ACG as were used for OAG but in the presence of a narrow angle. When signs of a precipitating factor (eg, exfoliation, uveitis) were in evidence, the term *secondary glaucoma* was applied. Otherwise, the condition was termed *primary*.

DATA MANAGEMENT

Unless otherwise indicated, data are given as mean (SD). Data were double entered from standard forms into a customized EpiInfo database (Centers for Disease Control and Prevention, Atlanta, Ga) with validation, range, and consistency checks. Analysis was performed using EpiInfo and Stata 6 statistical software (Stata Corp, College Station, Tex). In the calculation of confidence intervals (CIs) for prevalence, the binomial distribution was used and allowance for the design effect (ie, the excess variance of the estimates under the cluster-based selection procedure used instead of simple random sampling) was included.¹¹ Adjusted figures were derived by direct age and sex standardization to the 1996 indigenous population structure of Hlabisa.⁶

ETHICAL CONSIDERATIONS

Ethical approval was granted by the Ethics Committee of the Faculty of Medicine at the University of Natal, Durban, and the Hlabisa district tribal, health, and education authorities. Free and informed consent was obtained from each participant.

moscopy relative to that by the photographic method, but the mean difference (± 2 SD) was only 0.05 ± 0.15 . Paired measurements were within 0.1 in 66 (73.3%) of 90 participants, and in no case was the difference as high as 0.2.

The optic discs were assessed ophthalmoscopically in 962 right eyes and 952 left eyes. The distribution is

illustrated in **Figure 1**. Mean vertical CDR was 0.34 ± 0.19 for both right and left discs. A value of 0.7 was found to represent the 97.5th percentile for CDR in both right and left eyes, with or without the inclusion of subjects with glaucoma.

Optic disc margin hemorrhages were notably absent in all subjects, with or without glaucoma.

Table 1. Age and Sex Distribution of Subjects Examined

Age, y	No. (%) [*]		
	Male	Female	Total
40-49	63 (72.4)	191 (90.1)	254 (84.9)
50-59	73 (86.9)	196 (96.6)	269 (93.7)
60-69	64 (91.4)	183 (95.8)	247 (94.6)
70-79	61 (92.4)	122 (93.8)	183 (93.4)
≥80	19 (95.0)	33 (86.8)	52 (89.7)
All ages	280 (83.1)	725 (93.2)	1005 (90.1)

^{*}Percentages in parentheses indicate response rates.

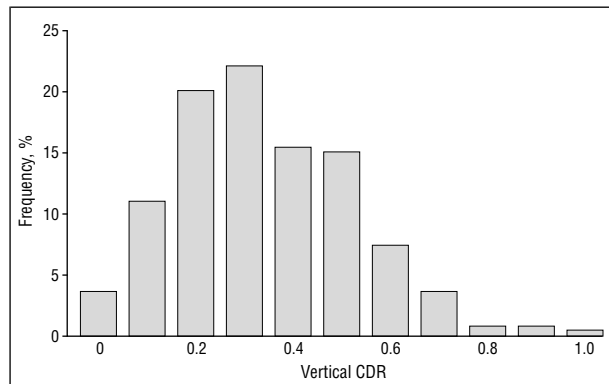


Figure 1. Frequency distribution of the vertical cup-disc ratio (CDR) (n=1914 eyes).

Table 2. Proportion of Eyes With Visual Field Defects According to Vertical CDR^{*}

Vertical CDR	No. of Eyes	No. (%) With Threshold Defect
0.7	20	10 (50.0)
0.8	12	11 (91.7)
≥0.9	7	7 (100.0)
All eyes	39	28 (71.8)

^{*}CDR indicates cup-disc ratio.

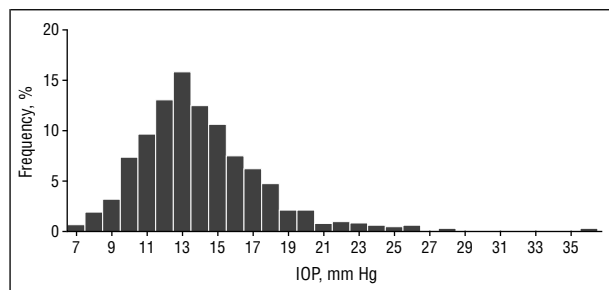


Figure 2. Frequency distribution of Goldmann intraocular pressure (IOP) in nonglaucomatous eyes (n=1790).

VISUAL FIELD TESTING

Suprathreshold visual field testing was completed in at least 1 eye of 867 participants (86.3% overall; 91.5% of those with a visual acuity of 20/200 [6/60] or better in at least 1 eye). Inability to perform visual field testing was independently associated with increasing age and visual impairment ($P<.001$). The 66-point suprathreshold test

Table 3. Glaucoma Type for 51 Subjects With Glaucoma^{*}

Glaucoma Type	Unilateral	Bilateral	Total (%)
POA	17	11	28 (54.9)
Exfoliative (open angle)	7	1	8 (15.7)
AC†	4	1	5 (9.8)
Aphakic	2	2	4 (7.8)
Traumatic	4	0	4 (7.8)
Phacolytic‡	1	0	1 (2.0)
Undetermined	1	0	1 (2.0)
Total	36	15	51 (100.0)

^{*}POA indicates primary open-angle; AC, angle-closure.

†Includes 1 case of primary and 4 cases of secondary (exfoliation [n = 2], spontaneous lens subluxation [n = 1], and uveitis [n = 1]) glaucoma.

‡Indicates exfoliation syndrome.

result was abnormal ($P<.01$) in 184 eyes (11.0% of eyes undergoing testing). With the use of category 1 diagnostic criteria, 22 of these were classified as glaucomatous, giving a positive predictive value to suprathreshold testing of 12.0%. The specificity was 90.1% (1478/1640).

Table 2 depicts the proportion of eyes with a vertical CDR of at least 0.7 in which visual field testing could be performed reliably that were found to have a threshold visual field defect.

INTRAOCULAR PRESSURE

The arithmetic mean Goldmann IOP was 14.2 ± 4.2 mm Hg (95% CI, 13.9-14.5 mm Hg) for all right eyes for which applanation tonometry was recorded (n=928) and 14.2 ± 4.1 mm Hg (95% CI, 14.0-14.5 mm Hg) for all left eyes (n=914). When glaucoma cases were excluded, then the mean values became 13.9 ± 3.4 mm Hg (95% CI, 13.7-14.1 mm Hg) for both right and left eyes. **Figure 2** illustrates the characteristic right-skewed Gaussian distribution of Goldmann IOP in eyes not classified as glaucomatous. Of these 1790 healthy eyes, 3.5% had an IOP above 21 mm Hg (2 SDs above the mean in this population) and in 40 (4.6%) of 870 healthy subjects, the IOP was above 21 mm Hg in at least 1 eye (defined as ocular hypertensive cases).

GLAUCOMA PREVALENCE

Glaucoma of any type was diagnosed in 51 subjects, giving an age- and sex-adjusted prevalence of 4.5% (95% CI, 3.2%-6.1%). Twenty-eight cases of POAG were found, excluding those with evidence of exfoliation syndrome, giving an age- and sex-adjusted prevalence of 2.7% (95% CI, 1.7%-4.0%) and making it the most frequently encountered type (**Table 3**). In 11 of these (39.3%), POAG was bilateral. Excluding cases with POAG or primary ACG, there were 21 glaucoma cases with an identifiable secondary cause (**Table 4**). Secondary glaucoma thus accounted for 21 (41.2%) of all 51 cases of glaucoma with an age- and sex-adjusted prevalence of 1.7% (95% CI, 0.9%-2.9%).

The distribution of glaucoma types is detailed in Table 3. Among the secondary cases, the most frequent underlying cause was exfoliation syndrome. Typical deposits of exfoliated material were identified in the ante-

Table 4. Glaucoma Prevalence by Age Group*

Age, y	POAG		Secondary Glaucoma		All Glaucoma†	
	No. of Cases	Prevalence, %	No. of Cases	Prevalence, %	No. of Cases	Prevalence, %
40-49	3	1.2	0	0	3	1.2
50-59	5	1.9	2	0.7	8	3.0
60-69	7	2.8	5	2.0	12	4.9
70-79	9	4.9	11	6.0	20	10.9
≥80	4	7.7	3	6.5	8	15.4
Crude Total‡	28	2.8 (1.8-4.2)	21	2.1 (1.2-3.4)	51	5.1 (3.7-6.8)
Adjusted‡§		2.7 (1.7-4.0)		1.7 (0.9-2.9)		4.5 (3.2-6.1)

*POAG indicates primary open-angle glaucoma.

†Includes primary angle-closure glaucoma (n = 1) and uncertain etiology (n = 1).

‡For prevalences, 95% confidence intervals are given in parentheses.

§Adjusted for age and sex.

rior segment of 11 glaucomatous subjects, representing 21.6% of all 51 glaucoma cases.

Secondary glaucoma in association with aphakia was identified in 6 eyes of 4 subjects. Among the eyes that had undergone cataract surgery, these represented 33.3% of 18 aphakic eyes. No glaucoma was found in the 8 pseudophakic eyes of 8 subjects. In all 6 eyes with aphakic glaucoma, the drainage angle was open, and no evidence of pupil block was seen. Five had undergone intracapsular surgery 5 to 15 years ago, which appeared to have been uneventful in 4 cases and which was complicated by a small vitreous strand adherent to the wound in the other. One eye had undergone extracapsular cataract extraction more recently, which was complicated by vitreous loss. In only 1 eye was the IOP elevated above 21 mm Hg, but all 6 eyes were blind as a result of untreated glaucoma.

Angle-closure glaucoma was diagnosed in 5 subjects, giving a crude population prevalence of 0.5% (95% CI, 0.2%-1.2%). Of these, a secondary cause was present in 4 (exfoliation [n=2], lens subluxation [n=1], and uveitis [n=1]), leaving only a single case of primary ACG.

Angle narrowing to the extent that less than 90° of the trabecular meshwork was visible occurred in 5 additional cases without evidence of glaucoma, giving an overall observed prevalence of narrow angles of 1.0% (95% CI, 0.5%-1.8%). In 1 case, the IOP was elevated in the absence of disc cupping or visual field loss. For the whole population, maximum angle width was Shaffer¹² grade 4 in 38.2%, grade 3 in 48.8%, grade 2 in 9.9%, and grade 1 or 0 in 3.1%.

The mean age of subjects with glaucoma was 69.5±11.1 years. Prevalence increased significantly with age for primary and secondary glaucoma ($P<.001$). In those older than 80 years, 15.4% were affected (Table 4), and 78.4% of all glaucoma occurred in those 60 years or older. Prevalence of POAG increased exponentially from 1.2% to 7.7% from the fifth to ninth decades of life.

The crude prevalence was higher in men than women for POAG (4.6% vs 2.1%) ($P=.05$), but this difference was not significant after adjusting for age ($P=.10$). For all glaucoma cases, men were significantly more likely than women to have glaucoma (8.6% vs 3.7%), with an age-adjusted odds ratio of 2.0 (95% CI, 1.0-4.4) ($P=.04$).

A previous diagnosis of glaucoma had been made in only 5 (9.8%) of the 51 cases, of which 3 (5.9%) had

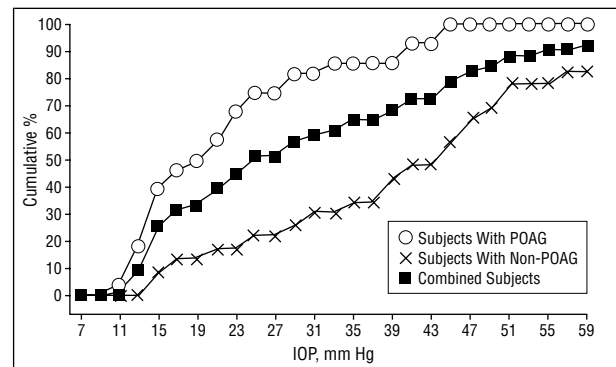


Figure 3. Cumulative intraocular pressure (IOP) curves showing the IOP of the glaucomatous eye of 28 subjects with primary open-angle glaucoma (POAG). For comparison, 23 subjects with non-POAG and the 51 subjects combined are shown. For bilateral glaucoma, the higher pressure was used.

received any disease-modifying treatment. Only 1 case of POAG (3.6%) was previously recognized.

The cumulative IOP distribution for subjects with glaucoma is shown in **Figure 3**. This refers to Goldmann applanation tonometry except in eyes with corneal irregularity, in which the Tono-Pen tonometry reading has been used. For bilateral cases, the higher value of the 2 eyes was taken. In the case of POAG, the mean and median (interquartile range) IOPs were 20.8±8.6 mm Hg and 18.0 mm Hg (15.5-24.5 mm Hg), respectively. These values are significantly higher than the IOP in nonglaucomatous subjects (mean, 13.3±3.3 mm Hg, and median, 13.5 mm Hg [12.0-15.5 mm Hg]) (Mann-Whitney, $P<.001$). In 16 (57.1%) of 28 affected cases and 24 (61.5%) of the 39 eyes, the IOP was 21 mm Hg or less in the affected eyes. Most POAG in this population is, therefore, normal-tension glaucoma and emphasizes the degree of overlap with the healthy population observed in IOP distribution. This finding is in contrast to findings with glaucoma of the non-POAG type; for these subjects, only 4 (17.4%) of 23 had an IOP of 21 mm Hg or less ($P=.004$), and the median pressure was 44 mm Hg.

PREVALENCE AND CAUSES OF BLINDNESS

Using the World Health Organization criteria (*International Classification of Diseases, 10th Revision* categories of visual impairment 3, 4, and 5),¹³ 41 subjects were bi-

laterally blind, giving an age- and sex-adjusted blindness prevalence in this population of 3.2% (95% CI, 2.2%-4.6%). In those older than 60 years, blindness prevalence was 7.8% (95% CI, 5.6%-10.9%) and increased rapidly above this age, reaching 25.7% (95% CI, 14.1%-41.2%) in those older than 80 years. An additional 81 subjects were unilaterally blind, so the adjusted prevalence of blindness in 1 or both eyes was 10.8% (95% CI, 8.7%-13.4%).

The principal causes of blindness are given in **Table 5**. Age-related cataract that had not undergone operation was the most frequent cause of unilateral and

Table 5. Causes of Blindness

Cause	Type of Blindness, No. (%)		
	Unilateral	Bilateral	Combined
Cataract	30 (37.0)	22 (53.7)	52 (42.6)
Glaucoma, total*	12 (14.8)	9 (22.0)	21 (17.2)
Other	39 (48.1)†	10 (24.4)‡	49 (40.2)
Total	81 (100.0)	41 (100.0)	122 (100.0)

*Unilateral blindness was caused by primary open-angle glaucoma in 3 cases; bilateral, in 6.

†Trauma resulted in corneal scarring (n = 9), atrophy of globe (n = 5), lens subluxation (n = 1), and enucleation (n = 1). Other causes included refractive error (n = 4), macular scarring secondary to inflammation (n = 3), corneal scarring with unknown cause (n = 2), retinal artery occlusion (n = 2), diabetic retinopathy (n = 1), diabetes-related cataract (n = 1), idiopathic macular hole (n = 1), atrophy of globe with unknown cause (n = 1), strabismic amblyopia (n = 1), toxic amblyopia (n = 1), cerebral trauma (n = 1), cerebrovascular accident (n = 1), and uncorrected aphakia (n = 1). Cause was unknown in 3 cases.

‡Climatic droplet keratopathy (n = 3), retinal vein occlusion (n = 2), corneal scarring (n = 2), cerebrovascular accident (n = 1), pigmentary retinopathy (n = 1), and unknown cause (n = 1).

bilateral blindness. However, in 9 (22.0%) of the 41 subjects who were bilaterally blind, the principal cause in both eyes was glaucoma. In 13 (31.7%), blindness was due to glaucoma in at least 1 of the 2 blind eyes. In the population 40 years and older, the age- and sex-adjusted prevalence of blindness in at least 1 eye exclusively attributable to glaucoma was 2.1% (95% CI, 1.3%-3.2%), and it was the cause of blindness in both eyes in 0.9% (95% CI, 0.5%-1.7%).

In eyes with secondary glaucoma, 18 (75.0%) of 24 were blind (excluding 4 eyes primarily blind due to trauma) compared with 16 (41.0%) of 39 eyes with POAG (Fisher exact test, $P = .01$). This difference in disease severity is reflected in the criteria by which the diagnosis was made. Without the results of visual field testing, a diagnosis of glaucoma would still have been made in 20 (95.2%) of the 21 subjects with secondary glaucoma under diagnostic categories 2 and 3 (advanced structural damage) compared with only 18 (64.3%) of the 28 with POAG ($P = .007$).

COMMENT

The results of this cross-sectional survey support the views that glaucoma prevalence is generally higher in those of African origin than in other racial groups and that it is principally POAG in type. However, real variations appear in the type and prevalence of glaucoma between different black populations.^{1,4,14-19} **Table 6** compares the methods and results of population-based prevalence studies specifically for POAG in black populations in Africa, the Caribbean, and the United States. Even allowing for differences in methods and diagnostic criteria, the age-

Table 6. Crude and Standardized Prevalence of POAG in Population-Based Surveys in Black Subjects*

Reference (Location)	Prevalence, % (95% CI)		Standardized Prevalence Ratio‡	Notes and Diagnostic Criteria§
	Crude	Adjusted†		
Mason et al ¹⁶ (St Lucia)	10.2 (8.6-11.9)¶	10.0	1.63	VF defect performed only on "disc/IOP suspects" and 1/3 of healthy subjects
Leske et al ¹⁷ (Barbados)	7.0 (6.3-7.8)¶	7.3	1.00	VF defect and 2 of following: CDR ≥ 0.8 or CDR asymmetry ≥ 0.2 or rim width ≤ 0.1 or notching or disc hemorrhage
Tielsch et al ¹⁴ (Baltimore, Md)	4.2 (3.0-5.0)¶	4.4	0.65	Best available from 8 categories based on VF and/or disc abnormalities
Neumann and Zauberman ¹⁸ (Liberia)	3.2 (2.4-4.3)¶	3.7	0.64	All primary glaucomas, with dubious sampling strategy; Schiotztonometric IOP > 25.8 mm Hg or IOP 21.9-25.8 and cupped disc
Buhrmann et al ¹ (Tanzania)	3.1 (2.5-3.8)¶	3.6	0.64	VF defect and CDR ≥ 0.5 or asymmetry ≥ 0.2 or end-stage cupping
	1.7 (1.3-2.2)¶#	NA	0.36#	
Present study (Hlabisa)	2.8 (1.8-4.2)	3.2	0.44	
David and Stone ¹⁵ (Tswana)	2.5 (1.6-3.6)¶¶	2.9	0.43	VF defect and CDR ≥ 0.5 or end-stage cupping
Wallace and Lovell ¹⁹ (Jamaica)	1.4 (0.6-2.7)¶¶	NA	NA	Aged 35-74 years; VF defect and cupped disc
Bartholomew ⁴ (Pondoland)	1.1 (0.7-1.6)¶	0.9	0.20	Not random sample; VF defect and CDR ≥ 0.6

*Subjects are 40 years and older unless otherwise indicated. Standardization used the Barbados Eye Study of Leske et al¹⁶ as a reference population. Variations in diagnostic criteria are noted. POAG indicates primary open-angle glaucoma; CI, confidence interval; VF, visual field; IOP, intraocular pressure; CDR, cup-disc ratio; and NA, not applicable.

†Adjusted by direct standardization against the census population of Leske et al¹⁶ (including nonparticipants), and adjusted for age and sex where sufficient information was available (ie, Neumann and Zauberman,¹⁸ Leske et al,¹⁷ Bartholomew,⁴ Mason et al,¹⁶ and the present study) and for age alone (Tielsch et al,¹⁴ David and Stone,¹⁵ and Buhrmann et al¹).

‡Indirectly standardized using age- and sex-specific prevalences of the black/mixed rate of population of Leske et al.¹⁶

§All studies except that of Neumann and Zauberman¹⁷ defined angle open by results of gonioscopy.

¶Simple random sampling methods are assumed.

¶¶Assumes exfoliative cases are included in the definition of POAG.

#VF defect and CDR ≥ 0.7 .

standardized prevalences in a range of African communities are remarkably similar to one another, but are less than in the US black population, and considerably lower than in Barbados and St Lucia in the West Indies.

Important differences in the prevalence of other types of glaucoma in different parts of the continent of Africa are also becoming apparent. Primary ACG was an uncommon finding in this Zulu population, with a prevalence in line with that in most reported white populations. This finding contrasts with the results of some of the other cross-sectional studies in African and African-derived populations in which prevalences as high as 1.0% have been reported^{1,14,15,20} and in which up to 28.9% of primary glaucoma was narrow angle in type.

Glaucoma in association with exfoliation syndrome was found to be the principal contributor to the relatively high rate of secondary glaucoma in the Hlabisa district and was the next most prevalent form after POAG. Exfoliative glaucoma is said to be rare in the US black population,^{21,22} and no case was found in rural Tanzania.¹ This confirms previous impressions that exfoliative glaucoma is particularly common in the Bantu peoples of South Africa.^{4,23}

These results stress the importance of avoiding the assumption that findings in one population of African origin can necessarily be extrapolated to others.

Recent investigators have demonstrated that the prevalence of POAG is sensitive to changes in definitions and diagnostic criteria, and so comparisons of prevalence rates between surveys must take into account differences in the diagnostic tests and their interpretation.²⁴ In the Hlabisa study, a simple, objective diagnostic scheme was used that had a number of strengths. It was easy to apply and flexible enough to take account of the relatively large number of subjects with advanced glaucoma in whom visual field testing could not be performed and in whom evidence of more severe structural damage was required to make the diagnosis. The scheme used clear and concise cutoff points that could easily be transposed onto data from other studies. The use of more than 1 level of severity of structural damage to the optic nerve allowed us to estimate a prevalence of glaucoma had visual field testing not been performed. This method has the potential to be extremely useful for direct comparison with studies in similarly inaccessible populations where visual field testing may not be possible for logistical reasons.

The diagnostic criteria used in Hlabisa were strictly applied and were quite conservative in relation to those of other studies. As a result, it is fairly certain that virtually all cases identified as glaucoma were genuine, and, if anything, the prevalences presented herein are minimum estimates. From the point of view of a resource-poor country in which early disease is almost never diagnosed or treated in a clinical practice, it is more useful from the public health perspective to err in this direction. The conservative nature of the diagnostic criteria, in addition to the lack of treatment, may explain the observed high proportion of blindness in glaucomatous eyes.

The results from the Hlabisa district, although somewhat sensitive to changes in the diagnostic algorithm, appeared to be more robust than those previously

reported. Thus, shifting the cutoff point for the minimum disc requirement from a vertical CDR of at least 0.7 down to at least 0.5 increased the prevalence of POAG only from 2.7% to 3.3%, and that for secondary glaucoma was unchanged. In the study in Tanzania, the same alteration to the diagnostic criteria increased the prevalence from 1.7% to 3.1%.¹

Migrant workers were excluded from the study population for logistical reasons, since many rarely return home. Assuming that they were healthy, the study sample might be expected to have disproportionately more eye disease. This effect was mitigated by the low prevalence of glaucoma and blindness in subjects younger than 50 years, who constitute most of the migrants.

The results of this study indicate that glaucoma is a significant health problem in this rural Zulu population. Although cataract not treated by operation remains the principal cause of blindness, glaucoma was a contributory factor in almost one third and was exclusively the cause in more than 20%. In an area free of onchocerciasis and trachoma, glaucoma was thus the second most important blinding disease. With considerable emphasis now being placed on the provision of cataract surgery among the indigenous people of South Africa, and with the population aging at a rapid rate, the prevalence and proportion of blindness due to glaucoma are likely to increase still further.

Case finding in glaucoma remains a considerable challenge. In this virtually untreated group of subjects with glaucoma, more than half of those with POAG had an IOP of no greater than 2 SDs above the mean for this population, which confirms findings reported previously that IOP measurement has only limited predictive value in the detection of primary glaucoma. The high proportion of normal-tension glaucoma in this population is in keeping with that in Tanzania,¹ where the mean IOP in POAG was only 17.7 mm Hg, but contrasts with findings in, for example, Barbados. In the Barbados Eye Study, only 30% of cases had normal tension.²⁵ The IOP in the nonglaucomatous population of Barbados ranged from 3 to 4 mm Hg higher than in healthy Zulus or Tanzanians.

Identifying cases early in the course of the disease requires sophisticated psychophysiologic tests,²⁶ and those currently available are not appropriate for use in this type of community. Despite the relatively high level of visual loss among the subjects with glaucoma identified in this study, very few had sought a clinical opinion or had received a previous diagnosis. Given the limited resources, a realistic short-term goal should be the prevention of a greater proportion of patients becoming blind in both eyes because of a failure to seek treatment when sight is lost in the first eye. This could be approached by increasing awareness of the need for early treatment, and further studies to examine why the population fails to seek health care would be useful.

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