Prevalence of Glaucoma in a Rural East African Population

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Purpose. To determine the prevalence of glaucoma in an adult population in rural central Tanzania.

Methods. Six villages were randomly selected from eligible villages in the Kongwa district, and all residents more than 40 years of age were enumerated and invited to a comprehensive eye examination including presenting visual acuity, refraction, automated 40-point Dicon (San Diego, CA) suprathreshold screening field test, Tono-Pen (Bio-Rad, Inc., Boston, MA) intraocular pressure (IOP) measurement, and standardized examination by an ophthalmologist of anterior segment, optic nerve head, and retina after pupil dilation. Gonioscopy and Glaucoma-Scope (Ophthalmic Imaging Systems, Sacramento, CA) optic disc imaging were performed on those with IOP higher than 23 mm Hg and cup-to-disc ratio (c/d) more than 0.6 and on a 20% random sample of participants.

Results. Of 3641 eligible persons, 3268 (90%) underwent ophthalmic examination. The prevalence of glaucoma of all types was 4.16% (95% confidence interval [CI] = 3.5, 4.9%). Primary open-angle glaucoma (OAG) was diagnosed in 3.1% (95% CI = 2.5, 3.8%), primary angle-closure glaucoma (ACG) in 0.59% (95% CI = 0.35, 0.91%), and other forms of glaucoma in 0.49%. The prevalence of glaucoma was found to be sensitive to changes in the diagnostic criteria.

Conclusions. The high prevalence of OAG in this group was similar to that of African-derived persons in the United States but less than in African-Caribbean populations. ACG was more prevalent in east Africans than suggested by anecdotal reports. (*Invest Ophthalmol Vis Sci.* 2000; 41:40–48)

Glaucoma is now estimated to be the second most prevalent cause of blindness worldwide after cataract,[1,2] causing a similar magnitude of blindness to that resulting from trachoma. The prevalence of open-angle glaucoma (OAG) has been evaluated in a wide variety of European-derived populations,[3–12] as well as in some African-derived populations in the United States and the Caribbean.[7,13–15] OAG is more prevalent among persons derived from Africa than among Europeans, as reported in several studies, one of which directly compared equal-sized samples of white and black persons.[7] However, there is considerable variation in OAG prevalence among black populations and no published, population-based study of black persons in Africa has used optic nerve and visual field examinations.

Angle-closure glaucoma (ACG) is reported to be much less common than OAG among Europeans[3–12] but is more prevalent than OAG among some Asian populations.[16–20] Asians appear to have rates of OAG similar to those of Europeans. The prevalence of ACG has not been as widely studied in black African and African-derived persons as OAG. Although the prevalence of ACG in this group is said to be low, no published, population-based data exist to provide appropriate estimates.

We report the prevalence of glaucoma in a survey of ocular disease among adults in central Tanzania. To study the prevalence of OAG and ACG, detailed definitions must be used that depend on ophthalmic examinations performed by highly skilled ophthalmologists. Differences in reported glaucoma prevalence may result from differences in glaucoma definitions and examination methods. To facilitate comparisons between these estimates and those in other populations, we endeavored to use simple definitions based on repeatable methodology and objective interpretation of findings. To determine the glaucoma disease status of subjects in our survey, we used tonometry, gonioscopy, automated visual field testing, optic disc imaging, and a complete examination by an ophthalmologist.

Methods

Our subjects resided in villages of the Kongwa district, Tanzania, an area with an estimated population of 300,000, the

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majority of which is Wagogo, an ethnic group of Bantu derivation. They live in rural villages of fewer than 10,000 persons, where most are engaged in nonmechanized agriculture. Trachoma is endemic in this region, where the dry season lasts 8 months, and water supplies are scarce. From 1987 to the present, the district has been the site of a blindness prevention and research program, performed by the Ministry of Health, the Central Eye Health Foundation, Helen Keller International, the Edna McConnell Clark Foundation, and the Dana Center for Preventive Ophthalmology. Past programmatic activities have focused chiefly on cataract and trachoma. The present project was the first population-based examination of a large number of men and women to target glaucoma as well.

There are 33 villages in the district within 1 hour of Kongwa town. We excluded from the sampling frame five villages that have active primary eye care programs, one village with a foreign-funded clinic, and the larger town of Kongwa. From the remaining 26 villages, 6 were selected at random. A house-to-house census of all persons 40 years of age or more was conducted in each village 1 to 3 months before the beginning of examinations. Age was based on self-report with the aid of a calendar of important events in Tanzanian history. All eligible adult residents were offered an examination.

In each village, the program was approved by elected officials, and individual consent was obtained from each participant. Schools or other public facilities were improved at study expense to provide examination locations, and a portable generator was used to power electrical instruments. The program was approved by the Johns Hopkins University Joint Committee for Clinical Investigation and the National Blindness Prevention Committee of Tanzania. It followed the tenets of the Declaration of Helsinki.

The study examinations were conducted over a 6-month period in 1996 by an ophthalmologist (RRB), three nurses with specific training in ocular diagnosis and treatment, a refractionist, and study technicians who performed visual field tests, visual acuity measurements, and fundus imaging. Pilot information on some examination techniques was reported previously.[21] Didactic and practical training of team members occupied 1 week, followed by pilot examinations in a nonstudy village. All employees passed rigorous certification tests before study examinations.

Visual acuity was measured at 4 m using a tumbling-E early-treatment diabetic retinopathy study (ETDRS) chart (Lighthouse, New York, NY) in ambient illumination with presenting correction, if any. In persons with acuity less than 6/18 in either eye, retinoscopy and subjective refraction were performed by a ophthalmic optician. Two measurements of seated blood pressure were taken with a random zero sphygmomanometer.

Visual field testing was attempted on every eye with 6/60 acuity or more, using the Dicon LD400 automated instrument. A threshold-related, suprathreshold screening program (Dicon 1) was administered with single-stimulus presentations at 40 locations per eye in the central 25° with best distance refraction and a +3 add. The test has a red, moving fixation target that stops before the presentation of a green target light 0.43° in diameter and 5 dB higher than expected threshold, corrected for eccentricity. Threshold was measured at selected points to determine the expected hill of vision in each eye. The subject signaled detection of the target by pressing a handheld button. The instrument was programmed to give audible instructions in the Kigogo or Kiswahili languages. The first tested eye was selected randomly, and the subject underwent testing in that eye, the fellow eye, and then the initial eye again. The first test was discarded to minimize the learning effect. If two or more adjacent points in the same hemifield were found abnormal in an eye, the full test was repeated in that eye. Therefore, all subjects whose vision was more than 6/60 in both eyes had three field tests and 1264 or 3091 (41%) had four or five tests, all on the same day. A reliable test had less than three false-positive results and a hill-of-vision index less than +2 dB. This index estimates the average threshold of the subject field based on the four initial test points relative to the proprietary expected value, with positive values denoting higher sensitivity than expected. A probable visual field defect was defined as two contiguous, abnormal points in both field tests of that eye, with one of the abnormal points shared between the two field tests. A definite field defect was defined as three or more contiguous points abnormal in both tests of that eye, with at least two points of a cluster being the same in the two fields. Contiguous points were required to cluster in the same upper or lower hemifield. Field defects were not attributed to glaucoma in eyes with clinical grading of nuclear cataract equal to or worse than photograph NC4 of the Lens Opacities Classification System (LOCS) III,[22] or with corneal scarring that obscured the view of the iris, or in those with retinal or congenital optic nerve lesions that would explain the field abnormality. Field test results were printed for clinical use, and a digital copy of field tests was stored.

Intraocular pressure (IOP) was recorded with a calibrated Tono-Pen by an eye nurse under topical proparacaine hydrochloride 1% anesthesia. The instrument gives the mean of four recordings and three such means (a total of 12 measurements) were obtained per eye, with the initial eye chosen at random. The IOP reported is the mean of the three recorded measurements.

The eye nurse also performed semiquantitative, anterior chamber depth estimation with a hand light and trachoma grading using the World Health Organization Simplified Grading Scheme with a hand light and loupe magnification. Next, the pupil was dilated, unless a hand light test indicated that the anterior chamber was shallow or the mean IOP was higher than 23 mm Hg. In these participants and in a 20% random sample, the ophthalmologist was consulted, and gonioscopy was performed before dilation.

Gonioscopy was performed initially with a Posner, four-mirror lens. All eyes with Shaffer grade I (narrow) or closed angles also underwent indentation gonioscopy, followed by gonioscopy with a Goldmann three-mirror lens. The angle was graded by recording the number of clock hours represented by each of five Shaffer grades (from grade 0 to grade IV) when viewed without indentation. Synechiae and other abnormalities were noted. The angle was deemed to be closed when the posterior trabecular meshwork was obscured by iris apposition. Gonioscopy was also performed after pupil dilation on persons with c/d of more than 0.6 in either eye. Participants with one or more clock hours of closed or grade I angle were requested to return the next day for repeat gonioscopy. All participants were counseled to return immediately should they have pain, redness, or decreased vision.

The ophthalmologist recorded any abnormalities of the conjunctiva, cornea, anterior chamber, iris, and lens by slit lamp examination. After dilation of the pupil, the ophthalmol-

ogist graded nuclear, cortical, and posterior subcapsular cataract by comparison to standard photographs based on an adaptation of the LOCS III system[22] under consideration by the World Health Organization for use in prevalence studies. Also examined were the posterior pole with specific notation of macular degeneration, epiretinal membranes, artery, and vein occlusions, diabetic retinopathy, sickle retinopathy, toxoplasmosis, and retinal detachment.

The optic disc was examined by both the ophthalmologist and an eye nurse. The ophthalmologist used a handheld, 78-D lens and 10× eye piece of the slit lamp (or indirect ophthalmoscopy where media clarity were impaired) for stereoscopic evaluation of the vertical optic disc and cup diameters with an eyepiece micrometer scale. From these measurements, the vertical c/d was calculated. Also noted were the presence of notching of the disc rim (defined as complete loss of neuroretinal rim over one or more clock hours in the superior or inferior quadrants), or optic pits, disc drusen, and disc hemorrhage. A sample of 40 persons was asked to return for repeat c/d measurements by the ophthalmologist with pupil dilation on a second day. The agreement between the two gradings was judged by the κ statistic. When exact agreement was valued as 1.0 and a difference between gradings of 0.1 was valued as 0.8, the κ weighted in this manner was 0.85.

The ophthalmologist had also been trained in the clinical evaluation of the retinal nerve fiber layer and in all subjects with c/d more than 0.6, nerve fiber layer was graded as definite atrophy (corresponding to level D3), probable atrophy (D2), or normal (D0 or D1).[23]

The eye nurses evaluated the optic nerve using a direct ophthalmoscope through a dilated pupil. They had undergone a 2-day training session on evaluation of the optic nerve head in glaucoma, including training in the spectrum of optic disc findings in glaucoma, practical grading by comparison to a series of optic disc photographs,[21] and identifying c/d by direct ophthalmoscopy after pupil dilation in normal and glaucomatous persons.

Finally, the optic disc was imaged with the Glaucoma-Scope (Ophthalmic Imaging Systems, Sacramento, CA)[24] in all persons with any of the following features: angle closure, c/d more than 0.6, or IOP higher than 23 mm Hg. In addition, images were obtained from the same 20% random sample of participants who underwent gonioscopy. The Glaucoma-Scope was customized to be portable, with data acquisition from its imaging head onto a commercial video camera. Video images were obtained by a team member who was trained to recognize the appearance of the optic disc. Optimal single images for each eye were selected to estimate c/d.[24]

The definition of primary OAG for this survey depended on the grading of the optic disc by the ophthalmologist, the visual field finding, the absence of an occludable angle as detailed below, and the absence of a secondary cause for glaucoma. We present three levels of definition for primary OAG: The first (definition 1) defines glaucoma only by the optic disc finding by the ophthalmologist. The following structural features, when present in at least one eye, defined a person as having OAG: c/d 0.9 or higher; or c/d higher than 0.7 with one or more of the following additional features: a definitely abnormal nerve fiber layer, at least one clock hour of complete rim loss (notch), or c/d asymmetry between eyes of 0.3 or more in eyes that had less than a 0.2-unit difference in disc diameter, measured by the Haag–Streit eyepiece micrometer (Zeiss, Inc., New York, NY). This definition would allow comparison of glaucoma prevalence to studies in which no field test was performed.

A second level of diagnosis for OAG (definition 2) included persons with the structural features described, and in addition, included those who had in at least one eye a definite, reliable visual field abnormality (according to the listed definitions) and had a c/d of 0.7 or more or a c/d asymmetry between fellow eyes of 0.2 or more (not explained by a disc diameter difference of 0.2 units on a standard Haag–Streit eyepiece micrometer).

A third level of diagnosis for OAG (definition 3) included those in definitions 1 and 2, but it also included those who had at least one eye with c/d of 0.5 or more and a definite, reliable field defect. This definition is, in our opinion, closest to the diagnostic criteria of the Baltimore Eye Survey. Therefore, the optic disc and visual field finding were used for diagnosis in every subject in which these were both available. Note that a few subjects were included as having OAG based on satisfying the definition 1 criteria for optic disc abnormality alone if they did not qualify for field testing or could not perform it reliably.

For the purpose of defining ACG, an occludable angle was said to be present in an eye with six or more clock hours of angle closure, defined as no view of the posterior trabecular meshwork. This determination was made without indentation gonioscopy. Peripheral anterior synechiae were identified by indentation gonioscopy and were considered to be corroborating evidence for angle occlusion.

Primary ACG was diagnosed in a person if one eye had primary occludable angle and also had one or more of the following criteria in that eye: IOP higher than 24 mm Hg, structural optic disc abnormality (see definition 1 for OAG), definite, reliable visual field damage, or a history compatible with an episode of acute angle closure or the development of an episode at examination. In addition, the fellow eye had to have an angle that was Shaffer grade 2 or less in at least eight clock hours.

OAG or ACG that was thought to have resulted from another ocular or systemic condition was labeled secondary glaucoma. A final group, called indeterminate glaucoma, was diagnosed in persons with one or more eyes with a vision of less than 3/60 and an IOP higher than 30 mm Hg in whom gonioscopy, disc examination, and field testing were not possible because of media opacity.

All study data were recorded on standard forms, checked for completeness, and entered into a database using customized software with range and value checks. Entered data were checked against original data forms for accuracy. Data analysis was performed with SAS statistical software for univariate and multivariate regression analysis (SAS, Cary, NC).

Results

Of 3641 persons identified in the census, 3268 persons began the examination process, and 3247 (89.2%) completed it. Study participants had an average age of 53.3 years, showed a slight female preponderance (55.4%; 1810/3247) and demonstrated the steep decline in population by decade typical in the developing countries (Table 1). Study participants resembled the eligible population closely, and participation was similar over all age groups, ranging from 87.5% to 91.1% (Table 1), and was

TABLE 1. Demographic Information on Sample

	Participants	Non-participants	% Participation
Mean age (y)	53.3 ± 10.9	52.7 ± 11.3	
Median age (y)	50	50	
Range (y)	40–99	40–99	
Male (*n,* %)	1456 (44.6)	214 (58.0)	87.2
Female (*n,* %)	1810 (55.4)	155 (42.0)*	92.1
Age groups (*n,* %)			
40–49	1371 (42.0)	165 (46.2)†	89.3
50–59	976 (29.9)	95 (26.6)	91.1
60–69	555 (17.0)	56 (15.7)	90.0
70–79	268 (8.2)	28 (7.8)	90.5
80 and over	91 (2.8)	13 (3.6)	87.5
Total	3268	373	89.8

* In eight persons, gender information was missing.
† In 23 persons, age information was missing.

slightly higher in women (92.1%; 1810/1965) than in men (87.2%;1456/1670; $P < 0.001$). Participation rates in the six study villages ranged from 84% to 94%.

The means ± SDs of IOP in the right and left eyes were 15.7 ± 4.3 mm Hg and 15.4 ± 4.5 mm Hg, respectively (3195 persons; $P > 0.05$). These values were not altered if those defined with glaucoma were removed. The distribution was skewed slightly toward higher IOP (Fig. 1), and the 97.5 percentile was 24 mm Hg. The mean IOP was similar for men (15.5 ± 4.0 mm Hg) and for women (15.6 ± 4.2 mm Hg; $P > 0.05$).

The mean c/d was 0.41 ± 0.16 in right eyes and 0.40 ± 0.16 in left eyes, as measured by the ophthalmologist in 3067 right and 3032 left eyes. It was not possible to visualize the optic nerve head in either eye in 79 participants (2.4%) because of opacities of the ocular media. Only 5.6% of left eyes and 4.2% of right eyes equaled or exceeded a c/d of 0.7. Asymmetry in c/d between fellow eyes higher than 0.2 occurred in fewer than 2.5% of persons (among 2929 persons with visible discs in both eyes). For both right and left eyes, higher IOP was significantly associated with a higher c/d. For each 1 mm Hg higher IOP, c/d increased by 0.008 units ($P = 0.001$; linear regression, $R^2 = 0.04$), indicating that much of the variance in c/d is explained by factors other than IOP.

The c/d gradings of eye nurses using direct ophthalmoscopy were compared with the gradings by the ophthalmologist using a 78-D lens and a slit lamp. Both the Pearson and Spearman correlation coefficients were significant (each 0.65; $P < 0.0001$). A weighted κ statistic was calculated with the gradings by the ophthalmologist rounded to the nearest 0.1 c/d unit. Differences between nurse and ophthalmologist gradings were given the following weights (0.1 = 0.75, 0.2 = 0.5, 0.3 = 0.25), yielding a weighted κ of 0.46. Subjects were divided into persons with c/d in one or both eyes of 0.7 or more, compared with those with c/ds in both eyes less than 0.7. The sensitivity and specificity of identifying those with a c/d of 0.7 or more by all nurses combined were 53.6% (81/151) and 95.4% (2197/2303), respectively.

A Glaucoma-Scope image was attempted in 736 eyes, but in 18% (130/736) no image could be obtained, most frequently because of opaque media from corneal opacity and cataract, both common causes of visual impairment in this population. Of images that were obtained, 82.1% (497/606) could be ana-

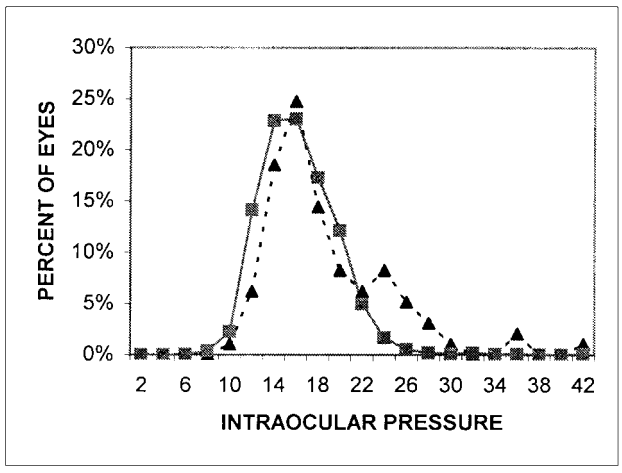

FIGURE 1. The mean IOP of the right and left eyes for normal subjects without any of the forms of glaucoma (■). There is a modest skew toward higher IOP. The distribution of mean IOP in the two eyes of 97 persons with primary OAG (▲) had more persons with higher IOP, but the distribution overlapped that of normal subjects considerably.

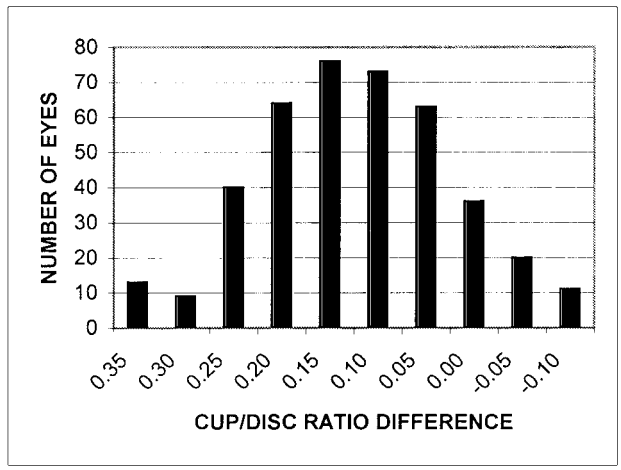

FIGURE 2. The difference between the c/d derived from the Glaucoma-Scope (Ophthalmic Imaging Systems, Sacramento, CA) and the ophthalmologist was normally distributed, with a larger estimate by the instrument of 0.11 units.

TABLE 2. Prevalence of primary OAG

	% Prevalence (CI)	*n*
Optic disc criteria only (Definition 1)	1.2 (0.8,1.6)	38
Optic disc criteria and definite field defect (Definition 2)	1.7 (1.3,2.2)	56
Definite field defect and compatible disc (Definition 3)	3.1 (2.5,3.8)	100
Total nonglaucoma (under Definition 3)		3116

CI, 95% confidence interval; *n,* number of persons.

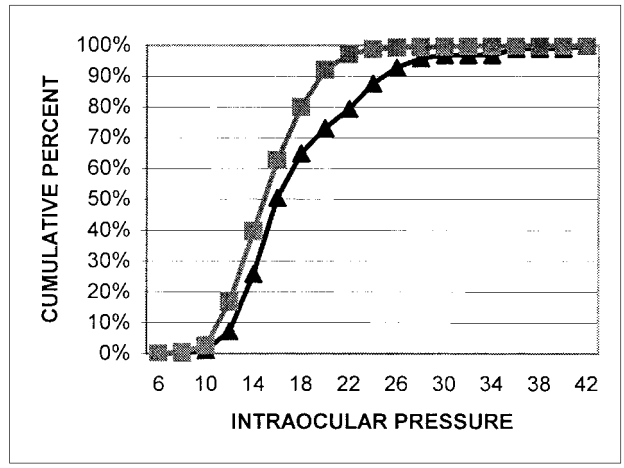

FIGURE 3. Cumulative percentage curves were constructed for increasing IOP levels as a method to compare the normal participants (■) and the subjects with primary OAG (▲). Although the OAG group had more persons with higher IOP, 75% of them had IOP less than 22 mm Hg.

lyzed (overall analyzed proportion 67.5%, 497/736). There was significant correlation between the assessment of c/d between ophthalmologist and the imaging instrument ($P = 0.001$, regression $R^2 = 0.55$). The Glaucoma-Scope graded the vertical c/d 0.11 units higher on average than did the ophthalmologist (Fig. 2), and measurement differences were normally distributed.

Visual fields were obtained in at least one eye of 3091 persons, or 98.3% of participants with visual acuity 6/60 or more in at least one eye. A total of 10,558 field tests were analyzed. The test result was considered definitely abnormal in 11.5% of participants (355/3091), indicated by three adjacent abnormal points in two consecutive field tests with two shared points in the abnormal clusters. Using definition 3 for OAG and including all forms of glaucoma, the positive predictive value of an abnormal field test result in at least one eye was 19.1% (115/355). The specificity of these field criteria was 90.3% (2688/2976 persons not defined as having any form of glaucoma). Mean test time per eye was 2 minutes, 25 seconds ± 41 seconds (SD).

The prevalence of OAG with each of the three definitions is given in Table 2. With the most inclusive definition (3), 3.1% of adults had primary OAG. Of these 100 persons, 39 were men and 61were women. The proportion of men to women did not differ between OAG subjects and the remainder of the examined population ($P = 0.24$). The prevalence of OAG was successively lower under definitions 2 and 1 than with definition 3 (Table 2). OAG prevalence increased with age among those 40 to 70 years of age (Table 3). In those more than 80 years of age, the age-specific prevalence failed to increase; however, there were only 91 persons of this age in the examined study population. Of those defined as primary OAG (definition 3), only 2/100 had previously received medical or surgical treatment for their disease. Those with primary OAG (definition 3) were significantly older than the general sample, 57.7 years compared with 53.0 years ($P < 0.0002$). Their mean IOP was also higher, 17.7 mm Hg compared with 15.3 mm Hg for non-OAG ($P < 0.0001$; Fig. 3). Interestingly, the OAG subjects identified by the more restrictive definition 1 were even older (mean, 62.9 years) and had a higher mean IOP, 21.3 mm Hg.

The IOP level among those not classified as having glaucoma was higher in older age groups ($P = 0.04$), although the estimated increase with age was very modest (0.25 mm Hg/decade) in univariate linear regression analysis. With age and systolic blood pressure included in the model, systolic blood pressure was positively associated with IOP (regression constant: mm Hg IOP/mm Hg blood pressure; $P = 0.0001$), but age was not. Systolic blood pressure was significantly associated with the presence of primary OAG adjusted for age ($P < 0.01$). Diastolic blood pressure and perfusion pressure (difference

TABLE 3. Age-Specific Prevalence of Primary OAG (Definition 3) in Kongwa and among Black Persons in the Baltimore Eye Survey and Barbados Eye Study

	Kongwa		Baltimore		Barbados	
Age	***n***	**% (CI)**	***n***	**% (CI)**	***n***	**% (CI)**
40–49	23	1.7 (1.1, 2.5)	6	1.0 (0.4, 2.1)	18	1.4 (0.8, 2.2)
50–59	31	3.2 (2.2, 4.5)	25	3.6 (2.3, 5.3)	45	4.1 (3.0, 5.4)
60–69	26	4.7 (3.1, 7.0)	31	5.1 (3.4, 7.2)	71	6.7 (5.3, 8.4)
70–79	15	5.6 (3.1, 9.2)	27	7.7 (4.9,10.5)	122	14.8 (12.5,17.4)
≥80	4	4.4 (1.2, 11.3)	11	10.9 (4.8,17.0)	52	23.2 (17.9,29.3)
Overall	3.0		3.3*		4.8*	
Total sample†	3247		2395		4314	

CI, 95% confidence interval; *n,* number of subjects with glaucoma in each subject group.

* Direct adjusted to Kongwa population.

† Sample size of African-derived persons in each study. Due to missing age data for one subject, the number of those with glaucoma in the present study (Kongwa) is 99 persons.

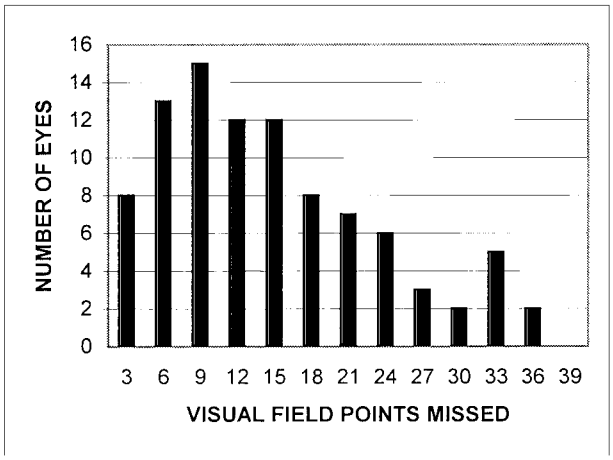

FIGURE 4. The number of missed points in the worse eye on Dicon screening perimetry among 93 primary OAG subjects. The data derive from only the first test on each eye and represent the total number of abnormal points per eye, regardless of whether the points are adjacent. On the *x*-axis, less than three indicates fewer than three total defects (zero, one, or two), less than six indicates three to five defects, less than nine indicates six to eight defects, and so on. Note that the severity of involvement was distributed rather evenly.

between diastolic and IOP) were not significantly correlated with presence of OAG, adjusted for age.

The distribution of damage among the OAG subjects can be evaluated by the distribution of the number of abnormal field test points. Of 100 OAG subjects, 95 had at least one eye qualified for field testing (acuity >6/60), and 93/95 (98%) completed the initial series of three field tests. Among those with OAG (definition 3), 85/93 (92%) had three or more abnormal points in the first field test of their worse eyes (Fig. 4). The eight eyes with two or fewer abnormal points were defined as having OAG due to severe glaucoma damage in the fellow eyes, which were disqualified from field testing because of poor visual acuity. Normal subjects without any form of glaucoma had a median value of two abnormal field points and more than 75% of normal subjects had six or fewer missed points in their worse eyes.

The prevalence of primary ACG was 0.58% (95% CI = 0.35, 0.91%), representing 19 persons. There were 6 men and 13 women with primary ACG (0.42% of men and 0.73% of women examined; $P = 0.36$, Fisher's exact test). Prevalence of ACG appeared to increase with age, but again, the limited number of affected persons produced no statistically significant trend (mean age of subjects with ACG, 57.6 years, normal subjects, 53.1 years; $P = 0.07$, *t*-test). Of those defined as having primary ACG, none had previously been made aware of the disease, nor had any received medical or surgical treatment. Four persons in this group had a history compatible with past acute episodes of high IOP (all untreated), and one person had a episode that occurred after dilation at the examination site (and was treated medically, followed by iridectomy). The mean IOP among eyes with primary ACG was 32.3 ± 9.0 mm Hg (significantly higher than normal, $P = 0.0001$); however, this is at least in part due to the inclusion of IOP levels of more than 24 mm Hg as one confirming criterion for the diagnosis.

The prevalence of secondary and indeterminate forms of glaucoma is given in Table 4. Among the individual groups of patients with secondary glaucomas, there were no significant associations with gender, but for all 135 persons with glaucoma of any type (including primary OAG here as definition 3), 86 were female and 49 male, a prevalence proportion of 1.41 for all persons examined ($P = 0.05$). Pigment dispersion syndrome and exfoliation syndrome were not detected in any person.

Persons were considered to have suspected glaucoma if they had either ocular hypertension or narrow angles detected by gonioscopy. There were 88 persons (2.7% of 3227) with IOP of 24 mm Hg or more in at least one eye who did not qualify as having glaucoma in any form. There were 10 persons (0.3% of 3268 persons examined) who had one half or more of the angle that was judged to be closed by gonioscopy but who did not meet the criteria for having ACG (i.e., there was an absence of IOP, disc, field, or historical corroboration).

Those with primary OAG by definition 3 were categorized in terms of the degree of visual impairment as measured by visual acuity and visual field defect. In the entire sample there were 123 persons with better acuity in either eye worse than 3/60. In each person, the ophthalmologist ascribed the most likely cause of blindness to each eye. There were 5 persons bilaterally blind due to primary OAG by this criterion (5/100, 5% of those with primary OAG; 5/3271, 0.15% of those examined) and 12 persons had at least one eye blind due to glaucoma (12/100, 12% of primary OAG; 12/3271, 0.37% of those examined). All those who were bilaterally blind due to OAG were identified under definition 1, and among them, the proportion of those with OAG under definition 1 was 5/39 (12.8%). Among those with primary ACG, bilateral blindness was present in 21% (4/19), and in those with secondary or indeterminate glaucoma, bilateral blindness was ascribed to glaucoma in 25% (4/16). The proportion of the total sample who were bilaterally blind due to any of the forms of glaucoma was 0.40% (13/3271), and for monocular glaucoma blindness it was 0.89% (29/3271).

We also calculated the proportion blind by either reduced acuity or by severely abnormal suprathreshold visual field among the primary OAG (definition 3) group. Blindness by field criteria alone was defined as having a better eye with at least 3/60 acuity that missed more than 30 of 40 points on the Dicon field. This assured that the field included major loss, including within the central 10°, or that the remaining central island was smaller than 10°. Because our tests did not quantify the severity of defect, we were not able to determine whether defects were relative or absolute; therefore, we may have overestimated field blindness. There were six persons (6/100, 6%) from the primary OAG group (definition 3) who satisfied

TABLE 4. Prevalence of All Forms of Glaucoma

	Number	% Prevalence (CI)
Primary OAG (definition 3)	100	3.08 (2.5, 3.8)
Secondary OAG	2	0.06 (0.01, 0.22)
Primary ACG	19	0.59 (0.35, 0.91)
Secondary ACG	3	0.09 (0.02, 0.27)
Indeterminate	11	0.34 (0.17, 0.61)
All forms of glaucoma	135	4.16 (3.5, 4.9)

CI, 95% confidence interval.

Proportions based on data for 3247 persons examined and in whom sufficient information was obtained for glaucoma diagnosis (21 others were examined but had missing data for this analysis).

this criterion in the better eye. Thus, 11% (11/100) of primary OAG subjects were bilaterally blind, either from acuity < 3/60 (five persons) or by virtue of severe field loss (six persons).

Discussion

The prevalence of primary OAG (definition 3) in Kongwa was remarkably similar to that of African-derived persons in East Baltimore and Barbados among those 40 to 70 years of age. The criteria of definition 3 appear similar to those used in the latter two studies, although exact comparability cannot be assured because of the variation in methods. In each study, field testing was attempted in all subjects who were not blind by acuity criteria; however, a different perimeter was used in the three projects. Both the Baltimore and Barbados studies screened all subjects with versions of a suprathreshold field test, the Full Field 120 screening test of the Humphrey perimeter (Humphrey Instruments, San Leandro, CA). Baltimore subjects had field defect confirmation by manual Goldmann field tests, whereas the Barbados study used automated Humphrey threshold testing. We chose to repeat the suprathreshold test for confirmation of defect. In the present study, the Baltimore study, and the Barbados study, the definition of OAG included field defect combined with compatible optic disc abnormality without a defining IOP level. In the Baltimore and Barbados studies, the disc was judged from combined clinical examination and stereophotographic analysis, whereas in the Kongwa study a more quantitative clinical examination with measurement of disc and cup was used in all subjects and validated by selective disc imaging.

The higher prevalence in the Barbados study compared with those in the Baltimore and Kongwa studies is primarily due to the higher prevalence in the oldest age brackets in Barbados (Table 3). All three studies had substantially higher rates of OAG at every age than the European-derived populations in the Baltimore survey[7] or in other reports on predominately white populations.[3–6,8–12] This reinforces the concept that persons derived from Africa share a predisposition to OAG that transcends dramatic differences in environmental, cultural, and socioeconomic exposures. Genetic influences are quite likely to explain this increased susceptibility.

The people of central Tanzania were not included in the slave trade to the New World to the same extent as the West African ancestors of the African-derived persons in the Baltimore and Barbados studies. However, they are a Bantu-derived group that shares ancestry with many of the present inhabitants of West African nations.[25] It will be of great interest to determine the prevalence of OAG among persons from other regions of Africa. It should not be assumed that the findings among all Africans will be similar.

The decline in the proportion of prevalent cases of OAG among the oldest age group in Kongwa district is surprising, but given the small numbers of eligible persons this may be a chance finding. The apparent drop in prevalence was not explained by an inability of the older age group to respond reliably in field tests and there was no reason to suspect selective nonparticipation of persons with glaucoma in this age group only.

Severe visual impairment appears to be a risk factor for mortality in rural Africa,[26] but the prevalence of blindness among persons with glaucoma in this age group is similar to the 16% prevalence of blindness in persons more than 80 years of age. The slightly higher average systolic blood pressure among persons with OAG could not be expected to increase mortality significantly.

Comparisons among prevalence surveys for OAG must consider differences in what tests are performed, what proportion of subjects are examined with each test, how the tests are interpreted, and what final definitions of OAG are implemented. In addition to the Barbados study, two other surveys of predominately black populations have been conducted in Caribbean countries (Jamaica[13] and St. Lucia[14]). Among these, the Jamaica study reported the lowest rates of OAG and in St. Lucia, the rates were highest. However, uniform testing of the visual field in all subjects in these samples was not conducted. Even with an intention to conduct field testing in each participant, a minority of the sample may be unable to give reliable responses with field testing. During the planning of our survey, we were concerned that field tests might be impossible because of practical problems of electrical supply and equipment durability and because of to the inability of our subjects to perform the test. Yet, 75% of our subjects performed a reliable field test, although they had no experience with complex electronic instruments. This supports the idea that field testing is practical among inexperienced observers in developing countries.

The Dicon suprathreshold test used here is a suprathreshold screening method, as is the Full Field 120 Humphrey program used to identify potential glaucoma subjects in the Baltimore and Barbados surveys.[27] To estimate the comparability of our Dicon results to Humphrey threshold, field-defect criteria, we tested subjects with OAG and age-matched normal subjects from the Baltimore Eye Survey Follow-up Study with the Dicon suprathreshold instrument and a threshold Humphrey field test (data presented at the 1998 meeting of the Association for Research in Vision and Ophthalmology, Ft. Lauderdale, FL). Among those with a Humphrey result of "outside normal limits" (Glaucoma Hemifield Test) and an optic disc with damage compatible with OAG, the Dicon test (three adjacent missed points in one hemifield) identified 52% (27/52) of eyes with Humphrey threshold defect, at a specificity of 89%. This is nearly identical with the 52% sensitivity and 90% specificity reported[27] for the optimum screening criterion of the Humphrey 120-point suprathreshold test used in the Baltimore survey. To avoid artificial inflation of OAG prevalence by inclusion of those with spurious field abnormalities, we required that the Dicon criterion be duplicated in the same area on two consecutive field tests in the Kongwa study. This is estimated to improve the specificity of the testing to 95%. Specificity was further increased by eliminating subjects whose abnormal field tests could have resulted from substantial media opacity or retinal findings. The requirement for confirmation in a second field would be expected to reduce sensitivity somewhat, but we have no direct estimates for this, because we did not perform second Dicon fields on the comparison group from the Baltimore Follow-up Study. Instead, we evaluated the effect of liberalizing the field defect criterion from a cluster of three to a cluster of two points, confirmed on consecutive fields (probable field defect, Table 5). Estimated prevalence increased by approximately 50%, but the confidence limits still included the Baltimore and Barbados prevalences.

Furthermore, although our Dicon field testing may underestimate OAG prevalence if used alone, our definitions in-

TABLE 5. Variation in Estimated Primary OAG Prevalence with Different Disc and Field Criteria

	FIELD		
	Definite and Reliable	**Probable and Reliable**	**All Probable**
Definition 2 (cup ≥0.7)	1.7 [1.3, 2.2] (56)	2.2 [1.7, 2.7] (72)	2.2 [1.8, 2.8] (72)
Definition 3 (cup ≥0.5)	3.1 [2.5, 3.8] (100)	4.4 [3.7, 5.2] (141)	4.8 [4.1, 5.6] (154)

Values in brackets are 95% confidence intervals for prevalence, and values in parentheses are the number of persons with glaucoma by that definition. For definition 1, in which no visual field criteria were used and glaucoma was defined only by the optic disc appearance, prevalence was 1.2%.

cluded persons with clearly glaucomatous optic discs, regardless of whether they met strict field defect criteria. Twenty-one of our 100 OAG subjects met definition 1 disc abnormality criteria but did not have reliable, definite field defects or could not be tested because of poor acuity or media opacity. Each of the previous glaucoma prevalence surveys have included those with obvious glaucomatous discs whose field testing was either unreliable or impossible. Finally, our testing of the Baltimore Eye Survey Follow-up population (described above) disclosed that abnormal Glaucoma Hemifield Test results on the Humphrey 24-2 program are found in as many as 30% (85/279) of normal persons. Some of the apparently poor sensitivity of screening tests may derive from falsely positive, threshold field testing.

The IOP distribution of the nonglaucoma population in Kongwa is similar both to black persons in Baltimore[28,29] and to those of European-derived populations.[8,30] Mean IOP in Kongwa was 15.7 mm Hg (right eyes), whereas it was reported as 16.0 mm Hg in Baltimore (African-American subjects) and 17 mm Hg in Barbados (mean of higher IOP eye). The IOP distribution of Asian persons measured by applanation tonometry is lower in than that of either European or African persons.[18–20] Although higher IOP was a risk factor for OAG in the Kongwa population (as in every previous population-based study), the overall population did not have an IOP distribution different from that of Europeans (for example, the Baltimore white population), nor was the IOP distribution of those with OAG higher than that of Europeans with OAG. Thus, the higher prevalence of OAG among African-derived persons must be explained by factors that are additive to IOP.

When the level of IOP among normal persons was correlated with c/d, the higher the IOP, the larger the c/d. This was also found in other population-based studies.[29–30] The resting position of the optic disc surface may be influenced by the prevailing IOP, so that with higher IOP, the disc is forced backward and measured c/d is larger. Alternatively, higher IOP may lead to greater loss of optic nerve fibers among all subjects in a population. Cross-sectional studies estimate that there is an age-related loss of approximately 5000 retinal ganglion cells per year.[31–35] It is possible that this loss is increased with higher IOP, even when IOP is in the normal range.

Imaging devices and video data acquisition can provide validation of the clinical measurements by an experienced human observer. It was impractical to bring a standard fundus camera to the locations where persons were examined for this study. Equipment such as the Glaucoma-Scope can be operated by batteries, allowing digital images to be part of every ocular disease study. The imaging system was operated by a trained employee with the equivalent of a high school education, after a modest training period. Objective screening and validation methods for optic disc and nerve fiber layer findings can contribute to glaucoma diagnosis in field work. Future instruments should be designed for simplicity of operation and low cost.

The level of agreement between the optic disc gradings of ophthalmic nurses and the ophthalmologist was only modest. However, the nurses identified more than half those with c/d of 0.7 or more at a specificity of 95%, after less than 1 week of didactic and practical training, comparing their observations to a standard photographic set of c/d examples on a plastic card.[21] It is possible that improved training could make this approach more suitable for prevalence surveys or screening activities; however, pupil dilation carries the risk of inducing angle closure. In this study, acute angle closure developed in one person after dilation and was promptly treated without complications.

Because treatment for OAG had been given to only 2% of those with OAG in Kongwa, their degree of blindness and visual impairment represents the natural course of OAG. In developed countries, population surveys find that 50% of those with OAG are already diagnosed and have received therapy.[2] Therefore, it is remarkable that the proportion of those who were blind due to OAG was not dramatically higher in Kongwa than among African-Americans in Baltimore. As discussed earlier, selectively greater mortality among the elderly blind may decrease the proportion of examined, impaired persons. However, this finding has implications for the scope of treatment programs for OAG. Eye drop therapy appears impractical at this time, with only laser or surgical interventions as possible IOP-lowering options. We propose that such surgical therapy for OAG in areas similar to Kongwa might be offered only to those at significant risk for blindness, including those with major field loss.

The occurrence of ACG in Kongwa was similar to that observed in the Baltimore Survey. As previously reported,[19–20] the majority of those with primary ACG (72%, 13/18) had development of permanent angle synechiae, optic disc damage, or field loss without a history of an acute episodes. When studied on a population basis, ACG is most often an asymptomatic disease. Screening of IOP, optic disc, and visual field identifies many of those with ACG. However, separation of those with ACG from those with OAG requires gonioscopic evaluation. Improvements are needed in screening methods for ACG.

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