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Epidemiology of glaucoma in Sub-Saharan Africa: Prevalence, incidence and risk factorsFatima Kyari¹, Mohammed M Abdull², Andrew Bastawrous³, Clare E Gilbert³, Hannah Faal⁴,¹ International Centre for Eye Health, Department of Clinical Research, London School of Hygiene and Tropical Medicine, London, UK; Department of Ophthalmology, College of Health Sciences, University of Abuja, Abuja, Nigeria² International Centre for Eye Health, Department of Clinical Research, London School of Hygiene and Tropical Medicine, London, UK; Abubakar Tafawa Balewa University Teaching Hospital, Bauchi, Nigeria³ International Centre for Eye Health, Department of Clinical Research, London School of Hygiene and Tropical Medicine, London, United Kingdom⁴ Africa Vision Research Institute, Durban, South Africa; Calabar Institute of Tropical Disease Research and Prevention, University of Calabar Teaching Hospital, Nigeria**Correspondence Address:**

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Abstract

Purpose: The purpose of this study is to review the epidemiology of different types of glaucoma relevant to Sub-Saharan Africa (SSA) and to discuss the evidence regarding the risk factors for onset and progression of glaucoma, including risk factors for glaucoma blindness. **Methods:** Electronic databases (PubMed, MedLine, African Journals Online- AJOL) were searched using the full text, Medical Subject Headings (MeSH) terms, author(s) and title to identify publications since 1982 in the following areas: population-based glaucoma prevalence and incidence studies in SSA and in African-derived black populations outside Africa; population-based prevalence and incidence of blindness and visual impairment studies in SSA including rapid assessment methods, which elucidate the glaucoma-specific blindness prevalence; studies of risk factors for glaucoma; and publications that discussed public health approaches for the control of glaucoma in Africa. **Results:** Studies highlighted that glaucoma in SSA is a public health problem and predominantly open-angle glaucoma. It is the second-leading cause of blindness, has a high prevalence, an early onset and progresses more rapidly than in Caucasians. These factors are further compounded by poor awareness and low knowledge about glaucoma even by persons affected by the condition. **Conclusion:** Glaucoma care needs to be given high priority in Vision 2020 programs in Africa. Many questions remain unanswered and there is a need for further research in glaucoma in SSA in all aspects especially epidemiology and clinical care and outcomes involving randomized controlled trials. Genetic and genome-wide association studies may aid identification of high-risk groups. Social sciences and qualitative studies, health economics and health systems research will also enhance public health approaches for the prevention of blindness due to glaucoma.

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Available from: <http://www.meajo.org/text.asp?2013/20/2/111/110605>**Full Text****Introduction**

Data from population-based surveys (PBS) indicate that glaucoma is the second leading cause of blindness, accounting for 8% of blindness among the 39 million people who are blind world-wide. [1] In Africa, glaucoma accounts for 15% of blindness and it is the region with the highest prevalence of blindness relative to other regions world-wide [2] (Adapted from Resnikoff, 2004) [2] [Table 1]. In 2006, the number of individuals estimated to be bilaterally blind from glaucoma was projected to increase from 8.4 million in 2010 to 11.1 million by 2020. [3] However, the numbers who are blind is just the tip of the iceberg as there are many more individuals with glaucoma who are at risk of blindness. In 2006, modeling the available data, it was estimated that 60.5 million people world-wide would have glaucoma by 2010, increasing by 20 million by 2020. The Africa region also has the highest incidence and prevalence of glaucoma [3] (Adapted from Quigley, 2006) [3] [Figure 1]. The prevalence of glaucoma is similar among the Caucasian populations of Europe, [4] USA [5],[6] and Australia [7],[8] being less than the prevalence in Latinos in the USA [9] and people of Asian origin. [10],[11],[12],[13],[14],[15],[16],[17] The black populations of the Caribbean, [18],[19] Africa [20],[21],[22],[23] and USA [5] have the highest prevalence of open-angle glaucoma (OAG). [24],[25],[26] Furthermore, there appear to be differences in the prevalence of glaucoma in different black populations in the Caribbean islands and within Africa, [24] which may be attributed to genetic diversity as well as environmental and socio-economic factors. [27],[28] (Table 1)(Figure 1)

Who goes blind from glaucoma is influenced by the age of onset of glaucoma and the natural history [29] as well as access to services, [30],[31],[32],[33] the quality of care provided [34] and adherence to treatment and follow-up. [32],[33] There is some evidence that glaucoma has an earlier age of onset in blacks [5],[35] and has a more aggressive clinical course. [34],[36],[37] In Africa, there are the additional factors of poor awareness, [38],[39],[40],[41],[42],[43],[44],[45] poor access to care, and less than optimal diagnosis and management. [46],[47],[48],[49],[50],[51],[52],[53] Socio-economic deprivation exacerbates the situation, leading to very late presentation. [54],[55],[56],[57],[58],[59] Indeed, in Africa, glaucoma has been referred to as the "silent thief of sight." [60]

Lately, there has been increased momentum about glaucoma care in Africa. At the World Glaucoma Association 1 st Africa glaucoma summit in Ghana in 2010, a decision was made to strengthen and incorporate glaucoma management, training and education into existing programs. [61] The Kampala resolution in 2012 called upon all those involved in glaucoma management "to highlight the importance of controlling vision loss from glaucoma as an integral part of eye healthcare and in health and safety policies." [62]

The purpose of this review is to describe the epidemiology of the different types of glaucoma in Sub-Saharan Africa (SSA). The scope of the review encompasses published data on the prevalence and incidence of glaucoma and discusses the evidence regarding risk factors for the onset and progression of glaucoma, including risk factors for glaucoma blindness. The designation SSA refers to the geographical area of Africa that lies south of the Sahara desert including Sudan and comprises 48 countries [63] and this review also included studies of other black populations outside SSA.

Studying glaucoma in populations has public health implications as it allows identification of potential risk factors for the disease as well as the blinding consequences, enabling control strategies to be targeted to groups most at risk. These, together with clinical intervention studies, inform diagnostic and therapeutic approaches that can be applied to patients with glaucoma, hence contributing to the Kampala resolutions.

Definitions

Glaucoma is an optic neuropathy associated with characteristic structural damage to the optic nerve and associated visual dysfunction, [64] which are seen clinically as enlargement of the optic disc cup and loss of field of vision. It is classified according to the anterior chamber angle morphology into OAG or angle-closure glaucoma (ACG). The morphological classification is very important because the types have different characteristics and present in varying proportions in different populations. OAG and ACG have different natural histories and risk factors

and require different management strategies, hence the importance of gonioscopy in the classification of glaucoma. A further classification is by etiology into primary or secondary glaucoma.

A standard definition and classification system for glaucoma was proposed in 1998 by the International Society of Geographical and Epidemiological Ophthalmology (ISGEO) [64] principally for use in population-based prevalence. The definition considers glaucoma as a group of diseases defined by end-organ (optic nerve) structural damage and functional deficit. In the ISGEO classification, glaucoma is defined by three levels of evidence, regardless of angle morphology (from Foster, 2000) [64] [Table 2]. The highest level of evidence is when both structural damage and functional deficit are seen; that is a large vertical cup:disc ratio (VCDR) and/or asymmetry between the two eyes. A large disc is defined by the distribution of cup:disc ratios in the normal population, an abnormally large disc being defined when it is ≥ 97.5 th percentile of the VCDRs of the normal population. The 1 st level evidence also requires characteristic defects in the visual fields (VF). The 2 nd level requires greater structural damage of the optic disc (i.e., VCDR ≥ 99.5 th percentile, or asymmetry) when VF testing is not possible. The 3 rd level is where VCDRs cannot be assessed and VF testing is not possible and the diagnosis of glaucoma is based on other clinical parameters: most importantly, intraocular pressure (IOP), visual acuity of less than 3/60 on the Snellen's chart and medical history (e.g., previous glaucoma surgery). [Table 2]

Methods

Search methods

Electronic databases (PubMed, Medline, African Journals Online- AJOL) were searched using the full text, Medical Subject Headings (MeSH) terms, author(s) and title to identify the relevant publications. The search terms used were glaucoma, prevalence (in title), Africa (and names of each of the countries) open-angle, angle-closure, blindness, and visual impairment. The search was restricted to publications in the last three decades (from 1982 to 2012) and papers and/or abstracts available in English. The following publications were included: (1) population-based glaucoma prevalence surveys in SSA; (2) population-based glaucoma prevalence surveys or incidence studies in African-derived black populations living outside Africa; (3) population-based prevalence surveys and/or incidence studies of blindness and visual impairment studies in SSA, including rapid assessment methods, which elucidate the cause-specific blindness prevalence due to glaucoma; (4) PBS in SSA and African-derived black populations, which reported risk factors for glaucoma and/or glaucoma blindness; and (5) publications that discussed public health approaches for the control of glaucoma in Africa. Reference lists of cited articles were searched for additional publications not identified by the database searches.

PBS of blindness and visual impairment and rapid assessment of avoidable blindness (RAAB) surveys that did not have data on the proportion of visual impairment or blindness due to glaucoma were excluded. Hospital/facility-based studies were not included.

Strengthening the reporting of observational studies in epidemiology (STROBE) guidelines

Population-based glaucoma prevalence surveys in SSA and black populations living outside Africa were critically appraised using the STROBE guidelines. [65],[66] These guidelines are to assess the clarity of reporting in relation to completeness and accuracy, but are not designed to assess the quality of the research. The completeness and accuracy of the reports aided the interpretation and the generalizability of the results. The 22 key points enumerated on the STROBE checklist for cross-sectional studies were assigned one score each. Some of the key points appraised included: "presenting key elements of study design early in the paper; describing the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection; mentioning the eligibility criteria, and the sources and methods of selection of participants; clarity on diagnostic criteria; describing all statistical methods, including those used to control for confounding; reporting numbers of individuals at each stage of the study-e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed; reporting other analyses carried out." A numerical summary score was given to each of the publications and an arbitrary classification was applied. Papers that scored $>75\%$ were classified as good, those that scored 55-75% were classified as satisfactory and those that scored $<55\%$ were classified as incomplete.

Results

Search results summary

PBS of glaucoma in SSA

A total of nine studies [20],[21],[22],[23],[67],[68],[69],[70],[71] were identified and all were included [Table 3]. Using the STROBE guidelines, [65],[66] three were classified as good, [20],[21],[22] one was satisfactory [67] and five had incomplete reporting. [23],[68],[69],[70],[71] [Table 3]

PBS of glaucoma in African-derived populations living outside Africa

Four glaucoma prevalence studies [5],[18],[19],[72] [Table 3] and one glaucoma incidence study [73] were included in the review. Using the STROBE guidelines, three surveys were classified as good. [5],[18],[19]

PBS of prevalence/incidence of blindness and visual impairment in SSA

Fifty-five publications were identified. Of these, 32 prevalence surveys [74],[75],[76],[77],[78],[79],[80],[81],[82],[83],[84],[85],[86],[87],[88],[89],[90],[91],[92],[93],[94],[95],[96],[97],[98],[99],[100],[101],[102],[103],[104],[105] [Table 4] and the only incidence study identified [106] were included in this review. Glaucoma was not clearly defined and/or was not mentioned as a specific cause of blindness in the other PBS of prevalence and RAAB publications. [107],[108],[109],[110],[111],[112],[113],[114],[115],[116],[117],[118],[119],[120],[121],[122],[123],[124],[125],[126],[127],[128] [Table 4]

Population-based studies that reported risk factors for glaucoma in SSA and African-derived populations

One report on risk for incident open-angle glaucoma [129] and 10 further publications that discuss risk factors for glaucoma were included in this review. [130],[131],[132],[133],[134],[135],[136],[137],[138],[139]

Prevalence of glaucoma

There are few PBS data that provide prevalence estimates of any/all types of glaucoma in SSA [20],[21],[22],[23],[67],[68],[69] [Table 3], and only four provided reliable estimates. [20],[21],[22],[67] Of these, three were undertaken in different districts in South Africa [21],[22],[67] and one in the Kongwa region of Tanzania. [20]

The surveys in Kongwa, Tanzania, [20] Hlabisa, South Africa [21] and Temba, South Africa [22] conducted the study on people aged 40 years and above; had robust methodologies, with a well-described sampling strategy, and detailed descriptions of IOP measurement and VF assessment. Gonioscopy and optic disc examination methods were clearly described. Two of the surveys [21],[22] were analyzed using the ISGEO classification [64] and IOP was included as a diagnostic criterion only when optic discs could not be assessed and VFs were not obtainable. The prevalence estimates of all types of glaucoma were 4.5% (95% confidence interval [CI] 3.2-6.1%) and 5.3% (CI 3.9-7.1%) respectively. The other study in Mamre, South Africa [67] also studied those aged 40 years and above. The prevalence estimate was similar (4.6%; CI not reported) but the methodology was less rigorous. The survey in Kongwa, Tanzania [20] used three diagnostic criteria based on the optic disc and VF definitions. When definite field defects in association with compatible disc changes were used to define glaucoma, the prevalence of all types of glaucoma was 4.16% (CI 3.5-4.9%).

The other studies used different methods and had limitations, which may have affected the estimate of glaucoma. For example, a survey in south-eastern Nigeria [69] used IOP as a major diagnostic criterion and disc assessment was performed by direct ophthalmoscopy through an undilated pupil. In this survey, the prevalence of glaucoma was 2.1% (CI not reported) in people 30 years and older. In northern Nigeria, [68] a survey of individuals aged 5 years and above reported the prevalence of glaucoma to be only 0.55% (CI 0.07-1.99%) in the 361 participants examined aged 35 years and above; and 1.02% (CI 0.12-3.64%) in the 196 participants aged 45 years and older. Glaucoma was defined based on typical glaucomatous disc appearance or IOP greater than 30 mmHg if the disc was not visualized. A further survey in southern Ghana, [23] which used European glaucoma study guidelines, did not use stringent diagnostic criteria, and those with media opacities with no view of the disc were excluded. Another limitation was the sampling strategy, which was largely a volunteer sample and included family members of those with a positive family history of glaucoma. In this survey, the prevalence of OAG was 8.4% (CI 7.74-9.06%) in those 30 years and older, which is likely to be an

over estimate. A study reported from western Cameroon, [71] which also used a voluntary sample, reported the prevalence of glaucoma to be 8.2% (CI not reported). Another study in Nigeria [70] excluded persons with IOP greater than 21 mmHg and did not assess VFs. In this survey, the prevalence of glaucoma suspects was 2.7% (CI not given). Previous authors suggested in 2009 that a conservative estimate of the prevalence of glaucoma in Africa in people 40 years and older be 4%. [46]

There have been four glaucoma surveys among black populations living outside Africa [Table 3]. In the Caribbean region, the prevalence of glaucoma in African-Caribbeans was 8.8% (CI not given) in those aged 30 years and above in St Lucia [18] and 6.8% (CI 6.1-7.6%) in aged 40 years and above in Barbados. [19] In African-Americans in Baltimore, USA [5] the glaucoma prevalence in those aged 40 years and above was 4.74% (CI 3.81-5.67%) among blacks, being four times higher than in whites (1.29%, CI 0.80-1.78). A prevalence of 3.9% (CI not given) was reported in a cross-sectional study of a voluntary sample of African and Caribbean people aged 35 years and above living in London. [72]

The prevalence of glaucoma in the studied populations aged 40 years and older in the Tanzania [20] and South Africa [21],[22],[67] surveys (range 4.2% to 5.3%) was comparable to the 4.2% prevalence in the African-American population of Baltimore, [5] but much lower than the prevalence of 7.1% in the African-Caribbean population of Barbados. [19] Although these surveys were not completely comparable as the definitions of glaucoma varied and the methodology was not uniform, a consistent pattern was revealed: that glaucoma is a public health problem in SSA.

Types of glaucoma

Where glaucoma was classified by angle morphology, OAG was approximately six times more prevalent than ACG in SSA [20],[21],[22],[23] [Table 3]. The exception was a study in those of mixed South-East Asian and western European origin in Mamre, South Africa. [67] In this study, Salmon reported a prevalence of 2.3% for ACG and 1.5% for OAG. However, 12 participants (1.2%) had full VFs and were classified as having ACG on the basis of their angle configuration only, without evidence of functional deficit. If the ISGEO definition of functional visual deficit had been used the prevalence estimate for ACG would have been lower. Nonetheless, the findings indicate that in SSA, ACG is more prevalent in those of SE Asian origin than in blacks. Pseudoexfoliation, aphakic glaucoma, uveitic glaucoma, lens-induced, and post-traumatic angle-recession glaucoma were classified as secondary glaucoma, [20],[21],[22],[67] with the prevalence ranging from 0.49% in Kongwa, Tanzania [20] to 2.0% in Temba, South Africa. [22] Exfoliative glaucoma was responsible for 16% of all glaucoma in Temba [22] and 21.6% of all glaucoma in Hlabisa in South Africa, [21] but was not detected in Kongwa, Tanzania. [20]

The publications for the surveys in the African-derived populations living outside Africa were reports for OAG and did not give prevalence of other types of glaucoma except in Barbados where the prevalence of secondary glaucoma was 0.7%. [19]

Incidence of glaucoma

Incidence rates provide evidence of long-term risk of a disease and are important for planning services and for policy. The cumulative incidence is the number of new cases seen over the time of observation divided by the population at risk. There are no PBS that report observed incidence of glaucoma in SSA. In the African-descent population of Barbados, the 9-year incidence of definite OAG was 4.4% (CI 3.7-5.2%) or 0.5%/year and showed an increased risk with age and in men. [73]

Awareness of glaucoma

A total of nine surveys reported whether or not participants with glaucoma knew they had the disease or if they were receiving treatment [Table 3]. In Kongwa, Tanzania, [20] 98.5% did not know they had the disease. Similarly, 90.2% in Hlabisa, South Africa [21] and 87.1% (of those with Primary OAG) in Temba, South Africa [22] were not aware they had the disease. In Mamre, South Africa, [67] 36 (78.3%) were newly diagnosed and another six out of the seven participants that were blind due to glaucoma were already receiving treatment. Ninety-three per cent in Akwapim-South [23] and 85.7% in Enugu, Nigeria [69] were newly diagnosed. Approximately, half in both racial groups (blacks and whites) in Baltimore [5] as well as in Barbados [19] did not know they had the disease.

Glaucoma blindness

Incidence of glaucoma blindness

In Uganda, the all-cause incidence of blindness was 9.9/1000 person years, with glaucoma accounting for 3.6% of incident cases (i.e., 0.36/1000 person years). [106] In the Barbados eye studies, OAG was the 2nd leading cause of incident blindness, accounting for 14.3% of the 9-year incidence (1%) i.e., 0.143% over 9 years. [140]

Proportion of people with glaucoma who are blind

The only SSA glaucoma prevalence surveys, which reported the proportion of participants with glaucoma who were blind were those conducted in Tanzania, South Africa and Ghana. The proportions were as follows: 14.1% in Kongwa, Tanzania, [20] 33% (of OAG) in Temba, South Africa, [22] 15.2% in Mamre, South Africa, [67] and 9.5% in Akwapim-south, Ghana. [23] In the Temba survey, 58% (32 of 55) of those with any type glaucoma were blind in at least one eye. [22] In Hlabisa, South Africa study, 41% of eyes with OAG were blind. [21]

In the Baltimore eye survey, the proportion of participants with OAG who were blind was 5.3%. [5],[141]

Glaucoma-specific blindness prevalence

Data on the glaucoma cause-specific blindness prevalence were available from the following sources: PBS of blindness and visual impairment, RAAB studies and World Health Organization (WHO) published data.

From the available data, the glaucoma-specific blindness prevalence was calculated for those aged ≥ 40 years, assumed to be 18% of the total population [Table 4]. In the seven surveys in which the studied populations were aged 40 years and older, [21],[22],[74],[75],[76],[77],[78] the glaucoma-specific blindness prevalence ranged from 0.26% in Ghana [78] to 1.79% in Temba, South Africa. [22] In the recent RAAB studies conducted in Eritrea, [79] Liberia [80] and Malawi, [81] the glaucoma blindness prevalence in the study population of 50-year olds and above were 1.37%, 0.66% and 0.52%, respectively. Glaucoma was the second or leading cause of blindness [74],[92] in the more recent surveys, but ranked third or fourth in older surveys, after cataract and corneal diseases. However, in all the surveys included in this review, only six had VF assessment as part of the examination protocol. [75],[77],[78],[102],[109],[126] In all the other surveys, glaucoma was diagnosed only as a cause of blindness and only included those who had lost central fixation in both eyes.

In Hlabisa, South Africa, the prevalence of blindness was 3.2% (CI 2.2-4.6%) in people aged 40 years and above, and 22% was due to glaucoma. [21] In Temba, South Africa, the prevalence of blindness was 5.6% (CI 3.9-7.7%) in people 40 years and older and the proportion due to glaucoma was 32%. [22]

A recent nationally representative population based survey of blindness and visual impairment in Nigeria reported the all-cause prevalence of blindness to be 4.2% (CI 3.8-4.6%) [142] and the proportion of blindness due to glaucoma was 16.7% among those aged ≥ 40 years. [75] The prevalence of blindness ranged from 3.3% (CI 2.4-4.5%) in the Delta ecological zone to 6.6% (CI 4.2-10.4%) in the northern Sahel ecological zone, and the proportion of blindness due to glaucoma varied from 13.2% in the Sudan Savannah to 23.5% in the Sahel ecological zones. The nationwide overall glaucoma-specific blindness prevalence was 0.7% (CI 0.55-0.88%) [75] with a four-fold difference in the glaucoma-specific blindness prevalence which ranged from 0.4% (CI 0.2-0.9) in the Delta to 1.6% (CI 0.6-3.8%) in the Sahel. [143] A high prevalence of blindness in all ages was reported in Bioko, Equatorial Guinea (3.2%) [84] and this was reflected as high prevalence estimate of glaucoma blindness of 2.36% in the 40+ year-olds. A high prevalence of blindness (10.4% in people 30 years and older) was reported in a survey in leprosy villages in north-eastern Nigeria, where glaucoma ranked 4th as a cause of blindness, nevertheless, with a high glaucoma-specific blindness prevalence of 1.02% in the 40+ year-olds. [83] This is in contrast to a survey undertaken decades ago in an area endemic for onchocerciasis in North-Eastern Nigeria where the prevalence of blindness was 11.8% in all ages and glaucoma did not feature as a cause as almost all blindness was due to onchocerciasis. [128]

In the Baltimore eye survey, [141] the overall prevalence of blindness was 1.21% and the proportion of blindness due to glaucoma was 14.1% among those aged 40 years and above. The glaucoma-specific blindness prevalence was 0.17%. Glaucoma blindness was compared between whites and blacks. In the blacks, glaucoma blindness was 0.37% and 6.6 times higher than the 0.06% glaucoma blindness prevalence in whites. Glaucoma blindness also occurred earlier in blacks with a prevalence of 0.29% in the age-group 50-59 years whereas none of the whites were blind due to glaucoma before the age of 60 years. In this population, glaucoma as well as cataract and diabetic retinopathy were more common as a cause of visual impairment in blacks while macular degeneration was more so in whites. [144]

Data on the prevalence and causes of blindness were published by WHO for the year 2002. [2] Survey data available at the time were extrapolated to countries without data in order to derive global estimates. The glaucoma-specific blindness prevalence was calculated from these data, which are presented according to the 17 WHO sub-regions [Table 1]. The proportion of blindness in all ages due to glaucoma globally was 0.7/1000, ranging from 0.18/1000 in the Western Pacific sub-region B3 to 1.5/1000 in both African sub-regions. Glaucoma blindness in Africa is, therefore, twice the global figure; and eight times higher than in the Western Pacific sub-region.

Risk factors

The study of risk factors gives information on who gets glaucoma (incidence studies), who has glaucoma (prevalence studies), who progresses and who goes blind due to glaucoma (risk of progression, prognostic factors). Risk factors for glaucoma incidence were reported from the Barbados eye study. [129] Risk factors for glaucoma prevalence were reported in six of the PBS of glaucoma in SSA [20],[21],[22],[23],[67],[69] and in all four of the PBS of glaucoma in the African-derived populations. [5],[18],[19],[72] Ten other publications related to the Akwapim-South, Ghana survey, [139] St Lucia survey, [137] Barbados eye study, [130] Baltimore eye survey, [132],[133],[135],[136] African descent and glaucoma evaluation study, [134] a multicenter study [138] and a PBS in African-Americans living in Canada [131] reported risk factors for glaucoma.

Who is at risk of developing glaucoma?

Risk factors for incident OAG were increasing age, higher IOP, lower systolic blood pressure (BP) to IOP ratio (BP/IOP), lower mean diastolic ocular perfusion pressure (diastolic BP minus IOP), thinner central corneal thickness (CCT), and a positive family history. [129] Racial variability of some of these risk factors at baseline has been demonstrated; [130] with higher IOP [131] and thinner CCT [131],[134] in African-derived groups.

Who has glaucoma?

Age was an important and consistent risk factor, with a higher prevalence of glaucoma associated with increasing age. [5],[19],[20],[21],[22],[23],[69],[72],[130] The age-specific prevalence of OAG was higher with increasing age: From 1.7% (CI 1.1-2.5%) to 5.6% (CI 3.1-9.2) in Kongwa, Tanzania, [20] from 1.2% (no CI reported) to 4.9% in Hlabisa, South Africa, [21] and from 0.6% (no CI reported) to 6.0% in Temba, South Africa, [22] in the age-group 40-49 years and the age-group 70-79 years, respectively. Similarly, higher prevalence of OAG was reported from 1.4% (CI 0.8-2.2%) to 14.8% (CI 12.5-17.4%) in Barbados; [19] and from 1.23% (CI 0.23-2.24%) to 9.15% (CI 5.83-12.48%) in blacks and from 0.92% (CI 0.2-7.2%) to 2.89% (CI 1.44-4.34%) in whites in the Baltimore eye survey, [5] in the age-groups 40-49 years and 70-79 years, respectively.

Gender was not consistently associated with prevalent cases of glaucoma. [5],[23],[69] However, some surveys reported a higher prevalence of OAG in men. [19],[21],[22],[67],[130] Men were also more likely to have secondary glaucoma, [22] especially following trauma. [67] ACG was more common in women. [67]

Higher IOP is another important factor associated with a higher prevalence of glaucoma, [20],[21],[130],[132] although IOP had a limited predictive value. [21] Hypertension was not significantly associated with glaucoma prevalence. [20],[72],[130] However, lower mean ocular perfusion pressure was associated with a higher prevalence in the surveys in African-derived populations of Barbados [130] and Baltimore [135] but, this was not reported in African-Caribbeans in London [72] or in the only survey that this factor was studied in SSA. [20] These factors associated with ocular blood flow i.e., systolic BP, diastolic BP and ocular perfusion pressure were stronger in older people. [132],[133],[135]

A positive family history of glaucoma was associated with higher prevalence of glaucoma. [130],[133]

The higher prevalence of glaucoma in blacks compared to whites was consistently demonstrated in the surveys involving the two racial groups. [5],[19],[72] Furthermore, those with darker skin and of African birth seemed to have a higher risk. [72] However, in the two studies involving a number of ethnic groups in SSA, ethnicity was not associated with a variation in prevalence of glaucoma; [22],[23] but the sample sizes were relatively small and the studies were confined to limited geographical areas with few ethnic groups represented.

Other risk factors for glaucoma include lower body mass index in men and history of cataract surgery. [130]

Who has glaucoma progression and who develops blindness due to glaucoma?

A survey in Ghana [139] explored the risk factors associated with severe disease and surveys in Baltimore [132] and St Lucia [137] explored the risk factors for glaucoma progression and blindness. The Temba, South Africa survey [22] was the only SSA survey that described the age of participants that were blind due to glaucoma. The risk of glaucoma blindness increased with increasing age. The average age of the blind glaucoma participants was higher (74.8 years) when compared to the average age (65.4 years) of the non-blind participants. In the Ghana study that combined population-based and facility-based samples, older age (more than 60 years) and IOP greater than 31 mmHg were associated with more severe disease and the absence of family history was associated with delay in seeking treatment. [139] Increasing age was also associated with progression of the disease. [136],[137] Aggressive glaucoma therapy reduces the progression of VF loss that leads to bilateral blindness; [136] and the proportion of patients with progressive VF loss is much higher in those untreated than in treated eyes. [137] Glaucoma progression was more severe in blacks [138] and blindness occurred at an earlier age in blacks than in whites. [141]

Discussion

World estimates on the prevalence of glaucoma and glaucoma blindness prevalence have been derived from projections and modeling from pooled data and surveys, [3] and by extrapolating data from countries with data to those without, [2] and more recently, using newly developed imputation methods based on country economic status. [1] However, these approaches have given different estimates for glaucoma. One explanation for the WHO estimates of glaucoma blindness being lower than other estimates is that data were obtained from population based surveys of blindness, where VF are usually not included in the definition of blindness. Individuals with extensive VF loss, but with preserved central fixation in at least one eye would not, therefore, be included in the WHO estimates. Another reason may be that age-standardization is included in modeling estimates and this will take into account the steep decline in population after age 40 years that is typical of developing country profile.

The number of high quality glaucoma surveys conducted in Africa is low and it is difficult to extrapolate the findings to wider populations as they were conducted in limited and defined geographical areas of large countries. These surveys were also often not directly comparable due to variation in the age of participants, and differences in the methods used to measure parameters of relevance to glaucoma and to define and classify the disease. Only two surveys used the ISGEO definition, which relates IOP and cup:disc ratios to population norms. This is important, given the recognized variation in the distribution of optic disc and cup size and IOP between populations. [12],[13],[14],[15],[16],[64],[145],[146],[147],[148],[149] There is only one small study of the incidence of glaucoma blindness in Africa, [106] and no studies on the incidence of glaucoma. Longitudinal studies to address these questions will also give information on the natural history of the disease, as a high proportion of individuals diagnosed with glaucoma do not seek treatment even when this is recommended.

More reliable data are required from large scale, rigorous PBS in order to revise and refine the prevalence and magnitude estimates of glaucoma and glaucoma blindness for SSA. Ideally, the surveys should use the same age range, and the standard definitions and classification system, and use comparable methods of assessing VF, IOP and cup:disc ratios. The sample sizes should be large enough to allow analysis of risk factors for glaucoma in order to identify the population most at risk. Ideally, such surveys should also collect data on family history of glaucoma and socio-demographic data. Data on whether different ethnic groups in SSA are more at risk than others is currently lacking, as there are no published studies, which have included a large enough sample of different ethnic groups. The relatively small sample size of the reviewed surveys would limit the power of the studies to detect differences. Data from the Nigeria national survey [150] are currently being analyzed and will provide data on risk factors including variations in ethnic groups. Again, this information would be of value for targeting control strategies.

The suggested prevalence of glaucoma in SSA of 4% in people 40 years and older [46] is a reasonable estimate as that is what these three "good" studies in SSA indicated. [20],[21],[22] Since, this prevalence estimate was suggested in 2009 for Vision 2020 planning purposes, there has been no additional high quality data to suggest that it needs to be changed.

The available evidence suggests that the prevalence of glaucoma is higher in SSA and in people of African descent who live outside Africa. A Bayesian meta-analysis that examined the relationship between OAG prevalence and age, gender, and racial group also showed that the pooled random effects prevalence of OAG was higher in the black populations (4.2%). [26] Given the lack of evidence that environmental and behavioral risk factors are associated with glaucoma, these findings suggest a genetic basis for the greater susceptibility in blacks. [28] The genetic basis of glaucoma is being increasingly recognised [151],[152] and genetic research and genome-wide association studies in Africa will possibly explain some of the variations and excess risk seen in black populations.

The most prevalent type of glaucoma in SSA is open-angle glaucoma. However, hospital-based studies tend to overestimate the proportion of ACG reporting a range of 6% to 18% of all glaucoma cases seen; [54],[153],[154],[155],[156],[157] and this may be related to the health-seeking behavior in which the pain in acute ACG acts as a trigger for the need to obtain treatment.

The very low awareness of having the disease as reported in the PBS signifies that only a small fraction of people with glaucoma access healthcare, leaving a large majority untreated and with the potential blinding effects. Indeed, in those that access healthcare, up to 42% of glaucoma patients presented with advanced disease and bilateral blindness; and over half were blind in one eye. [54],[55],[56],[57],[58],[59]

Glaucoma causes irreversible blindness due to loss of ganglion cells of the optic nerve leading to vision and VF loss. The proportion of people with glaucoma who are blind is higher in SSA than in any other region. The earlier age of onset of the disease in blacks has already been reported [35] and this has been corroborated in the PBS in SSA [20],[21],[22] and black populations where the prevalence of OAG in the age-group 40-49 years was much higher than in white populations of USA and Barbados. [5],[19] Interestingly, a similar variation of the 40-49 years age-specific prevalence of 0.4% (CI 0.0-0.9%) and 3.1% (CI 0.4-5.8%) between the white and non-white groups, respectively, in Piraquara City, Brazil was reported. [158] Comparatively, the 40-49 years age-specific prevalence in Caucasian Australians was 0.2% (CI 0.0- 0.56%), [8] and remarkably from as low as <0.2% (no CI reported) [159] and up to 1.5% (CI 0.4-2.5%) [160] in indigenous Australians. Glaucoma progression is also more aggressive in blacks. [36],[37],[138] Thus one of the plausible reasons why blacks in Africa and African-derived populations have more glaucoma blindness is that the early age of onset means they have the disease for a longer time.

The Nigeria national survey on blindness and visual impairment is the largest PBS that has ever been carried out in Africa. The prevalence data by geo-ecological zones showed wide variation between the Sahel and the Delta ecological zones. The proportion of blindness due to glaucoma was also higher, with a 4-fold difference in the prevalence of glaucoma blindness. [143] The only explanations are that the incidence of glaucoma blindness is higher and/or the disease is more aggressive and/or access to care is lower in the Sahel zone. Data on these factors are currently being analyzed.

Further studies are needed to explore risk factors for glaucoma blindness, which will help to identify those most at risk for example by gender, socio-economic status (e.g., level of education), age, and ethnic group. Exploration of biomedical risk factors associated with disease progression (e.g., IOP and ocular perfusion pressure) will also provide guidelines for setting and monitoring target IOP following treatment.

The ranking of glaucoma as a major cause of blindness from lower ranks in older surveys to second leading cause in most recent surveys may be attributable to the increase in control efforts of corneal diseases, notably vitamin A deficiency and trachoma which became less in magnitude, and a decrease in onchocerciasis blindness. In addition, the classification and diagnosis of glaucoma had improved in more recent surveys. However, it is probable that figures for glaucoma prevalence and blindness are underestimations especially in populations with a high prevalence of cataracts. Cataract and corneal diseases are more easily diagnosed in surveys and may occlude the view of the optic disc for a definite diagnosis of glaucoma. Furthermore, in ranking of principal cause of blindness using the WHO format, cataract or corneal scar may take precedence being recorded preventable causes of blindness even in eyes with co-existing glaucoma.

A large number of the PBS from which data of glaucoma-specific blindness prevalence were derived did not have VF assessments. These data therefore underestimate glaucoma-specific blindness which, if using the WHO definition of blindness, should also include those with a central VF of less than 10 degrees in the better eye. [161] The wide variation in glaucoma-specific blindness prevalence may be attributable to the sampling methodology and/or some studies done in areas where focal diseases were more prevalent. In addition, the definitions used for blindness as well as for glaucoma and the age of participants in the surveys varied. The age of the sample is very important since the disease is age-related. Even if definitions and measurements were standardized and the sample populations were all 40+ years, there could still be very different prevalence data because of the differences in the life expectancy and age structure of people aged 40 years and above between populations and regions. Age-standardization between the surveys would have eliminated the differences due to confounding by differences in age structure of the populations.

A limitation of this review process is that age-standardization of these data was not possible. Another limitation is that there was a language restriction in the search strategy. If a publication and abstract were not in English they might have been missed. However, this would only apply to Francophone and Lusophone Africa.

Application of these studies to the control of glaucoma in SSA

These studies have highlighted that glaucoma is predominantly OAG and it is a public health problem in SSA. It has a high prevalence, an early onset and progresses more rapidly than in Caucasians; and it is a major cause of blindness. Thus case-finding strategies need to be targeted at younger ages. Treatment needs to be more aggressive, life-long and with adequate follow-up, and monitoring of patient-physician contact frequency.

Challenges for the control of glaucoma in African populations have been elucidated. [46],[47],[50],[52] The disease is most often diagnosed late and there is a poor response to treatment possibly due to poor compliance or non-availability of any form of treatment. These factors are further compounded by poor awareness and low knowledge about glaucoma even by patients. Provider factors include poor facilities and equipment for glaucoma diagnosis and management, [53] inadequate number of ophthalmologists [162] and support teams and limited treatment options (e.g., lasers and trabeculectomy with adjunctive antimetabolites).

In order to reduce morbidity from glaucoma, a public health approach is needed for control and particularly targeted to those at risk. Possible solutions have been proposed and some are being implemented. [46],[50],[61],[62],[163] Approaches for control include: To increase public health education for awareness about glaucoma; to improve case-detection methods including opportunistic eye examinations; to encourage case-finding in first-degree relatives; to increase treatment options and availability of medications and surgery; to increase education and training for skilled glaucoma surgeons, patients' counselors and other glaucoma care workers; and to strengthen infrastructure of eye care centers and other systems for glaucoma diagnosis, treatment, and counseling of patients. These should be incorporated into existing Vision 2020 programs and blindness control strategies; and glaucoma care needs to be given high priority.

Further research

Despite the many challenges facing SSA, there is a need to streamline glaucoma control activities and provide evidence-based care. The process to undertake such research can be scheduled systematically and tailored according to local needs and available pooled resources. In the longer term, results and output of the research will be beneficial.

Epidemiological research

More population-based research is needed to clarify the nature of glaucoma in many more populations in Africa, to determine reasons for its variation and to better define target risk groups.

Social sciences/qualitative research

This is important in order to identify the factors and barriers to awareness and knowledge of blinding eye diseases; and compliance and adherence to treatment of glaucoma in SSA.

Clinical care and outcomes

Operational and clinical research for patient care is needed to define clinical guidelines (including issues of patient-physician contact frequency) and protocol of management for optimum glaucoma care. Monitoring of outcomes tools including patient reported outcome and experience measures [164] and quality of life and visual function measures need to be developed. Randomized control trials are needed to define appropriate choices of treatment and provide evidence-base for best clinical care.

Health systems research

Studies that also provide evidence for policy makers and management to facilitate systems for the management of the disease are important.

Health economics research

This will define issues such as cost-benefit of the different options of glaucoma treatment, the economic burden of the disease and health insurance coverage for glaucoma patients.

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