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Global Prevalence of Glaucoma and Projections of Glaucoma Burden through 2040

A Systematic Review and Meta-Analysis

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Purpose: Glaucoma is the leading cause of global irreversible blindness. Present estimates of global glaucoma prevalence are not up-to-date and focused mainly on European ancestry populations. We systematically examined the global prevalence of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG), and projected the number of affected people in 2020 and 2040.

Design: Systematic review and meta-analysis.

Participants: Data from 50 population-based studies (3770 POAG cases among 140 496 examined individuals and 786 PACG cases among 112 398 examined individuals).

Methods: We searched PubMed, Medline, and Web of Science for population-based studies of glaucoma prevalence published up to March 25, 2013. Hierarchical Bayesian approach was used to estimate the pooled glaucoma prevalence of the population aged 40−80 years along with 95% credible intervals (CrIs). Projections of glaucoma were estimated based on the United Nations World Population Prospects. Bayesian meta-regression models were performed to assess the association between the prevalence of POAG and the relevant factors.

Main Outcome Measures: Prevalence and projection numbers of glaucoma cases.

Results: The global prevalence of glaucoma for population aged 40−80 years is 3.54% (95% CrI, 2.09−5.82). The prevalence of POAG is highest in Africa (4.20%; 95% CrI, 2.08−7.35), and the prevalence of PACG is highest in Asia (1.09%; 95% CrI, 0.43−2.32). In 2013, the number of people (aged 40−80 years) with glaucoma worldwide was estimated to be 64.3 million, increasing to 76.0 million in 2020 and 111.8 million in 2040. In the Bayesian meta-regression model, men were more likely to have POAG than women (odds ratio [OR], 1.36; 95% CrI, 1.23−1.52), and after adjusting for age, gender, habitation type, response rate, and year of study, people of African ancestry were more likely to have POAG than people of European ancestry (OR, 2.80; 95% CrI, 1.83−4.06), and people living in urban areas were more likely to have POAG than those in rural areas (OR, 1.58; 95% CrI, 1.19−2.04).

Conclusions: The number of people with glaucoma worldwide will increase to 111.8 million in 2040, disproportionally affecting people residing in Asia and Africa. These estimates are important in guiding the designs of glaucoma screening, treatment, and related public health strategies. *Ophthalmology 2014;121:2081-2090 © 2014 by the American Academy of Ophthalmology.*

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Glaucoma is the leading cause of global irreversible blindness. It has been estimated that 60.5 million people were affected by primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) globally in 2010.[1−3] Because of the rapid increase in aging populations worldwide, accurate estimation of the current glaucoma prevalence and future projections of the number of people with glaucoma are critical for the formulation of adequate health policies tailored for the diverse populations worldwide.

The risk and subtypes of glaucoma vary among races and countries. In the United States, blacks have a higher POAG prevalence than whites.[4,5] While the prevalence of POAG in East Asian populations is higher than that of PACG,[6−9] Mongolians and Burmese are more affected by PACG than POAG.[10,11] Nevertheless, the current estimates of glaucoma prevalence from different population studies have several limitations that render accurate comparisons among them challenging. In particular, different studies vary in age group structures, sample size, geographic regions, ethnicity,

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examination methods, and glaucoma definitions.[12] Therefore, it is challenging to systematically examine the global trends of glaucoma.

There have been attempts to pool glaucoma prevalence estimates from different populations using meta-analysis.[2,13–15] Most notably, Quigley and Broman[2] reported worldwide glaucoma prevalence estimates in 2010 and 2020. Nevertheless, these previous estimates were determined approximately 1 decade ago and may be out of date. Furthermore, previous reviews focused more on populations of European ancestry. In recent years, there has been a rapid emergence of population-based studies in Asia, providing an opportunity to allow better estimation of global glaucoma prevalence.[7–11,16–33] Considering Asia represents approximately 60% of world populations, inclusion of data from contemporary Asian studies may provide a more up-to-date estimation of global glaucoma prevalence.

In this study, we aimed to estimate the global prevalence and future projections of glaucoma burden using the Hierarchical Bayesian (HB) approach. The HB model takes into account heterogeneity across populations and study characteristics, thus allowing more dissimilar studies to be included without compromising the validity of the integrated estimates.[34,35] Findings in this study will be useful for the design of glaucoma screening, treatment, rehabilitation, and related public health strategies.

Methods

Systematic Review Process

The review followed the Meta-Analysis of Observational Studies in Epidemiology guidelines for reporting our systematic reviews and meta-analyses.[36] We performed a literature search in the electronic databases of PubMed, Medline, and Web of Science. We limited our search to English publications and made a final search on March 25, 2013.

In our literature search, we included a combination of keywords, such as glaucoma, prevalence, epidemiology, population, and survey, in the form of title words or medical subject headings (Appendix A, available at www.aaojournal.org). Two reviewers (Y-C.T., X.L.) completed the literature search independently. In addition, the 2 reviewers further cross-checked reference lists of all identified articles to identify other relevant studies. This adopted strategy identified all articles used in previous reviews.[2,13,14,32]

Inclusion and Exclusion Criteria

The criteria for study inclusion were based on the examination guidelines for glaucoma-related population-based studies reported previously.[12,37] We included studies that met the following inclusion criteria: (1) population-based study of POAG or PACG from a defined geographic region, (2) clear definition on random or clustered sampling procedure, (3) 70% participation rate of the eligible population participants, (4) optic disc evaluation by ophthalmologists using slit-lamp biomicroscopy or fundus photography, (5) visual field testing with automated static perimetry was at least conducted among participants who were glaucoma suspects, (6) anterior chamber angle/depth evaluation determined by slit-lamp examination or gonioscopy was at least conducted among participants who were glaucoma suspects, and (7) POAG and PACG case definitions were based on structural or functional evidence of glaucomatous optic neuropathy evaluated by optic disc evaluation or visual field testing, respectively, and independent of intraocular pressure measurement. Thus, our POAG definition included persons with intraocular pressure at all levels.

However, we excluded studies if they (a) were interview, hospital, or clinic-based; (b) consisted of volunteer participants or participants with self-reported glaucoma; (c) did not report sampling strategy; (d) were published in languages other than English; and (e) reported the number of eyes with glaucoma as opposed to the number of individuals.

Two reviewers (Y-C.T., X.L.) independently selected the studies for final inclusion on the basis of these criteria. Disagreements between the 2 were resolved and adjudicated by the senior author (C-Y.C.).

Data Extraction

We extracted the following data from each study: region(s) in which the study was conducted, age group (only for POAG analysis), gender, habitation types (urban, rural, or mixed), ethnicity of study sample, year of study conducted, and participation response rate. We classified region(s) in which the study was conducted according to the United Nations' classification of macro-geographic continental regions, namely, Asia, Africa, Europe, north America, Latin America and the Caribbean, and Oceania.[38]

Bayesian Pooling of Glaucoma Prevalence

To address the issue of heterogeneity across studies, we used the HB approach to estimate the global prevalence of POAG, PACG, and glaucoma (defined as POAG and PACG combined). This approach allows us to take into account the different age distributions and effects of ethnicity and geographic region across studies, so that the final prevalence estimates reflect these sources of variability. Furthermore, the HB approach also takes into account within-study variability. This modeling approach also has been adopted and described in previous literature.[14,35,39]

Meta-analysis can be naturally described in a hierarchical structure in an HB model. Briefly, in our analysis, we used the HB approach to estimate the logit of glaucoma prevalence by modeling the hierarchical structure of the data extracted, taking into account the differences in age distribution, ethnicity, and geographic region across and within studies. We modeled the logit of glaucoma prevalence as a linear combination of covariates that varies across studies (i.e., age, ethnicity, geographic region) to account for between-study variability. We specified the number of people with glaucoma (y_{ij}) as binomially distributed: $y_{ij} \sim Binomial(n_{ij}, p_{ij})$, where n_{ij} was the total number of participants and p_{ij} was the prevalence of glaucoma in the i^{th} study for the j^{th} category of the varying covariate (e.g., some studies may consist of >1 dataset within the same study, where $j>1$). For example, when ethnic group was specified as j, the model would allow us to account for the variability between various ethnic groups in the same study. In our Bayesian approach, the prevalence of glaucoma p_{ij} was considered as a random variable that had a probability density function. Thus, the logit transformation of p_{ij} follows a Normal distribution: $logit(p_{ij}) = u_{ij}$ and $u_{ij} \sim Normal(\mu_{ij}, \sigma^2)$, where $\sigma^2 = 1/\tau$. Full details of the model are further specified in Appendix B (available at www.aaojournal.org).

We fitted the Bayesian model with the Markov chain Monte Carlo algorithm and obtained the posterior distributions for the logit of glaucoma prevalence. We then converted these estimations back to prevalence and represented them as means along with 95% credible intervals (CrIs), which represent the range of values within which the true value of an estimate is expected to be within 95% probability.