Published in final edited form as:

Ophthalmology. 2011 June ; 118(6): 1031–1037. doi:10.1016/j.ophtha.2010.10.024.

Differences in Rates of Glaucoma Among Asian Americans Compared With Other Races and Among Individuals of Different Asian Ethnicities

Joshua D. Stein, MD, MS¹, Denise S. Kim, BS¹, Leslie M. Niziol, MS¹, Nidhi Talwar, MS¹, Bin Nan, PhD², David C. Musch, PhD, MPH^{1,3}, and Julia E. Richards, PhD^{1,3}

¹Department of Ophthalmology and Visual Sciences, University of Michigan

²Department of Biostatistics, University of Michigan School of Public Health

³Department of Epidemiology, University of Michigan School of Public Health

Abstract

Purpose—To determine the incidence and prevalence rates of different glaucoma types among Asian Americans, contrast glaucoma incidence and prevalence rates for Asian Americans with other races, and evaluate the hazard of developing glaucoma among different Asian ethnicities and other races.

Design—Retrospective longitudinal cohort study

Participants—2,259,061 beneficiaries aged ≥40 enrolled in a large, national managed-care network in the United States (US) in 2001–2007

Methods—Incidence and prevalence rates of open-angle glaucoma (OAG), narrow-angle glaucoma (NAG), and normal-tension glaucoma (NTG) were determined for the beneficiaries and stratified by race and Asian ethnicity. Cox regression analyses determined the hazard of developing OAG, NAG, and NTG for Asian Americans compared with other races and among different Asian ethnicities, with adjustment for confounding factors.

Main Outcome Measures—Multivariable hazard of OAG, NAG, and NTG among different races and Asian ethnicities.

Results—The OAG prevalence rate for Asian Americans of 6.52% was similar to that of Latinos (6.40%) and higher than that of non-Hispanic whites (5.59%). The NAG and NTG prevalence rates (3.01% and 0.73%, respectively) were considerably higher among Asian Americans compared with each of the other races. After adjustment for confounding factors, Asian Americans had a 51% increased hazard of OAG (Hazard ratio (HR)=1.51 (95% confidence interval (CI) 1.42–1.60), a 123% increased hazard of NAG (HR=2.23 (95% CI 2.07–2.41), and a 159% increased hazard of NTG (HR=2.59 (95% CI 2.22–3.02) compared with non-Hispanic whites. Vietnamese Americans (HR=3.78, (95% CI 3.19–4.48), Pakistani Americans (HR=2.45, 95% CI 1.50–4.01) and Chinese Americans (HR=2.31, 95% CI 2.06–2.59) had considerably higher

© 2010 American Academy of Ophthalmology, Inc. Published by Elsevier Inc. All rights reserved.

Corresponding Author Joshua D. Stein MD, MS University of Michigan Kellogg Eye Center 1000 Wall Street Ann Arbor, MI 48105
jdstein@med.umich.edu Phone: 734-763-7246 Fax: 734-232-8181.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Financial disclosures: Musch: Pfizer, Inc., Glaukos Corp. All other authors: None

hazards of NAG while Japanese Americans (HR=4.37, 95% CI 3.24–5.89) had a substantially higher hazard of NTG, compared with non-Asian Americans.

Conclusions—Given the rapid rise in the number of Asian Americans in the US population, resources need to be devoted to identifying and treating glaucoma among these individuals. Eye-care providers should be aware of the increased hazard of developing OAG, NAG, and NTG among Asian Americans relative to other races. When evaluating Asian Americans, inquiring about ethnicity can provide additional information on risk of specific glaucoma types.

Financial Disclosures—The authors have no proprietary or commercial interest in any materials discussed in this article.

Glaucoma affects over 66 million individuals and is the second leading cause of blindness worldwide.¹ A 2002 study estimated that the majority of individuals who go blind from this disease reside in Asian countries.² In recent years there has been an influx of Asians migrating to the United States (US). According to the US Census Bureau, Asian Americans are the second fastest growing minority in the United States, increasing nearly 50% from 6.9 million in 1990 to 10.2 million in 2000. Present estimates from the 2006 US Census estimate that there are 14.9 million Asian Americans.³ While other studies have documented the prevalence of different forms of glaucoma among individuals living in different regions of Asia, little is known about the prevalence of different forms of glaucoma among Asian Americans residing in the United States.

Understanding whether Asian Americans are at increased or decreased risk for glaucoma and whether different subgroups of Asian Americans are more prone to specific types of glaucoma are questions that are of importance to clinicians caring for these patients, as well as health policy-makers determining how to prioritize limited healthcare resources, and researchers designing clinical trials. Studying Asian Americans separately from Asians is also important because heritability studies suggest that genetic composition does not fully account for glaucoma risk.⁴ The purpose of this study is to use a large, national cohort to determine the incidence and prevalence of open-angle glaucoma (OAG), narrow-angle glaucoma (NAG), and normal-tension glaucoma (NTG) among Asian Americans relative to other races, and whether individuals of different Asian ethnicities are more prone to specific glaucoma types.

Methods

Data Source

The i3 InVision Data Mart database (Ingenix, Eden Prairie, MN) contains detailed fully de-identified records of all beneficiaries in a large managed care network in the United States. We had access to data for beneficiaries in the Data Mart database who had any form of eye care from January 1, 2001 through December 31, 2007. This subset consisted of beneficiaries who had one or more International Classification of Diseases⁵ (ICD-9CM) codes for any eye-related diagnosis (360-379.9), or Current Procedural Terminology⁶ (CPT-4) code for any eye-related visits, diagnostic or therapeutic procedures (65091-68899 or 92002-92499), or any other ICD-9 or CPT codes adjudicated by an ophthalmologist or optometrist during their time in the medical plan. For each beneficiary in the sample, we had access to all medical claims (inpatient, outpatient, skilled nursing facility) both for ocular and non-ocular medical conditions. The database also contains detailed records of demographic (age, sex, race, ethnicity) and socioeconomic information (education level, household net worth) for each beneficiary.

Subjects

All individuals age 40 or older who were in the i3 InVision Data Mart database for more than one consecutive year and had one or more visits to an eye care provider during their time in the medical plan were identified. Individuals in the medical plan for 365 days or less and those who were not in the medical plan continuously from their beginning to their ending date of enrollment were excluded. (Figure 1, **available at** <http://aaajournal.org>) The race and ethnicity of each beneficiary were identified by the managed care company using information provided from two sources: public records (drivers license data) and from E-Tech (Ethnic Technologies, LLC., South Hackensack, NJ), a tool that uses information from the name of the beneficiary and the census block he or she lives in to assign race and ethnicity. Previous comparisons between assignment of race using E-Tech and information collected from patient self-report demonstrated that E-tech has a positive predictive value of 71%.⁷ Asian ethnicity was classified as the following: Chinese American, Filipino American, Indian American, Japanese American, Korean American, Pakistani American, and Vietnamese American. There were inadequate numbers of beneficiaries of the following Asian ethnicities to study them separately: Bangladeshi, Burmese, Laotian, Thai, Indonesian, Malaysian, Hawaiian, Samoan and Sri Lankan. Therefore, individuals of these ethnicities were grouped into the ethnicity category of "Other Asian Americans."

Glaucoma Incidence and Prevalence

ICD-9CM codes were used to determine whether each beneficiary had one or more diagnoses of glaucoma during their time in the medical plan. Incidence and prevalence rates were determined for open-angle glaucoma (OAG) (ICD-9 365.1, 365.10, 365.11, 365.12, 365.15) and narrow-angle glaucoma (NAG) (ICD-9 365.02, 365.2, 365.21, 365.22, 365.23, 365.61, 365.73). In this analysis, normal tension glaucoma (NTG) (ICD-9 365.12) was counted as a form of OAG. However, since NTG has previously been documented to be highly prevalent in certain subgroups of Asians, separate incidence and prevalence rates were determined for this specific subtype of glaucoma.

If an individual was diagnosed with suspected glaucoma and later on during their time in the plan given a diagnosis of some form of glaucoma, when determining glaucoma incidence and prevalence rates, they were counted in estimates for the specific type of diagnosed glaucoma. If an individual was given a diagnosis of suspected glaucoma but did not progress to OAG, NAG, or NTG, they were not included in the incidence or prevalence rates for these conditions. Beneficiaries could be diagnosed with more than one form of glaucoma during their time in the medical plan and were counted in the disease incidence and prevalence estimates for each type of glaucoma they were documented to have. For example, if a beneficiary was diagnosed with OAG in 2004 and diagnosed with NAG in 2006, they were counted as a prevalent case for each of these glaucoma types. The database does not contain information to determine whether persons diagnosed with two different glaucoma types had them in the same eye. Glaucoma prevalence rates were obtained by identifying the number of individuals diagnosed with the condition divided by the number of beneficiaries in the medical plan during the 7 year time period. When interpreting prevalence estimates, it is important to note that not every beneficiary was in the medical plan for all 7 years. Glaucoma incidence rates were calculated by dividing the number of newly diagnosed beneficiaries with the glaucoma type of interest by their time in the plan at risk. Diagnoses were considered incident cases if the enrollee did not have any record of the glaucoma type of interest during their first year in the medical plan. Glaucoma incidence and prevalence rates for the different races were compared using a test of rate ratios with non-Hispanic white, as the reference group. Similarly, a comparison of rate ratios was performed to compare glaucoma incidence and prevalence rates for each Asian ethnicity with that of Non Asians.

Analyses

All analyses were performed by using SAS 9.2 (Cary, NC). Participant characteristics were summarized for the entire sample using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Incidence and prevalence estimates were generated for the following glaucoma types: OAG, NAG, and NTG and stratified according to race and Asian ethnicity.

Next, Cox regressions were developed to determine the hazard of developing each of the 3 types of glaucoma.⁸ For the model, we used the first year each beneficiary was enrolled in the medical plan as a look back period. To avoid selection bias, follow-up of all enrollees started at one year after enrollment in the medical plan. The model is capturing incident cases since individuals diagnosed with glaucoma during the look back period were excluded from the analysis. Persons were followed until they developed the event (OAG, NAG, or NTG) or were censored (either when they left the medical plan or the last day for which we had data, December 31, 2007). For each beneficiary the age to event or the age to censoring were determined. Using age as the time axis and race (or Asian ethnicity) as the key predictor of interest, the Cox model was left-truncated at the age of index (one year after entry into the medical plan). Adjustments were made for age, sex, region of residence within the US, education level, household networth, and the following medical and ocular conditions: diabetes mellitus, systemic arterial hypertension, hyperlipidemia, sleep apnea syndrome, migraine headache, cataract, pseudophakia or aphakia, diabetic retinopathy, macular degeneration, and Charlson Index Score (a measure of overall health)⁹. (Table 1, **available at** <http://aaajournal.org>) A p-value of < 0.05 was considered statistically significant. The University of Michigan Institutional Review Board (IRB) determined this study was exempt from requiring IRB approval.

Results

Of the 2,259,061 individuals in the medical plan who met the inclusion criteria, 1,772,962 individuals (78.5%) were classified according to race and among these, 44,103 enrollees (2.5%) were Asian American. The median age at entry into the plan for the overall sample was 53 years (range 40-87 years); among Asian Americans in the sample, the median age at plan entry was 51 years (range 40-87 years).

Differences in Glaucoma Prevalence and Incidence Rates by Race

Overall, there were 131,836 cases of OAG, for a prevalence rate of 5.84%. The OAG prevalence among Asian Americans (6.52%) was similar to that of Latinos (6.40%). Both of these groups had higher OAG prevalence rates compared with that of whites (5.59%) and all three of these races had considerably lower OAG prevalence rates compared with blacks (12.19%). The rate ratio test, which compares the prevalence of OAG in each race with the OAG prevalence in whites showed significantly higher OAG prevalence rates in all three races relative to whites. In the overall sample, there were 31,551 cases of NAG, yielding a NAG prevalence rate of 1.40%. NAG prevalence was higher among Asian Americans (3.01%) than it was for whites (1.35%), blacks (1.65%), and Latinos (2.04%). Asian Americans, blacks, and Latinos all had significantly elevated prevalence rate ratios for NAG. The overall prevalence of NTG was 0.35%. NTG prevalence was higher among Asian Americans (0.73%) than among blacks (0.55%) and much higher than the NTG prevalence for whites (0.34%) and Latinos (0.37%). The incidence rate ratios observed were similar to the prevalence rate ratios for all three glaucoma types (Tables 2 and 3)

Differences in Glaucoma Prevalence and Incidence Among Asian Ethnicities

Of the 2,259,061 enrollees in the medical plan, 1,923,752 individuals (85%) had a documented ethnicity. 44,103 (2.5%) of the beneficiaries were determined to be of an Asian ethnicity including 15,918 Chinese Americans, 4,771 Japanese Americans, 8,312 Indian Americans, and 5,420 Vietnamese Americans. (Table 2) The OAG prevalence rate was highest for Japanese Americans (9.49%). Indian and Pakistani Americans had the next highest OAG prevalence rates (7.78% and 7.70%, respectively). The other Asian American ethnicities had lower OAG prevalence rates (range: 5.27-6.40%). In contrast to OAG, the prevalence of NAG was considerably higher among Chinese Americans (4.08%) and Vietnamese Americans (3.74%) relative to beneficiaries of each of the other Asian ethnicities (range: 1.97% - 2.66%). All Asian ethnicities had higher NAG prevalence rates as compared with the 1.41% prevalence rate for Non Asians. The NTG prevalence was 3 to 10 times higher among Japanese Americans (1.99%) than each of the other groups of Asian ethnicities (range 0.20% to 0.66%) and nearly all Asian ethnicities had higher NTG prevalence rates compared with Non Asians. Tables 2 and 3 show the prevalence and incidence rates and rate ratios for the various Asian ethnicities.

Univariate and Multivariable Analyses

Cox regression was performed to determine influence of race and ethnicity on the hazard of developing each glaucoma type. After adjusting for sociodemographic and clinical variables, Asian Americans had a 51% increased hazard of OAG (Hazard ratio (HR) = 1.51 (95% confidence interval (CI) 1.42 – 1.60), a 123% increased hazard of NAG (HR = 2.23 (95% CI 2.07 – 2.41), and a 159% increased hazard of NTG (HR = 2.59 (95% CI 2.22 – 3.02) compared with non-Hispanic whites. (Figure 2) In the multivariable model, the following Asian ethnicities demonstrated an increased hazard of OAG compared to Non Asians: Korean Americans (HR = 1.23 (95% CI 1.02-1.50), Chinese Americans (HR = 1.24 (95% CI 1.12 – 1.37), Vietnamese Americans (HR = 1.42 (95% CI 1.20-1.67), Japanese Americans (HR = 1.70 (95% CI 1.47- 1.97), Indian Americans (HR = 1.73 (95% CI 1.54 - 1.94), and Pakistani Americans (HR = 2.28 (95% CI 1.68 – 3.09). The hazard of NAG was highest among Vietnamese Americans (HR = 3.78, (95% CI 3.19 – 4.48%), Pakistani Americans (HR = 2.45, 95% CI 1.50-4.01) and Chinese Americans (HR = 2.31, 95% CI 2.06-2.59), although all Asian ethnicities had higher hazards of NAG compared with Non-Asians. The hazard of experiencing NTG was markedly higher among Japanese Americans (HR = 4.37, 95% CI 3.24 – 5.89) compared with Non-Asians. (Figure 3)

Discussion

Recent estimates from the US Census Bureau indicate that Asian Americans are the second fastest growing minority in the US population.³ From 2005 to 2006 alone, the Asian American population increased by nearly 500,000 persons and it is anticipated that this trend will continue for years to come.³ Given the dramatic rise in the number of Asian Americans, it is important for clinicians caring for these patients to be familiar with the types of ocular conditions that are more likely to affect these individuals. The present study focuses on determining the incidence and prevalence of different types of glaucoma among Asian Americans and whether individuals of different Asian ethnicities are more prone to certain glaucoma types.

There are a number of important findings generated from our analysis. While it was once thought that OAG was relatively uncommon among individuals of Asian descent^{10,11}, after adjusting for important confounding variables, we determined that the hazard of OAG among Asian Americans as a group is actually 50% higher than that of Non-Hispanic whites. The hazards of developing NAG and NTG were also considerably higher among

Asian Americans as compared with each of the other races. Another notable finding from this analysis is the remarkable difference in prevalence rates of different types of glaucoma among the different Asian ethnicities. Chinese-, Vietnamese-, and Pakistani-Americans exhibited a considerably higher hazard of NAG, while Japanese Americans had considerably higher hazard of developing NTG, relative to non Asians.

Comparison to Other Studies

Table 4 (available at <http://aaojournal.org>) summarizes the existing studies in the literature reporting prevalence estimates for different types of glaucoma among individuals of various Asian ethnicities.¹⁰⁻²⁹ Rudnicka and colleagues performed a systematic review of the literature on the subject and generated a meta-regression of existing studies to estimate the prevalence of OAG among Asians.³⁰ Based on the data from the 14 studies included in their regression model, they estimated the OAG prevalence in Asians to be 1.41%. This estimate is considerably lower than the prevalence estimate from the current analysis of 6.52%. Comparing the findings from this meta-regression, as well as from the various individual studies with the results of the present study is challenging for a number of reasons. Nearly all of these studies, including all of those in the meta-regression were conducted outside of the United States. Thus, if differences exist in prevalence rates between these studies and the current study, these differences could be due to environmental influences, access to care, or other factors that differ between care received in the United States and care received outside this country. Second, many of the enrollees in the current analysis were seen numerous times during their time in the medical plan whereas in other studies, often a study participant was seen by one eye care provider at one visit and the presence of absence of glaucoma determined at that one point in time. The more visits to an eye care provider, the greater the chances a patient will get diagnosed with OAG. Third, the distribution of persons from different regions of Asia varies considerably between those studies included in the meta-regression and those in the current study. Finally, the majority of existing studies are population-based cross-sectional studies that use specific criteria to diagnose a patient with a particular glaucoma type, and many of these studies report prevalence estimates for individuals of a specific age or urban/rural designation. By comparison, the current analysis is retrospective and uses claims data to determine whether individuals have glaucoma.

The only study we are aware of that assessed OAG prevalence among Asians residing in the United States is a large retrospective chart review by Pezmezci and colleagues of 1,732 Japanese Americans attending two private ophthalmology clinics in San Francisco, CA over a 10 year period.¹² In their study, they reported an OAG prevalence rate of 8.3%. While the prevalence rates obtained from the Pezmezci study is relatively similar to the OAG prevalence rate for Japanese Americans in the present study of 9.5%, caution should be made when directly comparing the rates from the two studies. Disparities in prevalence estimates can be due to differences in the length of follow-up between the two studies, differences in insurance status and access to care, and differences in definitions used to classify the presence or absence of OAG.

Strengths and Weaknesses

There are a number of strengths of using large administrative databases to study the epidemiology of glaucoma among Asian Americans. First, given the very large sample size, it is possible to not only determine glaucoma prevalence for Asian Americans, as a distinct group, but also to study individuals of different Asian ethnicities to ascertain differences in the types of glaucoma that affect them. Second, the i3 Data Mart database contains a geographically diverse group of individuals. Unlike studies that recruit patients from a specific city or region of the country which may be limited due to an over- or under-representation of individuals with certain socio-demographic characteristics in that

geographic locale, this dataset captures data on a wide array of individuals of different socio-demographic profiles. Finally, identifying the presence of glaucoma and glaucoma type by using billing codes may be more accurate than studies that rely on patient self-report to determine whether individuals have these conditions.

There are several limitations that need to be acknowledged. First, since the data for this analysis were generated from billing records and not from actual medical records, for an enrollee to receive a diagnosis of glaucoma, it requires the care provider to accurately diagnose the enrollee with this condition and to properly complete the billing records. Thus some patients may have been misdiagnosed or misclassified with the condition of interest. Second, there are a number of variables that are not included in administrative databases. The dataset does not capture information on visual acuity, visual field loss, refractive error, axial length, corneal thickness, gonioscopy findings, and other important clinical parameters which ideally would be important to consider when classifying the presence or absence of glaucoma and designating glaucoma type. Third, since the data on enrollee race and ethnicity was generated from surrogate measures and not from beneficiary self-report, some of the enrollees may have been misclassified. Given the very large sample size and fact that there is no reason to believe that individuals of certain races or ethnicities would be more or less likely to be misclassified as compared with others, we doubt that this limitation significantly impacts the study findings. Finally, all of the beneficiaries in this dataset had some form of health insurance. Thus, the findings from this analysis may not reflect glaucoma prevalence among uninsured individuals or those with other forms of insurance.

Implications

Several implications can be gleaned from this analysis. When evaluating Asian American patients over the age of 40 years, eye care providers should have a low threshold to perform gonioscopy to check the angle anatomy for narrow angles, especially in individuals of Chinese and Vietnamese ancestry. Furthermore, when evaluating Japanese Americans, providers should have a high index of suspicion for NTG, a diagnosis that may be easily overlooked if clinicians rely more on intraocular pressure measurements without carefully assessing the optic nerve, nerve fiber layer, and, when appropriate, perimetry. When designing population-based studies, recording of (or matching based on) a broad categorization of race (black versus white versus Asian) is inadequate. For these types of studies, researchers should also consider ethnicity. From a policy perspective, given the influx of Asian Americans over the past decade and projections that this group will continue to expand in the coming years, as these individuals age, additional resources will need to be allocated to diagnosing and treating them for glaucoma.

In conclusion, this is the first study we are aware of to assess incidence and prevalence rates of different forms of glaucoma among a large, geographically diverse group of Asian Americans. After adjusting for a number of important sociodemographic factors, ocular, and systemic comorbidities, we determined that OAG, NTG, and NAG are more prevalent among Asian Americans as compared with Non Hispanic whites. Furthermore, we identified differences in the types of glaucoma that affect individuals of different Asian ethnicities, with NTG considerably more common among Japanese Americans, while NAG is much more common among Chinese, Vietnamese, and Pakistani Americans. These differences will be important for clinicians to consider when caring for Asian American patients, for researchers when recruiting patients for clinical trials, and for policy makers responsible for making important decisions about the need for resources to care for the growing number of individuals of Asian descent residing in the United States.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Grant support: National Eye Institute K23 Mentored Clinician Scientist Award (1K23EY019511-01), National Eye Institute R01 (EY011671), American Glaucoma Society Clinician Scientist Grant, Blue Cross Blue Shield of Michigan Foundation, an unrestricted grant from Research to Prevent Blindness.

References

1. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. *Br J Ophthalmol*. 2006; 90:262–7. [PubMed: 16488940]
2. Resnikoff S, Pascolini D, Etya'ale D, et al. Global data on visual impairment in the year 2002. *Bull World Health Organ*. 2004; 82:844–51. [PubMed: 15640920]
3. Minority Population Tops 100 Million [press release]. U.S. Census Bureau. May 17 2007 [July 11, 2010]. Available at: http://www.census.gov/newsroom/releases/archives/population/c_b07-70.html.
4. Gottfredsdottir MS, Sverrisson T, Musch DC, Stefansson E. Chronic open-angle glaucoma and associated ophthalmic findings in monozygotic twins and their spouses in Iceland. *J Glaucoma*. 1999; 8:134–9. [PubMed: 10209731]
5. International Classification of Diseases 9th Revision Clinical Modification. ICD-9-CM for Physicians. Vol. 1 and 2. Contexo Media; Salt Lake City, UT: 2006.
6. CPT 2006: Current Procedural Terminology Professional Edition. American Medical Association; Chicago, IL: 2006.
7. DeFrank, JT.; Bowling, JM.; Rimer, BK., et al. Triangulating differential nonresponse by race in a telephone survey. *Prev Chronic Dis* [serial online]. 2007 [July 11, 2010]. p. A60 Available at: http://www.cdc.gov/pcd/issues/2007/jul/06_0102.htm.
8. Cnaan A, Ryan L. Survival analysis in natural history studies of disease. *Stat Med*. 1989; 8:1255–68. [PubMed: 2814073]
9. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987; 40:373–83. [PubMed: 3558716]
10. Jacob A, Thomas R, Koshi SP, et al. Prevalence of primary glaucoma in an urban south Indian population. *Indian J Ophthalmol*. 1998; 46:81–6. [PubMed: 9847479]
11. Hu CN. An epidemiologic study of glaucoma in Shunyi County, Beijing [in Chinese]. *Zhonghua Yan Ke Za Zhi*. 1989; 25:115–9. [PubMed: 2507254]
12. Pekmezci M, Vo B, Lim AK, et al. The characteristics of glaucoma in Japanese Americans. *Arch Ophthalmol*. 2009; 127:167–71. [PubMed: 19204234]
13. Yamamoto T, Iwase A, Araie M, et al. Tajimi Study Group Japan Glaucoma Society. The Tajimi Study report 2: prevalence of primary angle closure and secondary glaucoma in a Japanese population. *Ophthalmology*. 2005; 112:1661–9. [PubMed: 16111758]
14. Iwase A, Suzuki Y, Araie M, et al. Tajimi Study Group Japan Glaucoma Society. The prevalence of primary open-angle glaucoma in Japanese: the Tajimi Study. *Ophthalmology*. 2004; 111:1641–8. [PubMed: 15350316]
15. Shiose Y, Kitazawa Y, Tsukahara S, et al. Epidemiology of glaucoma in Japan--a nationwide glaucoma survey. *Jpn J Ophthalmol*. 1991; 35:133–55. [PubMed: 1779484]
16. Jonas JB, Xu L, Wang YX. The Beijing Eye Study. *Acta Ophthalmol*. 2009; 87:247–61. [PubMed: 19426355]
17. He M, Foster PJ, Ge J, et al. Prevalence and clinical characteristics of glaucoma in adult Chinese: a population-based study in Liwan District, Guangzhou. *Invest Ophthalmol Vis Sci*. 2006; 47:2782–8. [PubMed: 16799014]

18. Foster PJ, Oen FT, Machin D, et al. The prevalence of glaucoma in Chinese residents of Singapore: a cross-sectional population survey of the Tanjong Pagar district. *Arch Ophthalmol*. 2000; 118:1105–11. [PubMed: 10922206]
19. Vijaya L, George R, Baskaran M, et al. Prevalence of primary open-angle glaucoma in an urban south Indian population and comparison with a rural population: the Chennai Glaucoma Study. *Ophthalmology*. 2008; 115:648–54. [PubMed: 17664010]
20. Vijaya L, George R, Arvind H, et al. Prevalence of primary angle-closure disease in an urban south Indian population and comparison with a rural population: the Chennai Glaucoma Study. *Ophthalmology*. 2008; 115:655–60. [PubMed: 17869343]
21. Raychaudhuri A, Lahiri SK, Bandyopadhyay M, et al. A population based survey of the prevalence and types of glaucoma in rural West Bengal: the West Bengal Glaucoma Study. *Br J Ophthalmol*. 2005; 89:1559–64. [PubMed: 16299129]
22. Ramakrishnan R, Nirmalan PK, Krishnadas R, et al. Glaucoma in a rural population of southern India: the Aravind Comprehensive Eye Survey. *Ophthalmology*. 2003; 110:1484–90. [PubMed: 12917161]
23. Dandona L, Dandona R, Srinivas M, et al. Open-angle glaucoma in an urban population in southern India: the Andhra Pradesh Eye Disease Study. *Ophthalmology*. 2000; 107:1702–9. [PubMed: 10964833]
24. Dandona L, Dandona R, Mandal P, et al. Angle-closure glaucoma in an urban population in southern India: the Andhra Pradesh Eye Disease Study. *Ophthalmology*. 2000; 107:1710–6. [PubMed: 10964834]
25. Shen SY, Wong TY, Foster PJ, et al. The prevalence and types of glaucoma in Malay people: the Singapore Malay Eye Study. *Invest Ophthalmol Vis Sci*. 2008; 49:3846–51. [PubMed: 18441307]
26. Rahman MM, Rahman N, Foster PJ, et al. The prevalence of glaucoma in Bangladesh: a population based survey in Dhaka Division. *Br J Ophthalmol*. 2004; 88:1493–7. [PubMed: 15548796]
27. Casson RJ, Newland HS, Muecke J, et al. Prevalence of glaucoma in rural Myanmar: the Meiktila Eye Study. *Br J Ophthalmol*. 2007; 91:710–4. [PubMed: 17510475]
28. Bourne RR, Sukudom P, Foster PJ, et al. Prevalence of glaucoma in Thailand: a population based survey in Rom Klao District, Bangkok. *Br J Ophthalmol*. 2003; 87:1069–74. [PubMed: 12928267]
29. Sah RP, Badhu BP, Pokharel PK, et al. Prevalence of glaucoma in Sunsari district of eastern Nepal. *Kathmandu Univ Med J (KUMJ)*. 2007; 5:343–8. [PubMed: 18604052]
30. Rudnicka AR, Mt-Isa S, Owen CG, et al. Variations in primary open-angle glaucoma prevalence by age, gender, and race: a Bayesian meta-analysis. *Invest Ophthalmol Vis Sci*. 2006; 47:4254–61. [PubMed: 17003413]

Figure 1.
Sample Selection Process (Online publication only)

Figure 2.
Multivariable Cox Regression Results: Hazard of Developing Each Glaucoma Type for Different Races

The reference group is Non Asian; X-axis labels: Adjusted HR. Figures show the hazard ratios with 95% confidence intervals

Multivariable analyses adjusted for age, sex, household net worth, education level, hypertension, diabetes mellitus, hyperlipidemia, sleep apnea, migraine headache, cataract, pseudophakia / aphakia, macular degeneration, diabetic retinopathy

NAG = narrow-angle glaucoma; NTG = normal-tension glaucoma; OAG = open-angle glaucoma

Figure 3.
Multivariable Cox Regression Results: Hazard of Developing Each Glaucoma Type for Different Asian Ethnicities

Table 1

International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9CM) Codes Used in the Analysis

Condition	ICD-9CM Codes
Age-related macular degeneration	362.50, 362.51, 362.52, 362.57
Cataract	366, 366.0, 366.00, 366.01, 366.02, 366.03, 366.04, 366.09, 366.1, 366.10, 366.12, 366.13, 366.14, 366.15, 366.16, 366.17, 366.18, 366.19, 366.41, 366.45
Diabetes mellitus	250.0, 250.00, 250.01, 250.02, 250.03, 250.1, 250.10, 250.11, 250.12, 250.13, 250.2, 250.20, 250.21, 250.22, 250.23, 250.3, 250.30, 250.31, 250.32, 250.33, 250.4, 250.40, 250.41, 250.42, 250.43, 250.5, 250.50, 250.51, 250.52, 250.53, 250.5, 250.50, 250.51, 250.52, 250.53, 250.6, 250.60, 250.61, 250.62, 250.63, 250.7, 250.70, 250.71, 250.72, 250.73, 250.8, 250.80, 250.81, 250.82, 250.83, 250.9, 250.90, 250.91, 250.92, 250.93, 362.01, 362.02, 362.03, 362.04, 362.05, 362.06, 362.07
Diabetic retinopathy	362.01, 362.92, 362.03, 362.04, 362.05, 362.06, 362.07
Hyperlipidemia	272, 272.0, 272.1, 272.2, 272.3, 272.4, 272.5, 272.6, 272.7, 272.8, 272.9
Hypertension	401, 401.0, 401.1, 401.9, 405, 405.0, 405.1, 405.01, 405.09, 405.11, 405.19, 405.9, 405.91, 405.99, 362.11, 402, 402.0, 402.00, 402.01, 402.1, 402.10, 402.11, 402.9, 402.90, 402.91, 403, 403.0, 403.00, 403.01, 403.1, 403.10, 403.11, 403.9, 403.90, 403.91, 404.0, 404.00, 404.01, 404.02, 404.03, 404.1, 404.10, 404.11, 404.12, 404.13, 404.9, 404.90, 404.91, 404.92, 404.93
Migraine	346, 346.0, 346.00, 346.01, 346.1, 346.10, 346.11, 346.2, 346.20, 346.21, 346.8, 346.80, 346.81, 346.9, 346.90, 346.91
Narrow-angle glaucoma	365.02, 365.2, 365.21, 365.22, 365.23, 365.61, 365.73
Normal-tension glaucoma	365.12
Obesity	278.0, 278.00, 278.01, 278.02
Open-angle glaucoma	365.1, 365.10, 365.11, 365.12, 365.15
Pseudophakia or aphakia	V43.1, 379.3, 379.31
Sleep apnea syndrome	327.2, 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57

Table 2

Prevalence of Open-angle glaucoma, narrow-angle glaucoma, and normal-tension glaucoma among different races and Asian ethnicities*

PREVALENCE													
Strata	N Total	N	Rate	OAG		N	Rate	NAG		N	Rate	NTG	
				Rate ratio	C.I.			Rate ratio	C.I.			Rate ratio	C.I.
Overall	2259061	131836	5.84%			31551	1.40%			7870	0.35%		
Race													
White	1535008	85847	5.59%			20661	1.35%			5226	0.34%		
Black	78315	9550	12.19%	2.18	(2.13,2.23)	1295	1.65%	1.23	(1.16,1.30)	428	0.55%	1.61	(1.45,1.77)
Latino	99518	6367	6.40%	1.14	(1.12,1.17)	2029	2.04%	1.51	(1.45,1.59)	366	0.37%	1.08	(0.97,1.20)
Asian	44103	2875	6.52%	1.17	(1.12,1.21)	1329	3.01%	2.24	(2.12,2.37)	320	0.73%	2.13	(1.90,2.39)
Other	16018	947	5.91%	1.06	(0.99,1.13)	277	1.73%	1.28	(1.14,1.45)	48	0.30%	0.88	(0.66,1.17)
Ethnicity													
Non-Asian	1879649	111158	5.91%			26445	1.41%			6600	0.35%		
Vietnamese	5420	317	5.85%	0.99	(0.89,1.10)	221	4.08%	2.90	(2.54,3.31)	24	0.44%	1.26	(0.84,1.88)
Japanese	4771	453	9.49%	1.61	(1.46,1.76)	94	1.97%	1.40	(1.14,1.71)	95	1.99%	5.67	(4.63,6.94)
Chinese	15918	917	5.76%	0.97	(0.91,1.04)	596	3.74%	2.66	(2.45,2.89)	99	0.62%	1.77	(1.45,2.16)
Filipino	2514	161	6.40%	1.08	(0.93,1.26)	52	2.07%	1.47	(1.12,1.93)	16	0.64%	1.81	(1.11,2.96)
Korean	3948	208	5.27%	0.89	(0.78,1.02)	91	2.30%	1.64	(1.33,2.01)	18	0.46%	1.30	(0.82,2.06)
Indian	8312	647	7.78%	1.32	(1.22,1.42)	221	2.66%	1.89	(1.66,2.16)	55	0.66%	1.88	(1.45,2.46)
Pakistani	1000	77	7.70%	1.30	(1.04,1.63)	21	2.10%	1.49	(0.97,2.29)	2	0.20%	0.57	(0.14,2.28)
Other Asian	2220	95	4.28%	0.72	(0.59,0.88)	33	1.49%	1.06	(0.75,1.49)	11	0.50%	1.41	(0.78,2.55)

CI = confidence interval, NAG = narrow-angle glaucoma, NTG = normal-tension glaucoma, OAG = open-angle glaucoma

* 486099 enrollees did not have a recorded race and 335309 enrollees did not have a recorded ethnicity

Table 3

Incidence of Open-angle glaucoma, narrow-angle glaucoma, and normal-tension glaucoma among different races and Asian ethnicities*

INCIDENCE											
Strata	N Total	N	Rate	OAG Rate ratio	C.I.	N	Rate	NAG Rate ratio	C.I.	N	NTG Rate ratio C.I.
Overall	2259061	55090	0.93%			20316	0.33%			4672	0.08%
Race											
White	1535008	36705	0.84%			13617	0.30%			3170	0.07%
Black	78315	4319	2.09%	2.48	(2.40,2.56)	865	0.38%	1.27	(1.19,1.36)	266	1.68 (1.48,1.90)
Latino	99518	3142	1.19%	1.41	(1.36,1.46)	1375	0.50%	1.67	(1.58,1.76)	245	1.27 (1.11,1.45)
Asian	44103	1422	1.22%	1.44	(1.37,1.52)	832	0.69%	2.28	(2.13,2.45)	197	2.31 (2.00,2.66)
Other	16018	417	0.94%	1.12	(1.02,1.23)	184	0.40%	1.33	(1.15,1.54)	33	1.03 (0.73,1.45)
Ethnicity											
Non-Asian	1879649	48172	0.91%			17490	0.32%			4041	0.07%
Vietnamese	5420	170	1.18%	1.29	(1.11,1.50)	141	0.96%	3.02	(2.56,3.57)	13	1.18 (0.69,2.04)
Japanese	4771	213	1.57%	1.73	(1.51,1.98)	75	0.52%	1.63	(1.30,2.04)	50	4.74 (3.59,6.27)
Chinese	15918	432	1.06%	1.17	(1.06,1.28)	355	0.85%	2.68	(2.41,2.98)	67	2.16 (1.70,2.76)
Filipino	2514	78	1.14%	1.26	(1.01,1.57)	34	0.48%	1.50	(1.07,2.11)	13	2.49 (1.44,4.29)
Korean	3948	116	1.10%	1.20	(1.00,1.45)	55	0.50%	1.59	(1.22,2.07)	14	1.74 (1.03,2.94)
Indian	8312	322	1.45%	1.59	(1.43,1.78)	133	0.58%	1.81	(1.52,2.14)	32	1.87 (1.32,2.65)
Pakistani	1000	46	1.76%	1.94	(1.45,2.59)	17	0.63%	1.97	(1.22,3.16)	1	0.50 (0.07,3.55)
Other Asian	2220	45	0.75%	0.82	(0.62,1.10)	22	0.36%	1.12	(0.74,1.71)	7	1.55 (0.74,3.26)

CI = confidence interval, NAG = narrow-angle glaucoma, NTG = normal-tension glaucoma, OAG = open-angle glaucoma

* 486099 enrollees did not have a recorded race and 335309 enrollees did not have a recorded ethnicity

Table 4

Summary of Rates of Glaucoma Among Asians or Asian Americans in the Literature

Study	Year	Study Name	Ethnicity	n patients	Age range	Any Glaucoma	POAG	PACG	NTG	HTG	Comments
Pekmezci et al. ¹²	2009		Japanese-American	1732		6.47%			4.50%	1.10%	
Savaguchi [#]	2009					8.3%					
			Japanese	3762	40+		3.95%		3.27%		
Yamamoto et al. ¹³	2005	Tajimi Study	Japanese	3021	40+	5.00%		0.60%			
Iwase et al. ¹⁴	2004	Tajimi Study	Japanese	3021	40+		3.90%		3.60%	0.30%	
Shiose et al. ¹⁵	1991		Japanese	8126	40+	3.10%	0.58%	0.34%	2.04%		rates adjusted for age / sex
Hu et al. ¹¹	1989		Chinese			0.60%	0.11%	0.41%			
Liang et al. [*]	2009	Handan Eye Study	Chinese	6830	30+		1.60%				91% of cases had NTG
							1.70%				Prev. estimate for pts 40+
							2.60%				Prev. estimate for pts 50+
Liang et al. [^]	2009	Handan Eye Study	Chinese	6830	30+			0.60%			
								0.70%			Prev. estimate for pts 40+
								1.10%			Prev. estimate for pts 50+
Yuan et al. ^{\$}	2009	Bin District	Chinese	4956	40+			1.57%			
Jonas et al. ¹⁶	2009	Beijing Eye Study	Chinese	3251	40+	3.10%	2.17%	0.93%			
He et al. ¹⁷	2006	Liwan District	Chinese	1504	50+	3.80%	2.10%	1.50%			
Foster et al. ¹⁸	2000	Tanjong Pagar Survey	Chinese-Singaporean	1232	40-79	2.20%	1.20%				Observed prevalence rates
Kim et al. ^{##}	2009	Namil Study	Korean	1532	40+	4.70%	3.90%		3.10%	0.80%	
Lee et al. ^{**}	2009	Namil Study	Korean	1539	40+			0.50%			
Vijaya et al. ¹⁹	2008	Chennai Glaucoma Study	Indian	3850	40+		3.51%				Urban individuals
							1.62%				Rural individuals
Vijaya et al. ²⁰	2008	Chennai Glaucoma Study	Indian	3850	40+			0.88%			
Raychaudhuri et al. ²¹	2005	West Bengal Glaucoma Study	Bengali Indian	1269	50+	3.40%					Adjusted for age

Study	Year	Study Name	Ethnicity	n patients	Age range	Any Glaucoma	POAG	PACG	NTG	HTG	Comments
Ramakrishnan et al. ²²	2003	Aravind Comprehensive Eye Survey	Indian	5150	40+	2.60%	1.70%	0.50%			
							1.20%				Adjusted for age
Dandona et al. ²³	2000	Andhra Pradesh Eye Disease Study	Indian	2522	30+		1.62%				Adjusted for age / sex
							2.56%				Adjusted for age / sex
Dandona et al. ²⁴	2000	Andhra Pradesh Eye Disease Study	Indian	2522	30+			0.71%			Adjusted for age / sex
								1.08%			Adjusted for age / sex
Jacob et al. ¹⁰	1998	Vellore Eye Survey	Indian	972	30-60		0.41%	4.32%			
Shen et al. ²⁵	2008	Singapore Malay Eye Study	Malay	3280	40-80	4.60%					
						3.40%	2.50%	0.12%			Adjusted for age / sex
Rahman et al. ²⁶	2004	Dhaka Division	Bangladesh	2347	35+	3.10%	2.50%	0.40%			
Casson et al. ²⁷	2007	Meiktila Eye Study	Myanmar	2076	40+	4.90%	2.00%	2.50%			
Bourne et al. ²⁸	2003	Rom Klao District	Thai	701	50+	3.80%	2.30%	0.90%			
Sah et al. ²⁹	2007	Sunsari District	Nepalese	1600	40+	0.94%	0.56%	0.13%			

POAG = Primary open-angle glaucoma, PACG = primary angle-closure glaucoma, NTG = normal-tension glaucoma, HTG = high-tension glaucoma

Abstracts:

[#] Sawaguchi S, Nakamura Y, Tomidokoro A, et al. The prevalence of primary open angle glaucoma and secondary glaucoma in a rural island in southwest Japan. Paper presented at: World Glaucoma Congress, July 8, 2009; Boston, MA. Available at: <http://www.eventure-online.com/eventure/publicAbstractView.do;jsessionid=abcMjDyxCpNCI4x7ONeJs?id=103806&congressId=2399>. Accessed July 11, 2010.

^{*} Liang YB, Zhou Q, Wang NL, et al. Prevalence of glaucoma and ocular hypertension in a rural adult Chinese population: the Handan Eye Study. Presented at: World Glaucoma Congress, July 10, 2009; Boston, MA. Available at: http://www.eventure-online.com/eventure/publicAbstractView.do;jsessionid=abccJK19CKK36e3_qP1JJs?id=99990&congressId=2399. Accessed July 11, 2010.

[^] Liang YB, Yang XH, Wang N, et al. The prevalence of primary angle closure glaucoma and primary angle closure in a rural adult Chinese population: the Handan Eye Study. Presented at: World Glaucoma Congress, July 8, 2009; Boston, MA. Available at: <http://www.eventure-online.com/eventure/publicAbstractView.do;jsessionid=abcMjDyxCpNCI4x7ONeJs?id=100003&congressId=2399>. Accessed July 11, 2010.

^{\$} Yuan H, Qu W, Sun J, et al. Prevalence and risk factors for primary open-angle glaucoma in a rural northeast China population: a population-based survey in Bin district, Harbin. Presented at: World Glaucoma Congress, July 8, 2009; Boston, MA. Available at: <http://www.eventure-online.com/eventure/publicAbstractView.do;jsessionid=abcMjDyxCpNCI4x7ONeJs?id=99545&congressId=2399>. Accessed July 11, 2010.

^{##} Kim CS, Seong GJ, Lee NH, Song KC. Prevalence of primary open-angle glaucoma in central South Korea, the Namil Study. Presented at: World Glaucoma Congress, July 8, 2009; Boston, MA. Available at: <http://www.eventure-online.com/eventure/publicAbstractView.do;jsessionid=abcMjDyxCpNCI4x7ONeJs?id=99954&congressId=2399>. Accessed July 11, 2010.

Lee JH, Kim YY. Prevalence of angle-closure disease in a Korean population: the Namil Study report. Presented at: World Glaucoma Congress, July 8, 2009; Boston, MA. Available at: <http://www.eventure-online.com/eventure/publicAbstractView.do?sessionId=abcMjDyxCPNCI4x7ONeJs?id=99519&congressId=2399>. Accessed July 11, 2010.

**