Importance of population-based studies in clinical practice

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In the last decade, there have been reports on the prevalence of glaucoma from the Vellore Eye Survey, Andhra Pradesh Eye Diseases Survey, Aravind Comprehensive Eye Survey, Chennai Glaucoma Study and West Bengal Glaucoma Study. Population-based studies provide important information regarding the prevalence and risk factors for glaucoma. They also highlight regional differences in the prevalence of various types of glaucoma. It is possible to gather important insights regarding the number of persons affected with glaucoma and the proportion with undiagnosed disease. We reviewed the different population-based studies from India and compare their findings. The lacunae in ophthalmic care that can be inferred from these studies are identified and possible reasons and solutions are discussed. We also discuss the clinical relevance of the various findings, and how it reflects on clinical practice in the country. Since India has a significantly high disease burden, we examine the possibility of population-based screening for disease in the Indian context.

Key words: Blindness, India, population-based study, primary open angle glaucoma, primary angle closure glaucoma, risk factors

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Glaucoma is a major cause of blindness. It has been identified to be the second most common cause of blindness worldwide. In a recent publication, about 60 million persons are estimated to be affected by glaucoma.[2][3] Of these, an estimated 11.2 million cases are from the Indian subcontinent.[5]

There are regional differences in the prevalence of different types of glaucoma, and the way it presents.[5] From India, the prevalence and risk factors for glaucoma have been reported from several population-based studies. These include the Vellore Eye Survey (VES),[4] Andhra Pradesh Eye Diseases Survey (APEDS),[5,6] Aravind Comprehensive Eye Survey (ACES),[7] Chennai Glaucoma Study (CGS),[8-11] and West Bengal Glaucoma Study (WBGS).[12] We attempted to summarize some of the findings and risk factors they report. There are methodologic differences between the studies and diagnostic variations in the disease definition. The more recent studies have used the International Society of Geographical and Epidemiological Ophthalmology (ISGEO) classification proposed by Foster et al.[13] for use in population-based studies. The study criteria are summarized in Table 1 and the ISGEO criteria in Table 2.

Primary Open Angle Glaucoma

The reported prevalence for Primary Open Angle Glaucoma (POAG) varies between 1.62% and 3.51%.[4-6,8-12] [Table 3]. A trend toward higher prevalence was noted in the urban cohorts studied. Among the risk factors reported, increasing age was a consistent risk factor for POAG across all studies.[4-6,8-12] [Fig. 1]. The Fig 1 also compares the POAG prevalence with increasing age between all the population based from India and two international studies (The Barbados study[14] and the Rotterdam study[15]).

Risk factors for POAG

1. Race: Forty-six population-based studies were analyzed in a meta-analysis by Rudnicka et al.[16] to evaluate the effect of race on POAG prevalence. The pooled prevalence estimate for POAG was 1.4% (95% CI: 1.0-2.0%) in Asian populations, 4.2% in Black populations (95% CI: 3.1-5.8%), and 2.1% (95% CI: 1.6-2.7%) in White populations.

2. Age: As with most chronic diseases, the prevalence of disease increases with increasing age due to the increase in the cumulative number of persons with disease. This increase appears to be exponential in western populations as compared to Asian reports.[1,14,17] In the CGS (Urban),[8,10] the risk of disease in those above the age of 70 years was five times that of the 40-49 age group. [Fig. 1]

3. Intraocular pressure (IOP): Elevated IOP is no longer considered to be a diagnostic criterion for POAG. Most population-based studies report that between 30% and 60% of the subjects diagnosed to have POAG actually have an IOP recording in the statistically normal range.[1-12] On further visits, the IOP may be recorded to be greater than normal. This highlights the danger of considering a “normal” IOP in isolation while assessing the risk of POAG in an individual. While many of those with POAG have normal IOP, the risk of having POAG increases dramatically with increase in IOP. This is because among those with elevated IOP a large proportion will have POAG (the rest being ocular hypertensive or pre-perimetric disease), while those with POAG and a normal presenting IOP will form only a small proportion of all those with normal IOP even if they are a substantial percentage of those with the disease.
Table 1: Summary of the different population-based studies from India

| Study  | Study period | Population studied | Age group | Number examined (response rate %) | Diagnostic criteria for glaucoma |
|--------|--------------|---------------------|-----------|-----------------------------------|---------------------------------|
|        |              |                     |           |                                   | Elevated IOP | Optic disc | Visual field |
|        |              |                     |           |                                   | changes | changes | defects |
| VES    | 1994         | Urban               | 30-60     | 972 (50.3)                        | Yes/No       | Yes      | Yes      |
| APEDS  | 1996-2000    | Urban               | All ages  | 10273 (87.3)                      | No            | Yes      | Yes/No   |
| ACES   | 1995-97      | Rural               | 40+       | 5150 (93.0)                       | No            | Yes      | Yes/No   |
| CGS*   | 2001-03      | Rural               | 40+       | 3924 (81.75)                      | No            | Yes      | Yes/No   |
| CGS    | 2002-04      | Urban               | 40+       | 3850 (80.20)                      | No            | Yes      | Yes/No   |
| WBGS*  | 1998-99      | Rural               | 50+       | 1324 (83.1)                       | No            | Yes      | Yes/No   |

*The CGS and the WBGS used the ISGEO<sup>[13]</sup> criteria (with minor modifications) to diagnose disease. An IOP level that exceeds the 99.5th percentile for a normal population is used to diagnose disease only when the optic disc cannot be visualized and visual fields are not possible. APEDS: The Andhra Pradesh Eye Disease Study, CGS: The Chennai Glaucoma Study, WBGS: West Bengal Glaucoma Study, VES: Vellore Eye Study, ACES: The Aravind Comprehensive Eye Survey, RUR: Rural, URB: Urban, CI: Confidence Interval.

Table 2: International Society for Geographical and Epidemiological Glaucoma (ISGEO) criteria

| Category 1: Structural and functional evidence | Visual acuity | IOP and treatment | Optic disc | Field defect |
|-----------------------------------------------|---------------|-------------------|------------|-------------|
| CDR or CDR asymmetry ≥ 97.5<sup>th</sup> percentile for the normal population. Neural retinal rim width reduced to ≤0.1 CDR (Superior: 11-1 o’clock or inferior: 5-7 o’clock) | <3/60 IOP>99.5<sup>th</sup> percentile of normal population | CDR or CDR asymmetry ≥ 97.5<sup>th</sup> percentile for the normal population. Neural retinal rim width reduced to ≤0.1 CDR (Superior: 11-1 o’clock or inferior: 5-7 o’clock) | Defect consistent with glaucoma | Subjects who have not completed Visual fields |

Category 2: Advanced structural damage with unproved field defect

Category 3

<3/60 Evidence of glaucoma filtration surgery or using antiglaucoma medication

Classification of primary angle closure glaucoma

| Criteria                                                                 | Appositional closure contact between peripheral iris and posterior trabecular meshwork (pigmented TM not seen ≥180 or 270°) |
|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| PACS: Primary angle closure suspect (PACS)                               | PACS together with features indicating that TM obstruction by peripheral iris (peripheral anterior synechiae, elevated IOP, iris whorling, glaucomflecken, lens opacities or extensive TM pigmentation) |
| PAC: Primary angle closure (PAC)                                         | PAC together with evidence of glaucoma (as defined above)                                                         |

Table 3: Prevalence of Glaucoma in different studies

| Study  | Prevalence of POAG | Prevalence of PACG |
|--------|---------------------|--------------------|
|        | (n = 934)           | (n = 5150)         |
| VES    | 2.56 (1.22, 3.92)   | 1.08 (0.36, 1.80)  |
| PACG   | 1.7 (1.3, 2.1)      | 0.5 (0.3, 0.7)     |
| PAC    | 1.62 (1.42, 1.82)   | 0.87 (0.58, 1.16)  |
| PACS   | 3.51 (3.04, 4.0)    | 0.88 (0.6, 1.16)   |
| PB    | 0.71 (0.45, 0.98)   | 0.71 (0.45, 0.98)  |
| PB    | 2.75 (2.01, 3.49)   | 2.75 (2.01, 3.49)  |
| PB    | 6.27 (5.51, 7.03)   | 6.27 (5.51, 7.03)  |
| PB    | 7.24 (6.58, 8.02)   | 7.24 (6.58, 8.02)  |

VES reported POAG prevalence (30-60 years): 0.41% (95% CI: 0.08, 0.81) and PACG prevalence (30-60 years): 4.32 (95% CI: 3.01, 5.63). ACES reported PACG prevalence (40 years or more): 0.5% (95% CI: 0.3, 0.7). APEDS: The Andhra Pradesh Eye Disease Study, CGS: The Chennai Glaucoma Study, WBGS: West Bengal Glaucoma Study, VES: Vellore Eye Study, ACES: The Aravind Comprehensive Eye Survey, RUR: Rural, URB: Urban, CI: Confidence Interval. POAG: Primary open angle glaucoma, PACG: Primary angle closure glaucoma, PAC: Primary angle closure and PACS: Primary angle closure suspect.
confirmed by the VES, which was the first population-based glaucoma prevalence study from India.\(^4\) Jacob et al.\(^4\) reported that 10.3% of the population had occludable angles or angle closure glaucoma. Subsequent studies reported a substantial proportion of angle closure glaucoma. However, there were wide variations in the reported rates for PAC and PACG\(^3,5,7,8,11,13\) [Table 3]. These differences could be related to diagnostic criteria as well as gonioscopic technique and the use of standard testing conditions (dim illumination, a shortened slit beam that does not fall on the pupil). Studies that were carried out by persons with specialized glaucoma training have consistently reported higher rates of PACS and PACG.\(^4,5,9\)

There were diagnostic differences between the studies. For angle closure disease, both the VES and the CGS used non-visibility of the filtering trabecular meshwork for 180° or more of the angle to define angle closure. The VES\(^4\) classified those with PAC and PACG as PAC, the APEDS\(^9\) classified those with IOP greater than 22 mmHg or IOP, disc and field changes in those with occludable angles (270° or more of the angle narrow) as having PACG. On the basis of ISGEO\(^\text{13}\) definitions, this would include some of those now classified as PAC but would exclude those with synechial closure in the absence of raised IOP, disc or field changes, potentially resulting in underestimation of the prevalence of PAC and PACG combined. The ACES\(^7\) defined PACG if it met at least two of the criteria of glaucomatous optic disc damage or glaucomatous visual field defects in combination with anterior chamber angle partly (9'o clock hours) or totally closed, appositional angle closure or synechiae in the angle along with the absence of signs of secondary angle closure.

**Risk factors for PACG**

1. **Symptoms:** Most angle closure disease in India are asymptomatic\(^3,5,7,8,11,12\). The vast majority of patients have the chronic form of disease which does not present with significant visual symptoms. The presentation may be different from that of persons of Chinese origin who are more likely to present with acute symptoms.\(^2,23\)

2. **Ethnicity:** The prevalence of angle closure glaucoma shows much wider variations than for open angle glaucoma. The highest rates have been reported among Eskimos.\(^24\) High prevalence has also been reported from China, Mongolia, Southeast Asia, and India.\(^3,5,7,9,11,12,22,25-28\)

3. **Age:** Increasing age [Fig. 2] is a risk factor for PACG too. However, the increase does not appear to follow the exponential curve described for POAG. An exponential increase in prevalence was noted in the CGS (Urban cohort) for PACS with increasing age. Lenticular changes could be responsible for this finding.\(^3,20\)

4. **Biometry:** Eyes with angle closure disease appear to have a shorter axial length, a shallower anterior chamber, and a thicker lens than the normal population.\(^3,5,29,30\) All these factors contribute to a crowded anterior segment of the eye. In this situation, small increases in lens thickness or decrease in the anterior chamber depth would result in greater iris convexity and consequently a narrower angle recess.

5. **Gender:** Female gender has been reported to be an independent risk factor for angle closure glaucoma and for angle closure disease. This is possibly related to biometric differences between genders since women appear to have shorter eyes and a shallower anterior chamber depth than men.\(^2,29\)

**Primary Angle Closure Disease = Primary Angle Closure Suspects + Primary Angle Closure + Primary Angle Closure Glaucoma**

The clinical suspicion that angle closure glaucoma was a significant cause of ocular morbidity in the country was
In all population-based studies, the majority of those diagnosed in the study with glaucoma were previously undetected, previous diagnosis rates range from 6% to 17%. These rates are far below the 40-60% of previously diagnosed glaucoma from western studies. These poor detection rates are a cause for concern, since with greater life expectancy resulting in an aging population the number of those affected with glaucoma is expected to increase to 60 million by 2010. The poor detection rates are even greater when we look at data reported from the ACES and CGS. The ACES reported that even though 50% of those diagnosed with POAG in their study cohort had undergone an eye

**Incidence of Glaucoma**

Thomas *et al.* reported the 5-year incidence figures from the VES for angle closure, angle closure glaucoma, and POAG. Among ocular hypertensive 17.4% (95% CI: 1.95-32.75) progressed to POAG (3.5% per year). Among the 110 normals, one progressed to normal tension glaucoma (NTG). The relative risk of progression among ocular hypertensive (OHT) was 19.1 (95% CI: 2.2-163.4). All those who progressed had bilateral OHT. Bilateral OHT, higher peak IOP, and large diurnal variation were noted to be risk factors for progression.

For angle closure disease 22% (95% CI: 9.8-34.2) of PACS re-examined after a 5-year period progressed to PAC (seven synechial and four appositional); none of them developed disc or visual field changes.

The relative risk for progression among PACS was 24 (95% CI: 3.2-182.4). There was no significant difference in axial length, anterior chamber depth, or lens thickness between those who progressed and those who did not. Bilateral PACS was a clinical risk factor for progression. Primary angle closure was noted to progress to PACG in 28.5% (95% CI: 12-45%). Progression to PACG was based on the optic disc damage and visual field defects on automated perimetry. One-third of cases had undergone laser peripheral iridotomy at baseline, the others had refused laser. At the 5-year follow-up, 11% of those who underwent iridotomy progressed as compared to 36.8% of those who did not. There was no significant difference in biometric parameters between the progressed and non-progressed groups.

**Disease Estimates from Population-Based Studies**

Another estimate of the number of persons with glaucoma and at risk of disease in the country was recently reported. An estimated 6.48 (95% CI: 5.06-7.89) million person were estimated to have POAG, estimates for OHT were 4.7 (95% CI: 3.94-9.31) million. PACG affects an estimated 2.54 (95% CI: 1.88-4.28) million persons. Those with some evidence of damage to the trabecular meshwork such as raised IOP or peripheral anterior synchiae (PAS) or glaucomatous optic disc or visual field changes comprise 6.62 (95% CI: 4.78-9.41) million persons. The estimated total number of persons with angle closure disease is 27.66 (95% CI: 24.00-30.92) million. The prevalence of PACG and PAC show a linear increase with age.

### Blinding Due to Glaucoma

Glaucoma is the second leading cause of blindness in the adult population in India. Angle closure glaucoma causes blindness in a greater proportion of affected individuals than that of open angle glaucoma. The rates of bilaterally blind because of POAG in the APEDS, CGS (rural), CGS (Urban), and WBGS were 11.1%, 1.6%, 3.2%, 1.5%, and 5.2%, respectively. For angle closure glaucoma, the blindness rates for APEDS, CGS (rural), and CGS (Urban) were 16.6%, 2.9%, and 5.9%, respectively. The WBGS reported only three cases of PACG and none of whom were blind. PACG caused two times the proportion of bilateral blindness than that of POAG.

6. **Hyperopia**: An association of increasing hyperopia with the angle closure disease would be expected taking into account that hyperopic eyes are likely to be shorter and therefore at greater risk of angle closure disease. This has not been reported consistently from population-based studies. One possible explanation is related to the cataractous changes occurring in these eyes. Minor degrees of nuclear sclerosis are known to induce a myopic shift in refraction values. Since nuclear sclerosis is common among the study population and among those with angle closure disease, this myopic shift could confound any possible association with hyperopia.

Some of the studies have reported the prevalence of secondary glaucoma. The WBGS reported a rate of 0.08%, APEDS (0.21%) (among those aged 30 and above), and 0.3% in the ACES, respectively. Absolute glaucoma was diagnosed in 0.08% of those examined in the ACES. The prevalence of pseudoexfoliation (PXF) has also been reported by the rural arm of CGS and the APEDS, the reported prevalence of PXF was 3.8% and 3.01% and PXF glaucoma was 13% and 5.5%, respectively. In the rural arm of the CGS, 1.38% of the population had glaucoma with aphakia or pseudophakia. An additional 0.49% had PXF glaucoma. The ACES reported that the prevalence of PXF glaucoma was 0.44%.
to be overcome in order to improve diagnosis rates. Robin et al. report from the ACES that even though three-fourths of persons aged 40 years or older in the rural population required eye care services only one-third had undergone an eye examination at any time in their lives.

In the presence of the combination of a large population with glaucoma and low diagnosis rates in the country, screening is often considered to be an attractive option. While glaucoma meets many of the criteria for a disease for which screening could be considered such as the significant prevalence and a pre-symptomatic phase, there is a lack of an accepted screening test. The frequency doubling perimetry (FDP) in the screening mode shows promise. However, it is not specific for glaucoma and visual field defects could be because of other neuro-ophthalmological or retinal causes. The optic nerve head and nerve fiber layer imaging devices do not perform much better.

Table 4: Sensitivity and specificity of diagnostic tests for POAG

| Test                                           | Sensitivity | Specificity |
|------------------------------------------------|-------------|-------------|
| Tonometry (at cutoff IOP > 21 mmHg)            | 25.1-47.1%  | 92.4-95.3%  |
| Optic disc examination (CDR ≥ 0.55)            | 59%         | 73%         |
| Automated perimetry                            | 97%         | 84%         |
| Frequency doubling technology                   | 90-94%      | 91-96%      |
| Stereophotographs                              | 94%         | 87%         |
| HRT II                                          | 73, 84      | 77, 90      |
| OCT 3, RNFL                                    | 86.82       | 84.84       |
| GDx VCC                                        | 84          | 84          |

POAG: Primary open angle glaucoma, HRT: Heidelberg Retinal tomography, OCT: Optical coherence tomography, RNFL: Retinal nerve fiber layer analysis, GDx VCC: Scanning laser polarimetry

Figure 3: Area under ROC for IOP among CGS:POAG subjects. Diagnostic ability of intraocular pressure measurements among POAG subjects. (CGS: The Chennai Glaucoma Study, POAG: Primary open angle glaucoma, AROC: Area under receiver operated characteristic curve)
Table 5: Sensitivity and specificity of diagnostic tests for PACD

| Test                        | Sensitivity (%) | Specificity (%) |
|-----------------------------|-----------------|-----------------|
| Oblique flashlight test[55,56] | 80-86           | 69-70           |
| VH grade ≤ 2[57,58]         | 62-80           | 89.3-92         |
| AS-OCT[59]                  | 94.1            | 55.3            |
| SPAC[60]                    | 84.9            | 73.1            |

VH: van Herick grading, AS-OCT: Anterior segment Optical coherence tomography, SPAC: Scanning Peripheral Anterior Chamber Depth Analyzer, PACD: Primary Angle Closure Disease

in detecting glaucoma.[33,54] The devices have sensitivity and specificity values in the mid eighties which are inadequate for population-based glaucoma detection.[33,54] Screening methods to detect PACD have similar limitations.[57,58] Among the non contact screening methods, van Herick’s grading has reasonable sensitivity and specificity to screen for angle closure disease,[59] establishment of the diagnosis in the clinic will require gonioscopy performed under standard conditions (using a shortened slit beam that does not fall on the pupil) and of course IOP measurement and optic disc evaluation. The non-contact technique [Table 5] such as scanning peripheral anterior chamber depth analyzer (SPAC) and anterior segment optical coherence tomography (AS-OCT) have poor specificity and are inappropriate for screening because of the high false positive rates.[58-60]

With high false positive rates expected for most tests due to the 5% disease rate in the population use of these tests will result in large numbers of false positives. They will have to be evaluated in detail at a tertiary care center and may need to travel long distances for confirmatory tests. The majority of the test positives will be false positives, this is likely to adversely impact any screening program since most of those referred for further evaluation would turn out to be normal. This would adversely affect future participation in the program. The problems of “labeling” persons who may not have access to care, resulting in needless anxiety, also needs to be taken into consideration.

Conclusions

The population-based studies report very poor diagnosis rates for the disease and also highlight the poor diagnostic value of a single IOP recording. The necessity of actively looking to diagnose the disease becomes imperative when we consider that one in eight persons above the age of 40 years in India is either suffering from glaucoma or is at risk of the disease. The lack of any simple screening techniques only reinforces the fact that performing a comprehensive eye examination on every person who enters the eye care system is the only method of consistently detecting glaucoma. It is apparent that current standards of evaluation are suboptimal. Improving awareness about the disease and the required standards for examination among the general public may be the most effective way of ensuring that such evaluations become a part of the routine patient assessment in ophthalmic practice in the country.

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References

1. Resnikoff S, Pascolini D, Etya’ale D, Kocur I, Pararajasegaram R, Pokharel GP, et al. Global data on visual impairment in the year 2002. Bull World Health Organ 2004;82:844-51.
2. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. Br J Ophthalmol 2006;90:262-7.
3. George R, Ramesh S Ve, and Viajaya L, Glaucoma in India: Estimated burden of disease. J Glaucoma 2010;19:391-7.
4. Jacob A, Thomas R, Koshi SP, Braganza A, Mulyili J. Prevalence of primary glaucoma in an urban south Indian population. Indian J Ophthalmol 1998;46:81-6.
5. Dandonia L, Dandona R, Mandal P, Srinivas M, John RK, McCarthy CA, et al. Angle closure glaucoma in an urban population in southern India: the Andhra Pradesh eye disease study. Ophthalmology 2000;107:1710-6.
6. Dandonia L, Dandona R, Srinivas M, Mandal P, John RK, McCarthy CA, et al. Open angle glaucoma in an urban population in southern India: the Andhra Pradesh Eye Disease Study. Ophthalmology 2000;107:1702-9.
7. Ramakrishnan R, Nirmalan PK, Krishnadhas R, Thulasiraj RD, Tielsch JM, Katz J, et al. Glaucoma in a rural population of south India: the Aravind Comprehensive Eye Survey. Ophthalmology 2003;110:1484-90.
8. Vijaya L, George R, Paul PG, Baskaran M, Arvind H, Raju P, et al. Prevalence of open angle glaucoma in a rural south Indian population. Invest Ophthal Vis Sci 2005;46:4461-7.
9. Vijaya L, George R, Arvind H, Baskaran M, Paul PG, Ramesh SV, et al. Prevalence of angle closure disease in a rural south Indian population. Arc Ophthalmol 2006;124:403-9.
10. Raju, Vijaya L, George R, Baskaran M, Arvind H, Raju P, Ramesh SV, 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.
11. Vijaya L, George R, Arvind H, Baskaran M, Ramesh SV, Raju P, 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.
12. Raychaudhuri A, Lahiri SK, Bandyopadhyay M, Foster PJ, Reeves BC, Johnson GJ. 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.
13. Foster PJ, Buhrmann RR, Quigley HA, Johnson GJ. The definition and classification of glaucoma in prevalence surveys. Br J Ophthalmol 2002;86:238-42.
14. Leske MC, Connell AM, Schachat AP, Hyman L. The Barbados Eye Study. Prevalence of open angle glaucoma. Arch Ophthalmol 1994;112:821-9.
15. Dielemans I, Vingerling JR, Wolfs RC, Hofman A, Grobbe DE, de Jong PTVM. The prevalence of primary open-angle glaucoma in a population based study in the Netherlands. The Rotterdam Study. Ophthalmology 1994;101:1851-5.
16. Rudnicka AR, Shahru M-Vs, Owen CG, Cook DG, Ashby D. Variations in primary open-angle glaucoma prevalence by age, gender, and race: a Bayesian meta-analysis. Invest Ophthal Vis Sci 2006;47:4254-61.
17. Vijaya L, George R, Arvind H, Baskaran M, Ramesh S Ve, Raju P, et al. Central Corneal Thickness in Adult South Indians. The Chennai Glaucoma Study. Ophthalmology 2010;117:700-4.
18. Mitchell P, Smith W, Attebo K, Healey RR. Prevalence of open-angle glaucoma in Australia. The Blue Mountains Eye Study. Ophthalmology 1996;103:1661-9.
19. Klein BE, Klein R, Spensel WE, Franke T, Cantor LB, Martone J, et al. Prevalence of glaucoma: The Beaver Dam Eye Study. Ophthalmology 1992;99:1499-504.

20. Tielsch JM, Sommer A, Katz J, Toyoll RM, Quigley HA, Javitt J. Racial variations in the prevalence of primary open-angle glaucoma. The Baltimore Eye Survey. JAMA 1991;266:369-74.

21. Wolfs RC, Klaver CC, Ramrattan RS, van Duijn CM, Hofman A, de Jong PT. Genetic risk of primary open-angle glaucoma in a population-based familial aggregation study. Arch Ophthalmol 1998;116:1640-5.

22. Foster PJ, Johnson GJ. Glaucoma in China: How big is the problem? Br J Ophthalmol 2001;85:1277-82.

23. Foster PJ. The epidemiology of primary angle closure and associated glaucomatous optic Neuropathy. Sem Ophthalmol 2002;17:50-8.

24. Bonomi L, Marchini G, Marraff M, Bernardi P, De Franco I, Perfetti S, et al. Prevalence of glaucoma and intraocular pressure distribution in a defined population: the Egna-Neumarkt Study. Ophthalmology 1998;105:209-15.

25. He M, Foster PJ, Ge J, Huang W, Zheng Y, Friedman DS, Lee PS, Khaw PT. Prevalence and clinical characteristics of glaucoma in adult Chinese population-based study in Liwan District, Guangzhou. Invest Ophthalmol Vis Sci 2006;47:2782-8.

26. Foster PJ, Oen FT, Machin DS, Ng TP, Devereux JG, Johnson GJ, et al. The prevalence of glaucoma in Indian residents of Singapore: results of a cross-sectional population survey of the Tanjong Pagar district. Arch Ophthalmol 2000;118:1105-11.

27. Foster PJ, Baasanhu J, Alsibrik PH, Munkbayak D, Uranchimeg D, Johnson GJ. Glaucoma in Mongolia. A population based survey in Hovsgol province, Northern Mongolia. Arch Ophthalmol 1996;114:1235-41.

28. Casson RJ, Newland HS, Muecke J, McGovern S, Abraham L, Shein WK, et al. Prevalence of glaucoma in rural: the Meiktila Eye Study. Br J Ophthalmol 2007;91:710-4.

29. George R, Paul PG, Baskaran M, Ramesh SV, Raju P, Arvind H, et al. Ocular biometry in occludable angles and angle closure glaucoma: a population based survey. Br J Ophthalmol 2003;87:399-402.

30. Alsibrik PH. Primary angle-closure glaucoma. Oculometry, epidemiology, and genetics in a high risk population. Acta Ophthalmol Suppl 1976;127:5-31.

31. Krishnadass R, Nirmalan PK, Ramakrishnan R, Thulasiraj RD, Katz J, Tielsch JM, et al. Pseudoexfoliation in a rural population of southern India: The Aravind Comprehensive Eye Survey. Am J Ophthalmol 2003;135:830-7.

32. Arvind H, Raju P, Paul PG, Baskaran M, Ramesh SV, George R, et al. Pseudoexfoliation in South India. Br J Ophthalmol 2003;87:1321-3.

33. Thomas R, Nirmalan PK, Krishnaiah S. Pseudoexfoliation in South India: the Andhra Pradesh Eye Disease Study. Invest Ophthalmol Vis Sci 2005;46:1170-6.

34. Arvind H, George R, Raju P, Ramesh SV, Baskaran M, Paul PG, et al. Glaucoma in aphakia and pseudophakia in the Chennai Glaucoma Study. Br J Ophthalmol 2005;89:699-703.

35. Thomas R, Paul P, Rao GN, Muliyyil JP, Mathai A. Present status of eye care in India. Sur Ophthalmol 2005;50:85-103.

36. Vijaya L, George R, Arvind H, Baskaran M, Raju P, Ramesh SV, et al. Prevalence and causes of blindness in a rural south Indian population. Br J Ophthalmol 2006;90:407-10.

37. Thomas R, George R, Parikh R, Muliyyil J, Jacob A. Five year risk of progression of primary angle closure suspects to primary angle closure: a population based study. Br J Ophthalmol 2003;87:450-4.

38. Thomas R, Parikh R, Muliyyil J, Kumar RS. Five-year risk of progression of primary angle closure to primary angle closure glaucoma: a population-based study. Acta Ophthalmol Scand 2003;81:480-5.

39. Thomas R, Parikh R, George R, Kumar RS, Muliyyil J. Five-year risk of progression of ocular hypertension to primary open angle glaucoma. A population-based study. Indian J Ophthalmol 2003;51:329-33.

40. Ramesh SV, Pradeep GP, George R, Baskaran M, Arvind H, Madan RV, et al. Determinants of glaucoma awareness and knowledge in urban Chennai. Indian J Ophthalmol 2009;57:355-60.

41. Thomas R, Padma P, Jayaprakash M. Glaucoma Care Updates: Glaucoma in India. J Glaucoma 2003;12:81-7.

42. Rao GN. Ophthalmology in India. Arch Ophthalmol 2000;118:143-1.

43. Thomas R, Dogra M. An evaluation of medical college departments of ophthalmology in India and change following provision of modern instrumentation and training. Indian J Ophthalmol 2008;56:9-16.

44. Dandona R. Optometry and eye care in India. Indian J Ophthalmol 1998;46:175.

45. Dandona R, Dandona L, John RK, McCarthy CA, Rao GN. Awareness of eye diseases in an urban population in southern India. Bull World Health Organ 2001;79:96-102.

46. Krishnaiah S, Kovai V, Srinivas M, Shamanna BR, Rao GN, Thomas R. Awareness of glaucoma in the rural population of Southern India. Indian J Ophthalmol 2005;53:205-8.

47. Finger RP, Ali M, Earnest J, Nirmalan PK. Cataract surgery in Andhra Pradesh state, India: an investigation into uptake following outreach screening camps. Ophthalimic Epidemiol 2007;14:327-32.

48. Robin AL, Nirmalan PK, Krishnadass R, Ramakrishnan R, Katz J, Tielsch J, et al. The utilization of eye care services by persons with glaucoma in rural south India. Trans Am Ophthalmol Soc 2004;102:47-56.

49. Wilson JMG, Jungner G. Principles and Practice of screening for disease. (Public Health Papers No 34) Geneva: WHO; 1968.

50. Katz J, Sommer A, Gaasterland DE, Anderson DR. Comparison of analytic algorithms for detecting glaucomatous visual field loss. Arch Ophthalmol 1991;109:1684-9.

51. Tielsch JM, Katz J, Singh K, Quigley HA, Gottsch JD, Javitt J, et al. A population based evaluation of glaucoma screening: the Baltimore Eye Survey. Am J Epidemiol 1991;134:1102-10.

52. Anderson AJ, Johnson CA. Frequency doubling technology perimetry. Ophthalmol Clin North Am 2003;16:213-5.

53. Greaney MJ, Hoffman DC, Garway-Heath DF, Nakla M, Coleman AL, Caprioli J. Comparison of optic nerve imaging methods to distinguish normal eyes from those with glaucoma. Invest Ophthalmol Vis Sci 2002;43:140-5.

54. Medeiros FA, Zangwill LM, Bowd C, Weinreb RN. Comparison of the GDx VCC scanning laser polarimeter, HRT II confocal tomograph for the detection of glaucoma. Arch Ophthalmol 2004;122:827-37.

55. Condgon N, Quigley HA, Hung PT, Wang TH, Ho TC. Screening techniques for angle-closure glaucoma in rural Taiwan. Acta Ophthalmol Scand 1996;74:113.

56. Thomas R, George T, Braganza A, Muliyyil JP. The flashlight test and van Herick’s test are poor predictors for occludable angles. Aust NZ J Ophthalmol 1996;24:251-6.

57. Devereux JG, Foster PJ, Baasanhu J, Uranchimeg D, Lee PS, Erdenbeleig T, et al. Anterior chamber depth measurement as a
screening tool for primary angle-closure glaucoma in an East Asian population. Arch Ophthalmol 2000;118:257-63.

58. Foster PJ, Devereux JG, Alsbirk PH, Lee PS, Uranchimeg D, Machin D, et al. Detection of gonioscopically occludable angles and primary angle closure glaucoma by estimation of limbal chamber depth in Asians: modified grading scheme. Br J Ophthalmol 2000;84:186-92.

59. Nolan WP, See JL, Chew PT, Friedman DS, Smith SD, Radhakrishnan S, et al. Detection of primary angle closure using anterior segment optical coherence tomography in Asian eyes. Ophthalmology 2007;114:33-9.

60. Baskaran M, Oen FT, Chan YH, Hoh ST, Ho CL, Kashiwagi K, et al. Comparison of the scanning peripheral anterior chamber depth analyzer and the modified van Herick grading system in the assessment of angle closure. Ophthalmology 2007;114:501-6.

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