Spectrum of Eye Disease in Diabetes (SPEED) in India: A prospective facility-based study. Report # 4. Glaucoma in people with type 2 diabetes mellitus

Umesh C Behera, Harsha Bhattacharjee, Taraprasad Das, Clare Gilbert, G V S Murthy, R Rajalakshmi, Hira B Pant; on behalf of the SPEED study group

Purpose: To estimate the proportion of people with type 2 diabetes mellitus (T2DM) and glaucoma in a facility-based cross-sectional observational study in India. Methods: All people received a comprehensive eye examination. Glaucoma-specific examinations included application tonometry, optic disc and cup evaluation, and stereo biomicroscopy in all people; gonioscopy and visual field testing in glaucoma suspects. The International Society of Geographic and Epidemiologic Ophthalmology guidelines were used to diagnose and classify glaucoma. Results: The study recruited 11,182 people (average age: 58.2 ± 10.6; range 39–96 years). Glaucoma was diagnosed in 4.9% (n = 547) people. About 76.8% (n = 420) of those with glaucoma had bilateral disease, and 98.7% (n = 540) were >40 years. Among people with bilateral disease, 94.5% (n = 397) had primary glaucoma – open angle in 59.3% (n = 228) and angle closure in 40.2% (n = 169). Diabetes duration was ≤10 years in 71.5% (n = 300) people. On linear regression, the following were associated with glaucoma: advancing age [compared with <40 years age group; odds ratio [OR] in 50–60 year age group: 1.36 (95% confidence interval (CI): 1.01–1.8], P < 0.035); >60 years age group (OR: 2.05, 95% CI: 1.35–5.10, P < 0.003). Glycemic control did not have significant association (P = 0.425). Conclusion: Presence of glaucoma in people with T2DM in this cohort was similar to the general population prevalence studies in India. Glaucoma was invariably bilateral. A comprehensive eye examination in people age 40 years and older with diabetes and/or glaucoma is beneficial.

Key words: Diabetes, diabetic retinopathy, glaucoma

Glaucoma is an important cause of blindness. In 2015, visual impairment secondary to glaucoma accounted for 8.49% (2.99%–15.66%) of the world’s blindness.[1] The number of people with glaucoma is expected to increase from 64.3 million in 2013 to 76 million in 2020 and to 111.8 million by 2040.[2] The majority of adults with glaucoma live in Asia and Africa.[3] In 2013, the pooled overall glaucoma prevalence in Asia was 3.54%.[3] In a 2008 estimation, nearly 40 million of 309 million people age 40 years and above living in India were affected with glaucoma.[4] At around this age, lifestyle disease such as type 2 diabetes mellitus (T2DM) manifest, and findings from recent studies suggest a positive relationship of diabetes and glaucoma.[3,4] A recent systematic review and meta-analysis report significant increase in the odds of glaucoma in diabetes.[5] Reports from India on the prevalence of glaucoma in diabetics are limited, though a range of 2.5%–15.6% has been reported in the literature.[6,7] This communication is an analysis of the presence of glaucoma in people with T2DM reporting to the retina clinics (and subsequently referred to glaucoma clinics) in large referral centers participating in the Spectrum of Eye Disease in Diabetes (SPEED) study in India.

Methods

This multicenter, cross-sectional observational study recruited patients from 14 referral eye care facilities located in different zones of India. The ethics committee of each participating center approved the study. The study followed the tenets of the Declaration of Helsinki for human research. The details of the study are reported in Report #1.[8] In brief, patients with a known history of T2DM, confirmed by the in-house internist or people under treatment by an endocrinologist, presenting for the first time to the retinal clinic in each facility were included. A detailed pretested questionnaire was administered covering demographic data, current treatment, and medical history of systemic disorders. Previous eye diseases or eye

For reprints contact: reprints@medknow.com

Cite this article as: Behera UC, Bhattacharjee H, Das T, Gilbert C, Murthy GV, Rajalakshmi R, et al. Spectrum of Eye Disease in Diabetes (SPEED) in India: A prospective facility-based study. Report # 4. Glaucoma in people with type 2 diabetes mellitus. Indian J Ophthalmol 2020;68:S32-6.
treatment, and current ocular symptoms were included. A comprehensive eye examination included measurement of presenting vision (with spectacles, if available), subjective refraction, slit-lamp biomicroscopy, applanation tonometry, and gonioscopy in all glaucoma suspects (based on the slit-lamp and optic disc-cup examination before dilation of the pupil) and dilated (unless contraindicated) fundus examination using indirect ophthalmoscope. Patients suspected of having glaucoma were referred to the glaucoma specialist in the same eye care facility before dilation of pupil. In the glaucoma clinic, the intraocular pressure (IOP) was re-measured and gonioscopy re-performed; visual fields (Humphrey) were recorded when considered necessary by the glaucoma specialist.

Raised IOP measuring more than 21 mmHg on applanation tonometry, optic disc changes such as focal notch, neuroretinal thinning, vertical cup–disc ratio (VCDR) more than 0.5, based on population-based norms for India,[11] nerve fiber layer splinter hemorrhage at disc margin, and corroborating visual field changes were the basis for glaucoma diagnosis. By the gonioscopic findings, they were categorized into open- or narrow-angle glaucoma. They were further classified into primary and secondary glaucoma depending on the etiology. The International Society of Geographic and Epidemiologic Ophthalmology (ISGEO)[12] classification was used by all participating eye care centers. In brief, the ISGEO definition of glaucoma is based on the structural (VCDR) and functional (specific visual field) defects. ISGEO has proposed three levels of diagnosis certainty: Category 1 – optic disc abnormalities (VCDR >7.5th percentile in the normal population) and visual field defect compatible with glaucoma; Category 2 when the visual field test could not be performed satisfactorily – a severely damaged optic disc (VCDR >95.5th percentile of the normal population); and Category 3 when the optic disc could not be examined because of media opacity (and, hence, no field test was also possible), IOP exceeding the 95th percentile of the normal population, or evidence of previous glaucoma filtering surgery.

Diabetes status was defined as per the Indian Council of Medical Research (ICMR) guidelines.[13] A person was considered diabetic when the recent plasma glucose level was >126 mg/dL, and 2-h post-load glucose and random glucose was >200 mg/dL and HbA1c >6.5%. Hypertension was defined as per the Indian standards: normal when blood pressure was less than 130/85 mmHg and hypertensive when the blood pressure was more than 140/90 mmHg.[14] Diabetic neuropathy was defined as the presence of symptoms and/or signs of peripheral nerve dysfunction after excluding some of the common causes (vitamin B12 deficiency, alcohol-related neuropathy, etc.) by the in-house internists.[15]

Data collection software and app-base using Java were supplied to all participating centers on-line. Pooled data from the participating centers were analyzed using Stata14SE for Windows (Stata Corp., TX, USA). Descriptive statistics were used to summarize the cohort. The mean and standard deviation for continuous variables and percentage for categorical variables were determined. The median and interquartile range were used to report nonparametric data. The normality of the data was tested by Kolmogorov–Smirnov test. If the normality was rejected, then nonparametric test was used. Analysis of the trend was performed using Chi-square test. Univariate and multivariate logistic regression analyses were undertaken to identify risk factors for glaucoma. To evaluate the effects of several factors associated with the risk for glaucoma simultaneously, discrete logistic regression analysis was performed using age, gender, diabetes duration, association of hypertension, cardiovascular disease, neuropathy and stroke as independent variables with glaucoma as the dependent variable. A P value of <0.05 was considered statistically significant.

Results

The study recruited 11,182 people with T2DM in 14 eye care facilities covering all zones of India, and their demographic details are listed in Report #1. In brief, 59.2% of the people in the study were men and their mean age was 58.2 ± 10.6 years (range 19–96 years). All people suspected as having glaucoma in the retina clinic (based on the IOP and VCDR) were referred to a glaucoma specialist on the same day in the same eye care facility; all of them attended the glaucoma service the same day.

Glaucoma was detected in 4.89% (n = 547) of people; two-third (n = 342) of them were men; 98.7% (n = 540) were above 40 years age, and 60.3% (n = 330) were older than 60 years of age. About 76.8% (n = 420) of those with glaucoma had bilateral disease. The types of glaucoma were as follows: primary open-angle glaucoma (POAG) in 54.3% (n = 226/420) of people, primary angle-closure glaucoma (PACG) in 40.2% (n = 169/420) of people, and secondary glaucoma in 5.5% (23/420) of people [Table 1]. The VCDR, which was recorded in 449 people with glaucoma, was 0.6 or more in 64.6% (n = 290) of people; 98.7% (n = 330) were older than 60 years of age. About 76.8% (n = 420) of those with glaucoma had bilateral disease. The types of glaucoma were as follows: primary open-angle glaucoma (POAG) in 54.3% (n = 226/420) of people, primary angle-closure glaucoma (PACG) in 40.2% (n = 169/420) of people, and secondary glaucoma in 5.5% (23/420) of people [Table 1]. The VCDR, which was recorded in 449 people with glaucoma, was 0.6 or more in 64.6% (n = 290) of people; 98.7% (n = 330) were older than 60 years of age. About 76.8% (n = 420) of those with glaucoma had bilateral disease. The types of glaucoma were as follows: primary open-angle glaucoma (POAG) in 54.3% (n = 226/420) of people, primary angle-closure glaucoma (PACG) in 40.2% (n = 169/420) of people, and secondary glaucoma in 5.5% (23/420) of people [Table 1]. The VCDR, which was recorded in 449 people with glaucoma, was 0.6 or more in 64.6% (n = 290) of people; 98.7% (n = 330) were older than 60 years of age. About 76.8% (n = 420) of those with glaucoma had bilateral disease. The types of glaucoma were as follows: primary open-angle glaucoma (POAG) in 54.3% (n = 226/420) of people, primary angle-closure glaucoma (PACG) in 40.2% (n = 169/420) of people, and secondary glaucoma in 5.5% (23/420) of people [Table 1].

The proportion of people with glaucoma who had systemic diseases (reported by all participants in the SPEED study, Report

### Table 1: Type of glaucoma in people with type 2 diabetes mellitus

| Type of Glaucoma | Unilateral Glaucoma (n=889, %) | Bilateral Glaucoma (n=420, %) |
|------------------|-------------------------------|-----------------------------|
| POAG             | 455 (51.2%)                   | 228 (54.3%)                 |
| PACG             | 356 (40.0%)                   | 169 (40.2%)                 |
| Secondary Glaucoma | 78 (8.8%)                    | 23 (5.5%)                   |

POAG: Primary open-angle glaucoma; PACG: Primary angle-closure glaucoma

### Table 2: Distribution of glaucoma against the duration of diabetes

| Duration of Diabetes | Unilateral Glaucoma (n=889, %) | Bilateral Glaucoma (n=420, %) |
|----------------------|--------------------------------|-------------------------------|
| <5 years             | 402 (45.21)                    | 192 (45.71)                   |
| 6-10 years           | 222 (24.97)                    | 107 (25.48)                   |
| 11-15 years          | 110 (12.37)                    | 51 (12.14)                    |
| >16 years            | 155 (17.45)                    | 70 (16.67)                    |
| Total                | 889                            | 420                           |
# 1) was as follows: 4.9% had hypertension \((n = 271/5,500)\), 4.5% had cardiovascular disease \((30/672)\), and 5.7% had stroke \((3/52)\). Increasing age and coexisting neuropathy were associated with glaucoma. Compared with people less than 40 years of age, the odds of glaucoma in the 50- to 60-year age group was 1.36 \([95\% \text{ CI}: 1.01–1.8; P < 0.035]\) and for people age 60 years or older it was 2.05 \([95\% \text{ CI}: 1.57–2.67; P < 0.001]\). The odds of glaucoma in people with neuropathy was 2.62 \([95\% \text{ CI}: 1.35–5.10; P < 0.003]\). Glycemic control was not associated with glaucoma \((P = 0.425)\).

**Discussion**

In this study, 1 in 20 (4.9%) people with T2DM had glaucoma. The diagnosis and classification of glaucoma used both structural and functional changes in glaucomatous optic neuropathy, using population-based norms for India.\(^{[16]}\) Of the three characteristics, that is, VCDR, IOP, and visual fields, the former two (VCDR and IOP) were more often used in this study to diagnose glaucoma. The configuration of the angle on gonioscopy was used to classify glaucoma (incidentally, the configuration of the optic disc in the Indian eyes is no different than the Caucasian eyes).\(^{[20]}\)

Despite the fact that this study was a clinic-based study, the proportion of people with glaucoma was similar to the prevalence reported in two population-based studies in the United States, the Blue Mountain Eye Study and the Los Angeles Latino Eye Study.\(^{[17,18]}\) But it was lower than a hospital-based study in Maharashtra, India.\(^{[19]}\) In this study, there was a male predominance \((P = 0.007)\), but this could be biased as it was a hospital-based study and we suspect that many female patients possibly did not report to the retina clinic. A similar trend was noted in one of the studies from Oman.\(^{[20]}\) The prevalence is reported to be higher in African and American diabetic females than the male counterparts.\(^{[21,22]}\)

The overall proportion of people with glaucoma in this study (4.89%) lies within the range of prevalence data from population-based studies in India of participants age 30–50 years,\(^{[23‑31]}\) that is, POAG 1.62%–3.51% and PACG 0.71%–7.24%. POAG was more common than PACG. Advancing age is a well-recognized risk factor for glaucoma.\(^{[4,30]}\) In our cohort, 98.7% of the people were older than 40 years and the age-adjusted linear regression analysis showed a significant association \([Table 4]\). Furthermore, as the glaucoma prevalence in this study among the patients with or without PDR did not differ, the co-occurrence of diabetes and glaucoma may be independent of each other, reflecting a similar age of onset.\(^{[32‑34]}\) Simultaneous screening for diabetic retinopathy and

| Table 3: Stage of diabetic retinopathy among people with glaucoma (n=119) |
|-----------------------------|------------------|
| Diabetic retinopathy stage | Glaucoma          |
| No diabetic retinopathy     | 423              |
| Nonproliferative diabetic   |                 |
| retinopathy, n=66 (55.5%)  | Mild (43.93)     |
|                            | Moderate (42.42) |
|                            | Severe (13.63)  |
| Proliferative diabetic      |                 |
| retinopathy, n=53 (44.5%)  | NVE (86.79)      |
|                            | TRD (1.88)       |
|                            | VH (11.32)       |

NVE: New vessels elsewhere; TRD: Traction retinal detachment; VH: Vitreous hemorrhage

| Table 4: Logistic regression analysis of the variables with glaucoma as dependent variable |
|-----------------------------------------------|-----------|----------|
| Risk factors for glaucoma                     | Univariate| Multivariate|
|                                              | Odds ratio (95% CI) | P       | Odds ratio (95% CI) | P       |
| Sex                                           |            |          |                    |          |
| Female                                       | 1          | 0.105    | 1.18 (0.98-1.14)   | 0.077    |
| Male                                          | 1.16 (1.0-1.38) | 0.035* | 1.42 (1.05-1.9)   | 0.020*   |
| Age                                           |            |          |                    |          |
| <40 years                                     | 1          |          | 2.22 (1.69-2.92)   | <0.001*  |
| 40-50 years                                   | 1.36 (1.01-1.8) | <0.001* |                     |          |
| >60 years                                     | 2.05 (1.57-2.67) | <0.001* |                     |          |
| Diabetes control                              |            |          |                    |          |
| Well-controlled                               | 1          | 0.049*   | 1.39 (1.09-1.78)   | 0.007*   |
| Not controlled                                | 1.11 (0.86-1.44) | 0.435 | 1.11 (0.84-1.46)   | 0.452    |
| Some control                                  | 1.27 (1.0-1.62) | 0.049* | 1.39 (1.09-1.78)   | 0.007*   |
| Neuropathy                                    |            |          |                    |          |
| No                                            | 1          |          | 3.90 (1.86-8.16)   | <0.001*  |
| Yes                                           | 2.62 (1.35-5.10) | 0.003* |                     |          |
| Hypertension                                  |            |          |                    |          |
| No                                            | 1          | 0.934    | 0.93 (0.78-1.11)   | 0.424    |
| Yes                                           | 1.0 (0.84-1.18) | <0.001* |                     |          |
| Cardiovascular disease                        |            |          |                    |          |
| No                                            | 1          | 0.355    | 0.72 (0.48-1.09)   | 0.121    |
| Yes                                           | 0.8 (0.6-1.2) | <0.001* |                     |          |
| Stroke                                        |            |          |                    |          |
| No                                            | 1          |          | 1.23 (0.34-4.43)   | 0.749    |
| Yes                                           | 1.3 (0.4-4.1) | 0.689   |                     |          |
| Diabetes duration                             |            |          |                    |          |
| <5 years                                      | 1          |          | 0.89 (0.69-1.16)   | 0.387    |
| 6-10 years                                    | 0.90 (0.72-1.10) | 0.292 | 0.89 (0.69-1.16)   | 0.387    |
| 11-15 years                                   | 0.79 (0.60-1.04) | 0.097 | 0.89 (0.69-1.16)   | 0.387    |
| >16 years                                     | 1.01 (0.79-1.28) | 0.957 | 0.89 (0.69-1.16)   | 0.387    |

CI: Confidence interval, Well-controlled - fasting plasma glucose (FPG) 80-110 mg/dL; some control - FPG 111-125 mg/dL; not controlled >125 mg/dL, *Significant
glaucoma may help prevent blindness associated with both these conditions. The inclusion of VCDR assessment, which can be done at the time of DR screening or during image grading, would be feasible, requiring minimal additional resources.

The duration of diabetes has been implicated as a risk for development of glaucoma.[19,35] Our study did show a moderate association on multivariate analysis when the duration of diabetes ranged from 11 to 15 years [Table 4]. Sustained hyperglycemic state may cause glycation of lipids, increase oxidative stress, promote cellular apoptosis, and cause ganglion cell loss. There is also growing evidence to suggest that elevated protein kinase C may cause abnormalities of matrix metalloprotease in the trabecular meshwork and impair the aqueous outflow.[36]

Limitations of this study
The retina specialists used IOP of 21 mmHg for primary referral to the glaucoma service; this might have erroneously excluded some people with normal tension glaucoma. Data were not collected to identify individuals with ocular hypertension or pseudo-exfoliation. Moreover, the data capturing software was not designed to gather parameters to the detail of picking the subtypes of secondary glaucoma, particularly neovascular glaucoma. The diagnosis of glaucoma was more clinical (optic disc–cup evaluation, IOP, and gonioscopy when performed) and visual fields were performed when glaucoma was suspected on other grounds, which may have led to the misclassification of glaucoma status. The risk of glaucoma at various stages of diabetes was not analyzed, though no difference in prevalence of glaucoma was noted in proliferative and nonproliferative stage of diabetic retinopathy. Because it was a hospital-based study of people with known diabetes, it is possible that people who did not know their diabetes status or did not have visual impairment did not report to the retina clinic.

The strength of the study lies in the large cohort recruited from all regions of the country and uniform diagnostic criteria (ISGEO) used by all participating eye care facilities.

Conclusion
In conclusion, glaucoma in people with diabetes is common and increases with increasing age, as in the general population. In most instances, the condition is bilateral, and open-angle glaucoma is more common than angle-closure glaucoma. A relatively high proportion of people age 40 years and above in India have one or both conditions and this must be borne in mind while screening for diabetic retinopathy or examining people with diabetes and/or glaucoma.

SPEED study participating clinical facility organizations and investigators
1. Aravind Eye Hospital, Madurai (Dr. Kim Ramasamy, MD)
2. Divyajyoti Trust, Surat, India (Dr. Rohan Chariwala, MD; Dr. Uday Gaijwala, MD)
3. Dr Mohan’s Diabetes Specialities Centre and Madras Diabetes Research Foundation, Chennai, India (Dr. R Rajalakshmi, MD)
4. Dr. Rajendra Prasad Center for Ophthalmic Sciences, New Delhi (Dr. Rohan Chawla, MD; Dr Atul Kumar, MD)
5. Dr. Shroff’s Charity Eye Hospital, Delhi, India (Dr. Manisha Agarwal, MD)
6. H V Desai Eye Hospital (Dr. Kuldeep Dole, MD; Dr. Madan Despande, MD)
7. Little Flower Eye Hospital, Angamaly, India (Dr. Thomas Cherian, MD)
8. L V Prasad Eye Institute, Bhubaneswar, India (Dr. Umesh C Behera, MD)
9. L V Prasad Eye Institute, Hyderabad, India (Dr. Rajeev Reddy, MD; Dr. Taraprasad Das, MD)
10. Netra Nirmay Niketan, Purba Midnapur, Bengal (Dr Asim Sil, MD)
11. Post Graduate institute of Medical Education and Research, Chandigarh, India (Dr. Ramandeep Singh, MD; Dr. Manat Dogra, MD)
12. Pushpagiri Eye Institute, Hyderabad, India (Dr. K Viswanath, MD)
13. Sankara Nethralaya, Chennai, India (Dr. Muna Bhende, MD)
14. Sri Sankaradeva Nethralaya, Guwahati, India (Dr. Harsha Bhattacharjee, MS)

Financial support and sponsorship
The Queen Elizabeth Diamond Jubilee Trust, London, UK.

Conflicts of interest
There are no conflicts of interest.

References
1. Flaxman SR, Bourne RA, Resnikoff SR, Ackland P, Braithwaite T, Cicinelli MV, et al. on behalf of the Vision Loss Expert Group of the Global Burden of Disease Study. Global causes of blindness and distance vision impairment 1990–2020: A systematic review and meta-analysis. Lancet Glob Health 2017; doi.org/10.1016/S2214-109X (17)30393-5.
2. Thom YC, Li X, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma burden through 2040: A systematic review and meta-analysis. Ophthalmology 2014;121:2081-90.
3. Chan EW, Li X, Thom YC, Liao J, Wong TY, Aung T, et al. Glaucoma in Asia: Regional prevalence variations and future projections. Br J Ophthalmol 2016;100:78-85.
4. George R, Ve RS, Vijaya L. Glaucouma in India: Estimated burden of disease. J Glaucoma 2010;19:391-7.
5. Zhao D, Cho J, Kim MH, Friedman DS, Guellar E. Diabetes, fasting glucose and the risk of glaucoma: A meta-analysis. Ophthalmology 2015;122:72-8.
6. Ko F, Boland MV, Gupta P, Gadkaree SK, Vitale S, Guellar E, et al. Diabetes, triglyceride levels and other risk factors for glaucoma in the national health and nutrition examination survey 2005-2008. Invest Ophthalmol Vis Sci 2016;57:2192-7.
7. Shen L, Walter S, Melles RB, Glymour MM, Jorgenson E. Diabetes pathology and risk of primary open angle glaucoma: Evaluating causal mechanisms by using genetic information. Am J Epidemiol 2016;183:147-55.
8. Zhou YX, Chen XW. Diabetes and risk of glaucoma: A systematic review and a meta-analysis of prospective cohort studies. Int J Ophthalmol 2017;10:1430-35.
9. Song BJ, Aiello LP, Pasquale LR. Presence and risk factors for glaucoma in patients with diabetes. Curr Diab Rep 2016;16:124.
10. Das T, Behera UC, Bhattacharjee H, Gilbert C, Murthy GV, Rajalakshmi R, et al. Spectrum of eye disorders in diabetes (SPEED) in India: Eye care facility based study. Report # 1. Eye disorders in India: Eye care facility based study. Report # 1. Eye disorders in India: Eye care facility based study. Report # 1.
11. Dacosta S, Bilal S, Rajendran B, Janakiraman P. Optic disc topography of normal Indian eyes: An assessment using optical coherence tomography. Indian J Ophthalmol 2008;56:99-102.
12. Foster PJ, Buhrmann RR, Quigley HA, Johnson GJ. The definition
and classification of glaucoma in prevalence surveys. Br J Ophthalmol 2002;86:238-42.

13. Available from: https://medibulletin.com/wp-content/./2018/05/ICMR.diabetesGuidelines.2018.pdf. [Last accessed on 2019 Feb 26].

14. Indian guidelines for hypertension III. J Assoc Physicians India 2013;61:12.

15. Kapoor N, David K, Saravanan B. Approach to diabetic neuropathy. Curr Med Issues 2017;15:189-99.

16. Jonas JB, Thomas R, George R, Berenshtein E, Muliyil J. Optic disc morphology in south India: The Vellore Eye Study. Br J Ophthalmol 2003;87:189-96.

17. Mitchell P, Smith W, Chey T, Healey PR. Open-angle glaucoma and diabetes: The Blue Mountains Eye Study, Australia. Ophthalmology 1997;104:712-8.

18. Chopra V, Varma R, Francis BA, Wu J, Torres M, Azen SP. Type 2 diabetes mellitus and the risk of open-angle glaucoma: The Los Angeles Latino Eye Study. Ophthalmology 2008;115:227-32.

19. Dharmadhikari S, Lohiya K, Chelkar V, Kalyani VK, Dole K, Deshpande M, et al. Magnitude and determinants of glaucoma in type II diabetics: A hospital based cross-sectional study in Maharashtra, India. Oman J Ophthalmol 2015;8:19-23.

20. Khandekar R, Zutshi R. Glaucoma among Omani diabetic patients: A cross sectional descriptive study: Omani Diabetic Eye Study 2002. Eur J Ophthalmol 2004;14:19-25.

21. Wise LA, Rosenberg L, Radin RG, Mattox C, Yang EB, Palmer JR, et al. A prospective study of diabetes, lifestyle factors and glaucoma among African-American women. Ann Epidemiol 2011;21:430-9.

22. Pasquale LR, Kang JH, Manson JE, Willett WC, Rosner BA, Hankinson SE. Prospective study of type 2 diabetes mellitus and risk of primary open angle glaucoma in women. Ophthalmology 2006;113:1081-6.

23. 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. Arch Ophthalmol 2006;124:403-9.

24. 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.

25. Dandonda L, Dandonda R, Mandal P, Srinivas M, John RK, McCarty CA, et al. Angle closure glaucoma in an urban population in southern India: The Andra Pradesh Eye Disease Study. Ophthalmology 2000;107:1710-6.

26. Ramakrishnan R, Nirmalan PK, Krishnadas 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.

27. 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 Ophthalmol Vis Sci 2005;46:4461-7.

28. 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.

29. 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.

30. Nangia V, Jonas JB, Matin A, Bhojwani K, Sinha A, Kulkarni M, et al. Prevalence and associated factors of glaucoma in rural central India. The Central India Eye and Medical Study. PLoS One, 2013; doi.org/10.1371/journal.pone.0076434.

31. Palimkar A, Khandekar R, Venkataraman V. Prevalence and distribution of glaucoma in central India (Glaucoma Survey 2001). Indian J Ophthalmol 2008;56:57-62.

32. Xu L, Xie XW, Wang YX, Jonas JB. Ocular and systemic factors associated with diabetes mellitus in the adult population in rural and urban China. The Beijing Eye Study. Eye 2009;23:676-82.

33. de Voogd S, Ikram MK, Wolfs RC, Jansonius NM, Witteman JC, Hofman A, et al. Is diabetes mellitus a risk factor for open-angle glaucoma? The Rotterdam Study. Ophthalmology 2006;113:1827-31.

34. Tan GS, Wong TY, Fong CW, Aung T. Singapore Malay Eye Study. Diabetes, metabolic abnormalities, and glaucoma. Arch Ophthalmol 2009;127:1354-61.

35. Klein BEK, Klein R, Moss SE. Incidence of self-reported glaucoma in people with diabetes mellitus. Br J Ophthalmol 1997;81:743-7.

36. Wong VH, Bui BV, Vingrys AJ. Clinical and experimental links between diabetes and glaucoma. Clin Exp Optom 2011;94:4-23.