Original Research Article

Association of HbA1c levels with diabetic retinopathy

Chirag Singh1,*, Shashi Prabha Prasad1, Sucheta Kaul1, Divya Motwani1, Ashish Mishra1, Vishakh Padmakumar1

1Dept. of Ophthalmology, Dr. D Y Patil Medical College Hospital and Research Institute, Pune, Maharashtra, India

1. Introduction

According to WHO, Diabetes Mellitus refers to a group of metabolic disorders that share the phenotype of hyperglycemia and is defined as when a person has more > 2 readings of fasting plasma glucose of 126 mg/dl or 2-hour post-prandial glucose level >200 mg/dl or glycosylated haemoglobin (HbA1c) > 6.5%. This prolonged hyperglycemia is result from the defect in insulin secretion, insulin action or both.1 DM is classified into 2 categories: Type 1 is an Insulin dependent diabetes mellitus (IDDM) accounting for about 10% of DM cases and Type 2 which is non-insulin dependent diabetes mellitus (NIDDM) accounting for about 90% of cases.

Data from the 2015 International Diabetes Federation Atlas report that DM affects 415 million people globally.2 With uncontrolled population increasing daily, more caloric consumption and with advancement in technology people shifting towards sedentary lifestyle, this number is projected to reach 640 million by 2040, making diabetes as one of the largest global health issues of 21st century.2

India is considered as world capital of Diabetes. According to WHO, India has about 70 million people living with diabetes in 2015, increasing to 98 million by 2030.3

Diabetic retinopathy is among the most common causes of legal blindness affecting the age group of 20-74 years of age and is a frequent microvascular complications of DM.4

The prevalence of DR is considerably higher in type 1 than in type 2 DM, seen in all patients of type 1 & 70% of type 2 DM after 15 years of DM.5,6

Patients suffering from retinopathy are initially asymptomatic but gradually experience floaters, distortion and blurred vision which may later progress to irreversible changes. The relative risk of blindness in diabetes patients is approximately 5 times the risk of those without diabetes after adjusting for potential confounders.7

Glycosylated haemoglobin is non enzymatic addition of a sugar residue to haemoglobin. When glucose is bound
non-enzymatically to a terminal portion of Hb chain, its quantization becomes possible. This measurement is directly proportional to blood glucose concentration. As life span of RBCs is 120 days, this test, with allowances for the dynamics of RBCs production & disposal, indicate mean blood glucose over a 2-3 month period. At present, the consensus on best method for measuring glycosylated haemoglobin is to use a fractionated value of HbA1c. The normal value of HbA1c is < 6.9% of total haemoglobin.

DR is one of the most common causes of blindness, therefore there should be an effort for early diagnosis and treatment of DR. Poor glucose control is a risk factor and glycosylated haemoglobin indicates long term blood glucose concentration. This study has been done to establish an association between HbA1c levels with diabetic retinopathy so that progression of diabetic retinopathy can be predicted and early intervention can be instituted.

2. Materials and Methods

A hospital based observational analytical cross sectional study was conducted in a tertiary hospital and research centre in Pimpri Pune from the period of September 2018 to August 2020 after clearance from the ethics committee of the institute. Well informed consent was procured from all the subjects. The study was conducted in a total of 330 subjects in the all age group including both the sexes. The inclusion criteria was subjects with diagnosed diabetes mellitus. Exclusion criteria was patients with high myopes, patients with vitreo retinal degenerations and dystrophies, patients in hypertensive emergencies, or with active infections or patients having ocular diseases like hazy media and uveitis and patients with retinal diseases like retinal vascular oclusins or retinitis pigmentosa.

Participant Information Sheet(PIS) regarding details of study were prepared in English, Marathi and Hindi languages. PIS was given to the participants and they were explained about the type and purpose of study according to the language best understood. After due consent only they were enrolled in the study. Patients’ rights for participation in the study were safeguarded. Participation in the study was voluntary. Participants were free to withdraw from the study at any point without giving any reason and without any loss to medical care.

Thorough ophthalmic examination of both the eyes was done. Visual acuity was assessed-distant vision by Snellen’s chart and near vision by Jaeger’s chart. Auto Refractometry and BCVA (Best Corrected Visual Acuity) was done followed by slit lamp biomicroscopic examination of anterior segment. Retinal status was evaluated by indirect ophthalmoscopy and +2OD after dilatation with Tropicamide plus eye drops. Diabetic retinopathy was graded according to Early Treatment Diabetic Retinopathy (ETDRS) criteria. All patients HbA1c levels were evaluated and were compared for association and significance.

Data was collected, compiled and tabulated in Microsoft Excel sheet. The statistical analysis will be performed using software like Primer or SPSS 20. Quantitative data was analyzed in percentage and proportion. Qualitative data was analyzed with appropriate test of significance like Chi square test and t- student test to compare discrete variables. Confidence interval with P-value of <0.05 as a level of significance was applied.

3. Results

Out of the 330 subjects, 69.09% (228) subjects were in the age group 51-65 years, 16.36% (54) were between 36 and 50, 13.33% (44) were in 66-80 years, 0.91% (3) in 21-35 years and 0.3% (1) was above 80 years. Of the 232 subjects with DR, 71.55% (166) were in the age range 51-65 years, 15.52% (36) in 66-80 years, 12.07% (28) in 36-50 years, 0.43% (1) in 21-35 years and 0.43% (1) above 80 years. Most of the patients (69.1%) were in the 51-65 age range.

Out of 330 subjects 57.88% (191) were males and 42.12% (139) were females. Of the 232 patients with DR, 60.78% (141) were males and 39.22% (91) were female.

Of the 330 patients enrolled, 94.24% (311) had T2DM while 5.76% (19) had T1DM. In the patients diagnosed with DR, 93.97% (218) had T2DM while 6.03% (14) had T1DM. Of the 19 patients with T1DM, 74% (14) developed DR while 70% (218) of T2DM patients developed DR.

Average duration of diabetes was 9.46±4.97 years in the study population and 10.39±5.01 in the subjects with DR.

Of 330 subjects enrolled, 30% (99) had hypertension, 8.18% (27) had hyperlipidemia, 5.45% (18) had IHD, 0.91% (3) had CKD, 0.61% (2) had asthma and 0.3% (1) each of acromegaly, HbsAg+ and hypothyroidism. Of the 232 DR patients, 33.19% (77) had hypertension, 14.22% (33) had hyperlipidemia, 5.17% (12) had IHD, 1.29% (3) had CKD, 0.86% (2) had asthma and 0.43% (1) had hypothyroidism. Hypertension is the most common co-morbidity found associated in subjects with DR.

Of 330 subjects, there was no PDR/ NPDR in 32.73% (108) of the patients while 9.7% (32) patients had mild NPDR, 31.21% (103) had moderate, 2.73% (9) had severe and 1.82% (6) had very severe NPDR. 21.82% (72) had PDR in the right eye.

While in Left eye of 33.33% (110) patients was normal with no disease whereas 9.39% (31) had mild NPDR, 30% (99) had moderate NPDR, 3.94% (13) had severe NPDR and 2.12% (7) had very severe NPDR. 21.21% (70) patients had PDR.

Mean HbA1c level in the study was 8.6 mg/dl with a SD of ±2.13.

In our study, fasting blood sugar level was <100 in 16 patients (7 eyes had NPDR), 101-150 in 143 (131 eyes had NPDR), 151-200 in 88 (118 eyes had NPDR and 32 had PDR), 201-250 in 34 (23 eyes had NPDR and 41 had PDR), 251-300 in 30 (15 eyes had NPDR and 41 had PDR)
and >300 in 19 patients (6 eyes had NPDR and 28 eyes had PDR).

In our study, mean fasting blood sugar level was 174.63 with a SD of +65.72 mg/dl.

Patients with less than 6 HbA1c level have 138mg/dl as mean fasting blood glucose level. Between 6-7 HbA1c level mean fasting blood glucose was 135.85 mg/dl, between 7-8 have 151.45mg/dl while between 8-9 patients have 177.55 mg/dl as mean blood glucose level. While patients with more than 9 HbA1c level have 223.87 mg/dl as mean blood glucose level.

In our study, of the 330 patients, 69.09% (228) patients were in the age group 51-65. Of the 23 patients with DR, 71.55% (166) were in the age range 51-65 years, 15.52% (36) in 66-80 years, 12.07% (28) in 36-50 years, 0.43% (1) in 21-35 years and 0.43% (1) above 80 years. Most of the patients (69.1%) were in the 51-65 age range. In a study by Lokesh S et al., majority of the patients (38%) were in the age range 61-70 years. Similar findings were reported by Khalid M et al., Pragati Garg, Zhang R, and Long M where majority of the patients were above the age of 50 years.

In our study, 57.88% (191) were males and 42.12% (139) were females. Of the 232 patients with DR, 60.78% (141) were males and 39.22% (91) were female. Male to female ratio was 1.37:1 in the entire study group and it was 1.55:1 among patients with DR. Literature reported mild preponderance of males, as seen in studies by Lokesh S et al. (68%) [85], Khalid MA (61.4%). However, in studies by Pragati G et al. (46.85%) and Long M et al. (47.2%) [88] number of female patients was slightly greater than the males.

Of the 330 patients enrolled, 94.24% (311) had T2DM while 5.76% (19) had T1DM. In the patients diagnosed with DR, 93.97% (218) had T2DM while 6.03% (14) had T1DM. Of the 19 patients with T1DM, 74% (14) developed DR while 70% (218) of T2DM patients developed DR. In a study conducted by Thomas RL et al., prevalence of any DR in those with Type 1 diabetes was 56.0%, and in Type 2 diabetes was 30.3%. Matuszewski W et al. reported that the prevalence of any DR in T1DM was 32.58% and 23.4% in T2DM in north-east Poland. In a nine-year follow-up study conducted by Romero-Aroca P et al., the incidence of any DR was 47.26% with annual incidence 15.16% in T1DM, and 26.49% with annual incidence 8.13% in Type 2 Diabetes Mellitus. In a study conducted in Scotland data revealed a higher cumulative incidence of DR in patients with T1DM (21.7%) than in those with T2DM (13.3%).

Average duration of diabetes was 9.46 ± 4.97 years in the study population and 10.39 ± 5.01 in the patients with DR. In the study conducted by Lokesh S et al., average duration of diabetes mellitus was 9.8 ± 5.34 years. Long M et al. reported that severe NPDR/proliferative retinopathy had the longest duration of diabetes followed by those with mild NPDR (14.4 years) then subjects with no retinopathy (7.5 years). Karadeniz Z et al. reported that the presence and the severity of DR was increasing as the duration of DM increases. In a study conducted by Ramanathan RS, 40% patients of DR had duration between 10-15 years, 55% patients had a duration of >15 years. Melo, L.G.N et al. also reported that longer duration of DM is a risk factor for development of DR.

Of 320 patients enrolled, 30% (99) had hypertension. Hypertension is the most common co-morbidity in patients with DR. In Lokesh S et al. study, 54% of patients

### Table 1: Age distribution

| Age Distribution | No. of Patients (%) | No. of Patients with DR (%) |
|------------------|---------------------|-----------------------------|
| 21 to 35         | 3 (0.91)            | 1 (0.43)                    |
| 36 to 50         | 54 (16.36)          | 28 (12.07)                  |
| 51 to 65         | 228 (69.09)         | 166 (71.55)                 |
| 66 to 80         | 44 (13.33)          | 36 (15.52)                  |
| 81 and above     | 1 (0.30)            | 1 (0.43)                    |

### Table 2: Gender distribution

| Gender Distribution | No. of Patients (%) | No. of Patients with DR (%) |
|---------------------|---------------------|-----------------------------|
| Female              | 139 (42.12)         | 91 (39.22)                  |
| Male                | 191 (57.88)         | 141 (60.78)                 |

### Table 3: Type of diabetes mellitus

| Type of Diabetes Mellitus | No. of Patients (%) | No. of Patients with DR (%) |
|---------------------------|---------------------|-----------------------------|
| Type 1                    | 19 (5.76)           | 14 (6.03)                   |
| Type 2                    | 311 (94.24)         | 218 (93.97)                 |

### Table 4: Duration of diabetes mellitus (years)

| Duration of Diabetes Mellitus (years) | Mean | Std Dev |
|---------------------------------------|------|---------|
|                                       | 9.46 | 4.97    |

### 4. Discussion

Out of the 330 subjects enrolled, 70.3% (232) had diabetic retinopathy. Lokesh S et al. reported prevalence of DR as 64%, in Blue mountain study it was 29% while the prevalence rate was 50.3% in Winconsin epidemiologic study. Chennai urban Rural Epidemiological study (CURES) showed an overall prevalence of diabetic retinopathy of 17.6%. In a study conducted by Khalid M et al. in Saudi Arabia prevalence of DR was 35.8%, two studies conducted in USA by reported a prevalence of 28.2% and 28.5%. In a study conducted in UK DR prevalence of DR was 30.1%.
Table 5: Associated diseases

| Associated diseases | No. of Patients (%) | Percentage of Patients | No. of patients with DR (%) | Percentage of patients with DR |
|---------------------|---------------------|------------------------|----------------------------|-------------------------------|
| Asthma              | 2 (0.61)            | 0.61%                  | 2 (0.86)                   | 0.86%                         |
| IHD                 | 18 (5.45)           | 5.45%                  | 12 (5.17)                  | 5.17%                         |
| Hypertension        | 99 (30)             | 30.00%                 | 77 (33.19)                 | 33.19%                        |
| Hyperlipidemia      | 27 (8.18)           | 8.18%                  | 33 (14.22)                 | 14.22%                        |
| CKD                 | 3 (0.91)            | 0.91%                  | 3 (1.29)                   | 1.29%                         |
| Acromegaly          | 1 (0.30)            | 0.30%                  | 0 (0)                      | 0.00%                         |
| HbsAg+              | 1 (0.30)            | 0.30%                  | 0 (0)                      | 0.00%                         |
| Hypothyroidism      | 1 (0.30)            | 0.30%                  | 1 (0.43)                   | 0.43%                         |

Table 6: ETDRS classification and mean HbA1c - right eye

| ETDRS Classification- RT eye | No. of Patients | Percentage of Patients | Mean HbA1c | Mean Duration of diabetes in years |
|------------------------------|-----------------|------------------------|------------|-----------------------------------|
| No Disease                   | 108             | 32.73%                 | 8.55       | 7.19                              |
| Mild NPDR                    | 32              | 9.70%                  | 8.11       | 8                                  |
| Moderate NPDR                | 103             | 31.21%                 | 8.2        | 9.61                              |
| Severe NPDR                  | 9               | 2.73%                  | 8.95       | 11.44                             |
| Very Severe NPDR             | 6               | 1.82%                  | 7.63       | 11.33                             |
| PDR                          | 72              | 21.82%                 | 9.49       | 12.05                             |

Correlation: The value of R is 0.3433, co-efficient of determination: 0.1179 suggests a positive correlation between mean GHL and duration of diabetes and grade of diabetic retinopathy.

Table 7: ETDRS classification & HbA1c - left eye

| ETDRS Classification- LT eye | No. of Patients | Percentage of Patients | Mean HbA1c | Mean Duration of diabetes in years |
|------------------------------|-----------------|------------------------|------------|-----------------------------------|
| No Disease                   | 110             | 33.33%                 | 8.44       | 7.08                              |
| Mild NPDR                    | 31              | 9.39%                  | 8.05       | 8.32                              |
| Moderate NPDR                | 99              | 30.00%                 | 8.29       | 9.76                              |
| Severe NPDR                  | 13              | 3.94%                  | 8.99       | 10.69                             |
| Very Severe NPDR             | 7               | 2.12%                  | 8.03       | 12.83                             |
| PDR                          | 70              | 21.21%                 | 9.52       | 12.32                             |

Correlation: The value of R is 0.3489, Co-efficient of determination: 0.1217 suggests a positive correlation between mean GHL and duration of diabetes and grade of diabetic retinopathy.

Table 8: Glycosylated hemoglobin level

Glycosylated Hemoglobin Level
Mean 8.60
Std Dev 2.13

Table 9: BSL-F(mg/dl)2

| BSL-F(mg/dl)2 | No. of Patients | No. of Eyes with NPDR | No. of Eyes with PDR |
|---------------|-----------------|-----------------------|----------------------|
| <100          | 16              | 7                     | 0                    |
| 101-150       | 143             | 131                   | 0                    |
| 151-200       | 88              | 118                   | 32                   |
| 201-250       | 34              | 23                    | 41                   |
| 251-300       | 30              | 15                    | 41                   |
| >300          | 19              | 6                     | 28                   |

Table 10: HbA1c

| HbA1c | No. of Patients | No. of Eyes with NPDR | No. of Eyes with PDR |
|-------|-----------------|-----------------------|----------------------|
| <6    | 12              | 12                    | 3                    |
| 6.0 - 7.0 | 62              | 58                    | 8                    |
| 7.1 - 8.0 | 84              | 87                    | 21                   |
| 8.1 - 9.0 | 81              | 87                    | 39                   |
| >9    | 91              | 55                    | 71                   |
had coexisting hypertension. Two studies conducted in US\textsuperscript{26,27} reported associations based on the prevalence of any retinopathy, with certain nonglycemic factors such as hypertension, dyslipidemia, ageing and obesity. Hammes HP et al\textsuperscript{28} also reported that hypertension was significantly associated with development of DR. Lima, VC et al\textsuperscript{29} reported that in their study, hypertension and dyslipidemia did not reach the statistical significance level established (p < 0.05).

In the right eye, out of 330 subjects 108 (32.73\%) showed no signs of diabetic retinopathy with a mean HbA1c value of 8.55\% and mean duration of diabetes among these was 7.19 years. While in 72(21.82\%) subjects, it showed presence of proliferative diabetic retinopathy with a mean HbA1c value of 9.49\% and mean duration of diabetes among these was 12.05 years. The value of R is 0.3433, co-efficient of determination: 0.1179 suggests a positive correlation between mean HbA1c and duration of diabetes and grade of diabetic retinopathy.

In the left eye, out of 330 subjects, 110(33.33\%) subjects showed no signs of diabetic retinopathy with a mean HbA1c value of 8.44\% and mean duration of diabetes was 7.08 years. While 70(21.21\%) subjects showed signs of proliferative diabetic retinopathy with a mean HbA1c value of 9.52\% and mean duration of diabetes was 12.32 years. The value of R is 0.3489, Co-efficient of determination: 0.1217 suggests a positive correlation between mean HbA1c and duration of diabetes and grade of diabetic retinopathy.

In our study, fasting blood sugar level was <100 in 16 patients (7 eyes had NPDR), 101-150 in 143 (131 eyes had NPDR), 151-200 in 88 (118 eyes had NPDR and 32 had PDR), 201-250 in 34 (23 eyes had NPDR and 41 had PDR), 251-300 in 30 (15 eyes had NPDR and 41 had PDR) and >300 in 19 patients (6 eyes had NPDR and 28 eyes had PDR). BSL-F >100 was found to be a risk factor for development of NPDR while >150 has shown preponderance to PDR. In Lokesh S et al. study,\textsuperscript{16} 32\% of patient had fasting blood sugars more than 200, 48\% of patients had fasting blood sugars in the range of 126-199 and 20\% had Fasting blood sugars less than 126.

In our study, HbA1c level was <6 in 12 patients (mean BSL-F: 138.41 mg/dl; 12 eyes had NPDR and 3 eyes had PDR), 6.0-7.0 in 62 (mean BSL–F: 135.85 mg/dl; 8 eyes had NPDR and 8 had PDR), 7.1-8.0 in 84 (mean BSL-F: 151.45 mg/dl; 87 eyes had NPDR and 21 had PDR), 8.1-9.0 in 81(mean BSL-F: 177.55 mg/dl; 87 eyes had NPDR and 39 had PDR), >9.0 in 91(mean BSL-F: 223.87 mg/dl; 55 eyes had NPDR and 71 had PDR). High HbA1c level was correlated to high BSL-F level and subsequently high number of NPDR and PDR eyes.

Diabetic control and complication trial (DCCT)\textsuperscript{32} have shown a strong relationship between HbA1c and the development and progression of DR. Lokesh S et al study\textsuperscript{16} showed lower frequency of DR in patients with lower HbA1c group and an increase in frequency of DR as the HbA1c increases. UKPDS landmark trial\textsuperscript{33} also reported similar findings where intensive blood-glucose control substantially decreases the risk of microvascular complications in patients with T2DM. Khalid M et al\textsuperscript{12} reported a strong relationship between HbA1c and development of DR (p <0.001). Patients with uncontrolled diabetes had higher chances of developing DR (66.61\%). Similar findings were reported by Garg Petal, Long Metal\textsuperscript{19} and Lind Metal.\textsuperscript{34} Zhang R et al.\textsuperscript{18} reported that when fasting plasma glucose exceeded 7.03 mmol/L and HbA1c exceeded 6.4\%, the prevalence of DR increased sharply. In Asian patients with T2DM,\textsuperscript{35} higher mean HbA1c level was associated with moderate or worse DR

### Table 11: BSL-F

| BSL-F (mg/dl) | Mean | Std Dev |
|---------------|------|---------|
| Mean          | 174.63 | 65.72   |

### Table 12: Correlation between HbA1c and mean BSL-F

| HbA1c     | Mean BSL-F |
|-----------|------------|
| <6        | 138.41     |
| 6.0 - 7.0 | 135.85     |
| 7.1 - 8.0 | 151.45     |
| 8.1 - 9.0 | 177.55     |
| >9        | 223.87     |
5. Conclusion

Our study showed that as the HbA1c level increases prevalence of DR also increases and there is a strong relationship between HbA1c level and DR. Apart from HbA1c levels, poor control and duration of DM also showed a significant association. Advanced age, male gender, type of DM, smoking status, alcohol consumption, co-morbidities such as hypertension and dyslipidemia also showed an association with prevalence of DR.

6. Limitations

1. The study sample was small to extrapolate to regional and national trends.
2. Treatment modalities was not discussed.
3. Long term follow up and outcome of treatment modalities was not discussed.
4. Cost implications in management of diabetes and retinopathy arising thereof were not studied.

7. Source of Funding

None

8. Conflict of Interest

None.

References

1. Powers A, Niswender K, Molina C. Diabetes Mellitus: Diagnosis, Classification, and Pathophysiology. In: Harrison’s Principles of Internal Medicine. McGraw-Hill Medical; 2020. p. 2580–58.
2. International Diabetes Federation. IDF Diabetes Atlas, 7th edition. Brussels, Belgium: International Diabetes Federation; 2015.
3. Pandey SK, Sharma V. World diabetes day 2018: Battling the Emerging Epidemic of Diabetic Retinopathy. Indian J Ophthalmol. 2018;66(11):1652–3.
4. Fong DS, Aiello LP, Ferris FL, Klein R. Diabetic Retinopathy. Diabetes Care. 2004;27(10):2540–53.
5. Yau JW, Rogers SL, Kawasaki R. Global prevalence and risk factors associated with Diabetic Retinopathy. Diabetes Care. 2012;35(3):556–64.
6. Fong DS, Aiello L, Gardener TW, King GL, Blankenship G, Cavallero JD, et al. Retinopathy in diabetes. Diabetes Care. 2004;27(1):84–7.
7. Bhavasar AR, Emerson GG, Emerson MV. Epidemiology of diabetic retinopathy. In: Browning D, editor. Diabetic Retinopathy: Evidence-based Management. New York: Springer; 2010. p. 55–75.
8. Klein R, Klein BE, Moss SE, Davis MD, Demets DL. Glycosylated hemoglobin predicts the incidence and progression of diabetic retinopathy. JAMA. 1988;260(19):2864–71.
9. Mitchell P, Smith W, Wang JJ, Attebo K. Prevalence of diabetic retinopathy in an older community. Ophthalmology. 1998;105(3):406–11.
10. Klein R, Klein BE, Moss SE, Davis MD, Demets DL. The Wisconsin Epidemiologic Study of Diabetic Retinopathy: III. Prevalence and risk of diabetic retinopathy when age at diagnosis is 30 or more years. Arch Ophthalmol. 1984;102(4):527–32.
11. Rema M, Premkumar S, Anitha B, Deepa R, Pradeepa R, Mohan V. Prevalence of Diabetic Retinopathy in Urban India: The Chennai Urban Rural Epidemiology Study (CURES) Eye Study. Invest Ophthalmol Vis Sci. 2005;46:2328.
12. Alabdulwahhab KM. Relationship between Diabetic Retinopathy and HbA1c in Type 2 Diabetics, Kingdom of Saudi Arabia. J Res Med Dent Sci. 2019;7(5):1–4.
13. Toy B, Day S. Non-mydriatic fundus camera screening for diabetic retinopathy in a Northern California safety-net setting. Invest Ophthal Vis Sci. 2013;54:1552–7.
14. Owsley C, McGwin G, Lee DJ. Diabetes eye screening in urban settings serving minority populations: detection of diabetic retinopathy and other ocular findings using telemedicine. JAMA Ophthalmol. 2015;133:174–81.
15. Thomas RL, Dunstan FD, Luzio SD, Choudhury SR, North RV, Hale SL, et al. Prevalence of diabetic retinopathy within a national diabetic retinopathy screening service. Br J Ophthalmol. 2015;99(1):64–8.
16. Lokesh S, Shivaswamy S. Study of HbA1C levels in patients with type 2 diabetes mellitus in relation to diabetic retinopathy in Indian population. Int J Adv Med. 2018;5(6):1397.
17. Garg P, Misra S, Yadav S, Singh L. Correlative Study of Diabetic Retinopathy with HbA1c andMicroalbuminuria. Int J Ophthalmol. 2018;11(2):282–6.
18. Zhang R, Li Y, Zhang S, Cai X, Zhou X, Ji L. The Association of Retinopathy and Plasma Glucose and HbA1c: A Validation of Diabetic Diagnostic Criteria in a Chinese Population. J Diabetes Res. 2016;2016:1–7.
19. Long M, Wang C, Liu D. Glycated hemoglobin A1C and vitamin D and their association with diabetic retinopathy severity. Nutr Diabetes. 2017;7(6):e281.
20. Matuszewski W, Baranowska-Jurkun A, Stefanowicz-Rutkowska MM, Modzelewski R, Pieczyński J, Bandurska-Stankiewicz E. Prevalence of Diabetic Retinopathy in Type 1 and Type 2 Diabetes Mellitus Patients in North-East Poland. Medicina. 2020;56(4):164.
21. Romero-Aroca P, Navarro-Gil R, Valls-Mateu A. Differences in incidence of diabetic retinopathy between type 1 and 2 diabetes mellitus: a nine-year follow-up study. Br J Ophthalmol. 2017;101(10):1346–51.
22. Looker HC, Nyangoma SO, Cromie DT. Scottish Diabetes Research Network Epidemiology Group; Scottish Diabetic Retinopathy Collaborative. Rates of referable eye disease in the Scottish National Diabetic Retinopathy Screening Programme. Br J Ophthalmol. 2014;98:790–5.
23. Karadeniz ZS, Yilmaz MT. Duration of diabetes and prevalence of diabetic retinopathy: Istanbul Diabetic Retinopathy Study—IDRS results 1. Diabetes Metab Syndr Clin Res Rev. 2007;1(1):43–8.
24. Ramanathan RS. Correlation of duration, hypertension and glyemic control with microvascular complications of diabetes mellitus at a tertiary care hospital. Int J Ophthalmol. 2017;10(7):2034–8.
25. Melo LGN, Morales PH, Drummond KRG, Santos D, Pizarro M, Barros BSV, et al. Current epidemiology of diabetic retinopathy in patients with type 1 diabetes: a national multicenter study in Brazil. BMC Public Health. 2018;18(1):989.
26. Tsugawa Y, Mukamal KJ, Davis RB, Taylor WC, Wee CC. Should the hemoglobin A(1c) diagnostic cutoff differ between blacks and whites?: a cross- sectional study. Ann Intern Med. 2012;157(3):153–9.
27. Bower JK, Brancati FL, Selvin E. No ethnic differences in the association of glycated hemoglobin with retinopathy: the national health and nutrition examination survey. Diabetes Care. 2005;36(3):569–73.
28. Hammes HP, Welp R, Kempe HP, Wagner C, Siegel E, RWH. Risk Factors for Retinopathy and DME in Type 2 Diabetes—Results from the German/Austrian DPV Database. PLOS ONE. 2015;10(7):e0132492.
29. Lima VC, Cavalieri GC, Lima MC. Risk factors for diabetic retinopathy: a case-control study. Int J Retina Vitreous. 2016;2:21. doi:10.1186/s40942-016-0047-6

30. He BB, Wei L, Gu YJ, Han JF, Li M, Liu YX, et al. Factors associated with diabetic retinopathy in Chinese patients with Type 2 diabetes mellitus. Int J Endocrinol. 2012;2012:157940. doi:10.1155/2012/157940

31. Mehta K, Sharma R, Bhatti JS. Prevalence and predictors of diabetic retinopathy in the population of Punjab: North Indian diabetic retinopathy epidemiology and molecular genetic study (ni-dreams). Int J Health Sci Res. 2018;8(9):1–9.

32. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. New Engl J Med. 1993;329(14):977–86.

33. UK Prospective Diabetes Study (UKPDS) Group. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). Lancet. 1998;352(9131):837–53.

34. Lind M, Pivodic A, Svensson AM, Ólafsdóttir AF, Wedel H, Ludvigsson J. HbA1c level as a risk factor for retinopathy and nephropathy in children and adults with Type 1 diabetes: Swedish population based cohort study. BMJ. 2019;366:l4894. doi:10.1136/bmj.l4894

35. Foo VHX, Tan GS, Sabanayagam C, Huang H, Ikram MK, Cheung GCM, et al. HbA1c Variability and Diabetic Retinopathy in Asian Type 2 Diabetes. Invest Ophthalmol Vis Sci. 2014;55:4412.

Author biography

Chirag Singh, Junior Resident
Shashi Prabha Prasad, Professor
Sucheta Kaul, Junior Resident
Divya Motwani, Junior Resident
Ashish Mishra, Junior Resident
Vishakh Padmakumar, Junior Resident

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