

Original Research Article

Correlation between HbA1c Levels and Severity of Diabetic Retinopathy in Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Observational Study

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ABSTRACT

Background: Diabetic retinopathy is a major microvascular complication of type 2 diabetes mellitus, and chronic glycaemic exposure is a potentially modifiable determinant of retinal microvascular damage. HbA1c provides an integrated estimate of recent glycaemic control and may help identify patients at greater risk of advanced retinopathy.

Objective: To evaluate the association between HbA1c level and diabetic retinopathy severity in patients with type 2 diabetes mellitus.

Methods: This cross-sectional observational study included 48 patients with type 2 diabetes mellitus. Diabetic retinopathy severity was recorded using ETDRS-linked grades and grouped as no diabetic retinopathy, mild non-proliferative diabetic retinopathy (NPDR), moderate NPDR, severe NPDR, and proliferative diabetic retinopathy (PDR). HbA1c, diabetes duration, age, body mass index, treatment category, hypertension, dyslipidaemia, and macular oedema status were analysed. Spearman rank correlation and Kruskal-Wallis testing were used for ordinal and between-group comparisons.

Results: Mean age was 56.54 ± 9.98 years, mean diabetes duration was 14.08 ± 6.92 years, and mean HbA1c was $8.37 \pm 1.81\%$. Retinopathy was absent in 7 (14.6%), while mild NPDR, moderate NPDR, severe NPDR, and PDR were present in 13 (27.1%), 13 (27.1%), 4 (8.3%), and 11 (22.9%), respectively. Mean HbA1c increased stepwise from 5.93% in patients without retinopathy to 10.93% in PDR. HbA1c correlated strongly with ETDRS grade (Spearman $\rho=0.967$, $p<0.001$), and HbA1c differed significantly across severity groups (Kruskal-Wallis $H=44.22$, $p<0.001$). A partial rank analysis controlling for diabetes duration showed an attenuated but persistent association (partial $\rho=0.375$, $p=0.009$).

Conclusion: Higher HbA1c levels were strongly associated with greater diabetic retinopathy severity in this clinical cohort. The association was partly explained by longer diabetes duration, but remained statistically significant after accounting for duration. These findings support the clinical importance of sustained glycaemic control together with regular retinal surveillance in patients with type 2 diabetes mellitus.

Keywords: Diabetic Retinopathy, HbA1c, Type 2 Diabetes Mellitus, ETDRS, Glycaemic Control, Non-Proliferative Diabetic Retinopathy, Proliferative Diabetic Retinopathy.

INTRODUCTION

Diabetic retinopathy (DR) remains one of the most important microvascular complications of diabetes mellitus and a major cause of avoidable visual impairment among working-age adults. The global burden continues to rise in parallel with diabetes, with contemporary estimates indicating a substantial increase in

the number of people affected by DR and vision-threatening retinopathy over the coming decades.^[1] Earlier pooled epidemiological evidence likewise identified glycaemic control, duration of diabetes, blood pressure, and diabetes type as major determinants of retinopathy risk.^[2]

India carries a particularly important clinical and public-health burden. The National Diabetic Retinopathy Survey documented a considerable burden of retinopathy among people with diabetes, while the SMART India screening study demonstrated marked geographic and sociodemographic variation in disease occurrence.^[3,4] Facility-based data from the SPEED study further showed that diabetic retinopathy and sight-threatening disease are common among patients with type 2 diabetes who reach eye-care services, emphasising the need for systematic retinal assessment within routine diabetes care.^[5]

Glycated haemoglobin (HbA1c) is widely used as an integrated marker of glycaemic exposure. In South Indian patients with type 2 diabetes, the CURES Eye Study identified HbA1c and diabetes duration as independent factors associated with increasing DR severity.^[6] This relationship is clinically relevant because HbA1c is modifiable, whereas accumulated diabetes duration is not. Understanding how current HbA1c relates to retinal severity may therefore help clinicians identify individuals who require closer metabolic and ophthalmic follow-up.

Retinopathy severity can be expressed using the Early Treatment Diabetic Retinopathy Study (ETDRS) scale, which provides an ordered framework for grading retinal microvascular disease.^[7] In the present study, ETDRS-linked grades were used to examine the relationship between HbA1c and retinopathy severity in patients with type 2 diabetes mellitus. The primary objective was to determine the correlation between HbA1c level and DR severity; secondary analyses explored diabetes duration and other routinely recorded clinical characteristics.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional observational study was conducted in the Department of Ophthalmology at KVG Medical College Sullia, Dakshina Kannada for a period of one year. The analytic cohort comprised 48 patients with type 2 diabetes mellitus who underwent ophthalmic evaluation and had complete clinical and metabolic information available for analysis.

Study Population

Patients with type 2 diabetes mellitus were included when HbA1c, duration of diabetes, diabetic retinopathy severity, ETDRS grade, age, sex, body mass index (BMI), treatment category, hypertension status, dyslipidaemia

status, and macular oedema status were recorded. Records lacking the variables required for the primary analysis would have been excluded; however, all 48 participant records were complete. The sampling approach was not specified, and no claim of random or consecutive sampling was made.

Assessment of Diabetic Retinopathy

Diabetic retinopathy was analysed according to the ETDRS-linked grade documented at ophthalmic assessment. For clinical presentation, grades were grouped as no DR (ETDRS level 10), mild NPDR (level 35), moderate NPDR (levels 43 or 47), severe NPDR (level 53), and PDR (levels 61 or 65). Macular oedema was recorded as present or absent. The retinal image acquisition platform and grading workflow were not available for further specification.

Metabolic and Clinical Variables

HbA1c was analysed as a continuous percentage value. Duration of diabetes was expressed in years and BMI in kg/m². Antidiabetic treatment was categorised as oral hypoglycaemic agents (OHA), insulin, or combined OHA plus insulin therapy. Hypertension and dyslipidaemia were recorded as binary clinical variables.

Data Quality and Statistical Analysis

Participant identifiers were screened for duplication, all variables were checked for missing values and plausible numeric ranges, and DR categories were cross-checked against the corresponding ETDRS levels. No participant-level value required alteration or imputation. Summary-level inconsistencies were resolved by recalculating all descriptive and inferential statistics directly from the 48 individual records. Continuous variables are reported as mean $\pm$ standard deviation and categorical variables as number and percentage. Because DR severity is ordinal and group sizes were unequal, Spearman rank correlation was used to assess associations with ETDRS grade, and the Kruskal-Wallis test was used to compare HbA1c across the five DR categories. A sensitivity partial-rank correlation was calculated between HbA1c and ETDRS grade while controlling for diabetes duration. A two-sided p-value <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted after obtaining institutional ethical clearance and in accordance

with accepted ethical principles for research involving human participants. Participant confidentiality was maintained throughout the study, and clinical information was used only for the stated research purpose. No experimental therapeutic intervention was administered as part of the study.

RESULTS

All 48 records passed completeness and internal-consistency checks and were retained

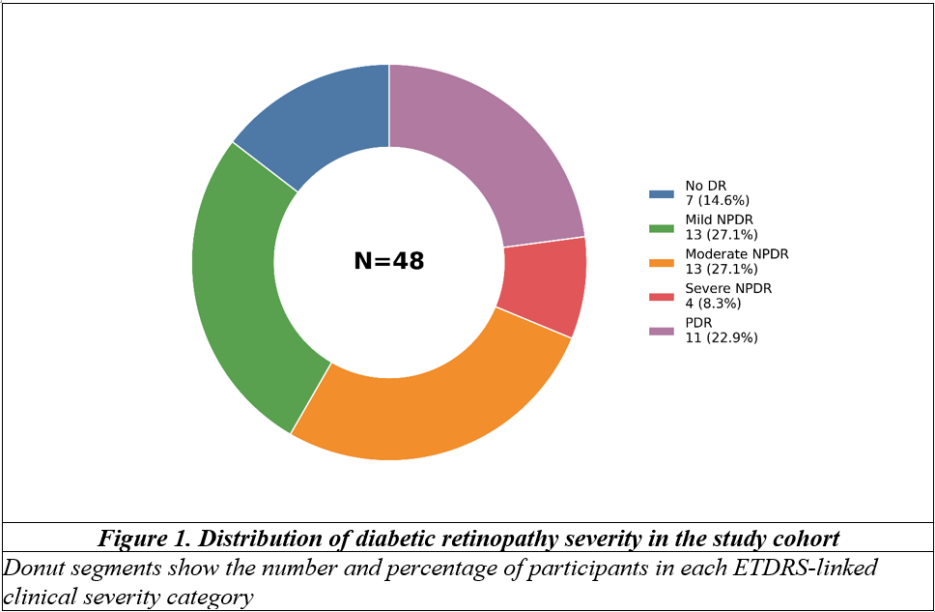
for analysis. The mean age was 56.54 ± 9.98 years (range 38-73), and 29 (60.4%) participants were male. Mean diabetes duration was 14.08 ± 6.92 years, mean HbA1c was 8.37 ± 1.81%, and mean BMI was 26.89 ± 2.82 kg/m². Hypertension was recorded in 32 (66.7%), dyslipidaemia in 29 (60.4%), and macular oedema in 18 (37.5%) participants (Table 1).

Characteristic	Value
Age (years)	56.54 ± 9.98
Male sex	29 (60.4%)
Female sex	19 (39.6%)
Diabetes duration (years)	14.08 ± 6.92
HbA1c (%)	8.37 ± 1.81
BMI (kg/m²)	26.89 ± 2.82
OHA treatment	25 (52.1%)
Insulin treatment	18 (37.5%)
OHA + insulin	5 (10.4%)
Hypertension	32 (66.7%)
Dyslipidaemia	29 (60.4%)
Macular oedema	18 (37.5%)

Table 1. Demographic, metabolic and clinical characteristics of the study population (N=48)
Values are mean ± SD or n (%). BMI: body mass index; OHA: oral hypoglycaemic agents

DR was absent in 7 (14.6%) participants. Mild NPDR and moderate NPDR were each present in 13 (27.1%) participants, severe NPDR in 4 (8.3%), and PDR in 11

(22.9%). The distribution is shown in Figure 1 and summarised with metabolic characteristics in Table 2.



DR category	n (%)	ETDRS level(s)	HbA1c, mean $\pm$ SD (%)	Diabetes duration, mean $\pm$ SD (years)	Macular oedema, n (%)
No DR	7 (14.6%)	10	5.93 $\pm$ 0.34	4.29 $\pm$ 1.11	0 (0.0%)
Mild NPDR	13 (27.1%)	35	7.02 $\pm$ 0.39	9.00 $\pm$ 1.91	0 (0.0%)
Moderate NPDR	13 (27.1%)	43/47	8.50 $\pm$ 0.51	14.92 $\pm$ 2.50	3 (23.1%)
Severe NPDR	4 (8.3%)	53	9.62 $\pm$ 0.28	19.50 $\pm$ 0.58	4 (100.0%)
PDR	11 (22.9%)	61/65	10.93 $\pm$ 0.63	23.36 $\pm$ 2.01	11 (100.0%)

Table 2. HbA1c, diabetes duration and macular oedema according to diabetic retinopathy severity
NPDR: non-proliferative diabetic retinopathy; PDR: proliferative diabetic retinopathy; ETDRS: Early Treatment Diabetic Retinopathy Study

Mean HbA1c increased progressively across retinal severity groups, from 5.93 $\pm$ 0.34% in participants without DR to 10.93 $\pm$ 0.63%

among those with PDR (Figure 2). The between-group difference was statistically significant (Kruskal-Wallis H=44.22, p<0.001).

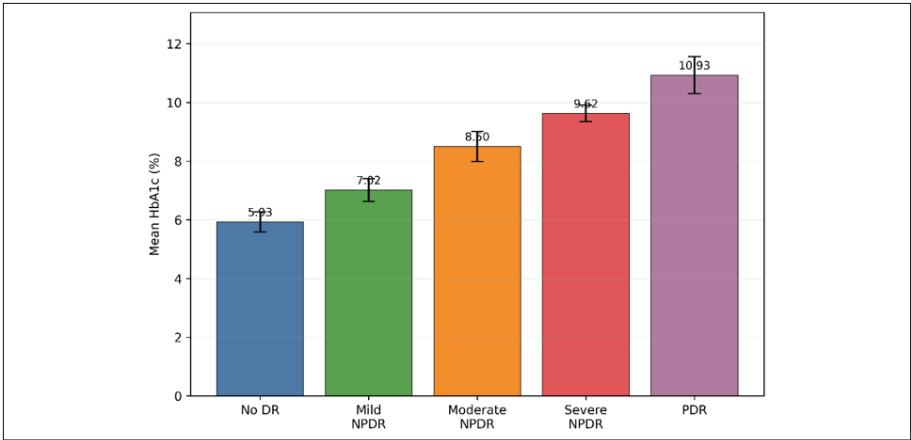


Figure 2. Mean HbA1c level according to diabetic retinopathy severity
Bars show mean HbA1c and error bars represent standard deviation. The figure demonstrates the stepwise rise in HbA1c across increasing retinal severity

The primary ordinal analysis demonstrated a very strong positive correlation between HbA1c and ETDRS grade (Spearman rho=0.967, p<0.001) (Figure 3). Diabetes duration was similarly correlated with ETDRS

grade (rho=0.961, p<0.001). Age and BMI also showed positive correlations, although these variables were strongly interrelated within this small clinical cohort (Table 3).

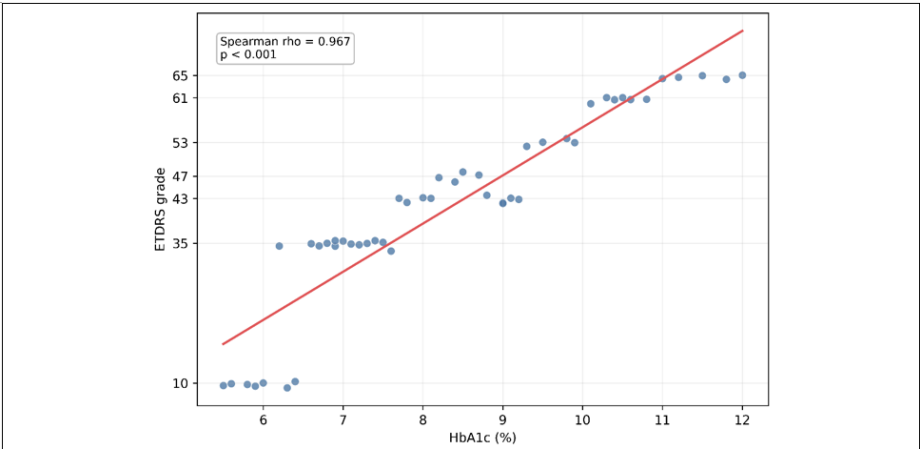


Figure 3. Relationship between HbA1c and ETDRS diabetic retinopathy grade
Each point represents one participant; slight vertical jitter is used only to reveal overlapping observations at identical ETDRS grades. The fitted line is descriptive; inference is based on Spearman rank correlation

After controlling for diabetes duration, the association between HbA1c and ETDRS grade was attenuated but remained statistically significant (partial $\rho=0.375$, $p=0.009$). Macular oedema was recorded in 18 (37.5%) participants and was concentrated in more advanced retinal categories: it was absent in

the no-DR and mild-NPDR groups, present in 3 of 13 moderate-NPDR participants, and present in all participants classified as severe NPDR or PDR (Figure 4). Because of sparse cells and the small sample, these categorical patterns were treated descriptively rather than as independent risk estimates.

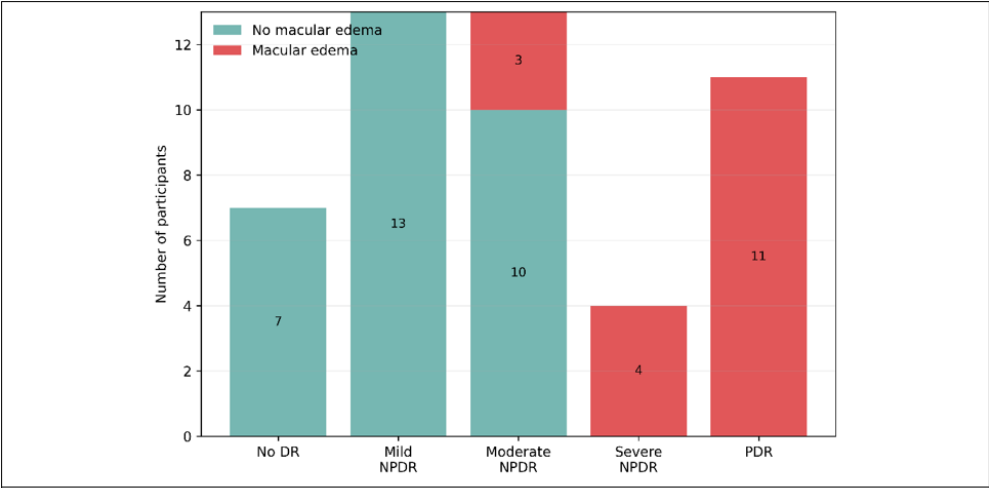


Figure 4. Distribution of macular oedema across diabetic retinopathy severity categories
Stacked bars display participant counts with and without recorded macular oedema in each DR category

DR category	Hypertension, n (%)	Dyslipidaemia, n (%)	Macular oedema, n (%)
No DR	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mild NPDR	4 (30.8%)	3 (23.1%)	0 (0.0%)
Moderate NPDR	13 (100.0%)	11 (84.6%)	3 (23.1%)
Severe NPDR	4 (100.0%)	4 (100.0%)	4 (100.0%)
PDR	11 (100.0%)	11 (100.0%)	11 (100.0%)

Table 4. Selected comorbidities according to diabetic retinopathy severity
Percentages are calculated within each retinopathy category. Inferential testing was not emphasised because of sparse cells in several categories

DISCUSSION

The principal finding of this study was a strong, graded association between HbA1c and diabetic retinopathy severity. Mean HbA1c rose from approximately 5.9% in participants without retinopathy to 10.9% among those with PDR, and the ordinal correlation with ETDRS grade was very strong. Diabetes duration followed an almost parallel pattern. When duration was accounted for using a partial rank analysis, the HbA1c association became substantially smaller but remained statistically significant. This attenuation is clinically important: it indicates that the apparent strength of the unadjusted HbA1c-retinopathy relationship in this cohort is partly inseparable from cumulative duration of diabetes.

The direction of these findings is consistent with established longitudinal evidence. UKPDS 35 showed a continuous

relationship between glycaemic exposure and diabetic microvascular complications in type 2 diabetes, with lower updated mean HbA1c associated with lower microvascular risk.^[8] Earlier Wisconsin epidemiological work also demonstrated that higher glycosylated haemoglobin predicted both the incidence and progression of diabetic retinopathy after accounting for major clinical covariates.^[9] Although the present cross-sectional study cannot establish temporal causality, the graded retinal pattern is therefore biologically and epidemiologically plausible.

Indian studies provide particularly relevant comparisons. In the urban SN-DREAMS cohort, longer duration of diabetes was the strongest predictor of retinopathy, while insulin use and other clinical characteristics also identified higher-risk groups.^[10] Rural SN-DREAMS similarly linked

DR with longer diabetes duration, higher HbA1c, insulin use and systolic hypertension.^[11] A primary-care study from Tamil Nadu reported associations of retinopathy with hypertension, longer duration and poor glycaemic control.^[12] These observations align with the present finding that both HbA1c and duration increase in step with retinal severity.

Longitudinal Indian evidence further supports the importance of cumulative systemic exposure. Four-year SN-DREAMS follow-up identified blood pressure and other metabolic factors in incident or progressive disease,^[13] while the 15-year follow-up continued to implicate baseline diabetes duration and HbA1c in long-term retinal outcomes.^[14] A recent Indian systematic review and meta-analysis also found higher HbA1c and insulin use to be associated with diabetic retinopathy risk across a large pooled population.^[15] Together, these studies place the present observations within a broader Indian evidence base rather than treating HbA1c as an isolated marker.

The distribution of disease in this cohort should not be interpreted as a prevalence estimate. Forty-one of 48 participants had some degree of DR, a proportion far higher than population-based Indian estimates. This difference is readily explained by the clinical composition of the sample and the absence of population-based sampling. The same caution applies to macular oedema, which was present in 37.5% of participants and clustered almost entirely in advanced DR categories. These figures describe this cohort only.

The comorbidity pattern was also highly ordered. Hypertension and dyslipidaemia were absent among participants without DR and became more common with increasing severity. Yet these associations cannot be interpreted independently because age, diabetes duration, HbA1c and BMI were themselves strongly correlated in the sample. With only 48 participants and sparse cells in several severity categories, a multivariable ordinal model would be unstable and potentially misleading. The partial-rank analysis was therefore used only as a limited sensitivity check for the central HbA1c question.

Strengths and Limitations

Strengths include complete participant-level information, internal consistency between recorded DR categories and ETDRS levels, use of an ordered severity scale, and recalculation of all statistics after data-quality checks. The study also evaluates a clinically actionable

exposure, HbA1c, alongside duration of diabetes rather than interpreting glycaemia in isolation.

Several limitations require emphasis. The sample was small and apparently clinic-enriched, limiting generalisability. The cross-sectional design does not establish whether higher HbA1c preceded progression to a more severe retinal grade. The sampling method, HbA1c assay platform, retinal image acquisition method and detailed grading workflow were not available for specification. In addition, age, diabetes duration, HbA1c and BMI were unusually strongly correlated, which increases collinearity and makes independent effect estimation difficult. The very orderly metabolic gradient across DR categories should therefore be confirmed in a larger prospectively characterised cohort before predictive or causal conclusions are drawn.

CONCLUSION

In this cohort of 48 patients with type 2 diabetes mellitus, higher HbA1c levels were strongly associated with increasing ETDRS diabetic retinopathy severity. Diabetes duration showed a similarly strong relationship, and adjustment for duration attenuated, but did not eliminate, the association between HbA1c and retinal grade. The findings reinforce the practical importance of sustained glycaemic control and regular retinal assessment, while also showing that HbA1c should be interpreted together with cumulative diabetes exposure rather than as a stand-alone determinant of retinopathy severity.

Source of Funding

Nil.

Conflict of Interest

None declared.

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