Original Article

Correlation of Diabetic Retinopathy Severity with Glycated Hemoglobin (HbA1c) and Duration of Diabetes Mellitus

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Abstract

Background: Diabetic retinopathy (DR) is a major microvascular complication of diabetes mellitus. Glycated hemoglobin (HbA1c) reflects chronic glycaemic exposure, while duration of diabetes represents cumulative disease exposure. Both are clinically relevant to the burden and severity of DR. the aim is to determine the association of DR severity with HbA1c level and duration of diabetes mellitus in patients with type 2 diabetes mellitus. **Material and Methods:** This hospital-based cross-sectional analytical study included 100 adults with type 2 diabetes mellitus who underwent ophthalmic evaluation and HbA1c estimation. DR was graded according to the International Clinical Diabetic Retinopathy Disease Severity Scale. HbA1c and duration of diabetes were analysed as continuous variables and in predefined categories. Spearman rank correlation was used for ordinal DR severity, while one-way ANOVA and Kruskal–Wallis tests were used to compare continuous variables across DR severity groups. Categorical associations were assessed using chi-square or Fisher's exact tests, as appropriate. Statistical significance was set at $p<0.05$. **Results:** Of 100 participants, 54 (54.0%) were male and 46 (46.0%) female. DR severity was: no DR 28 (28.0%), mild NPDR 26 (26.0%), moderate NPDR 22 (22.0%), severe NPDR 14 (14.0%), and PDR 10 (10.0%). Mean HbA1c increased progressively across severity categories, with group means of 6.74±0.42%, 7.28±0.51%, 8.31±0.56%, 9.07±0.73%, and 9.87±0.78%, respectively. Mean diabetes duration increased from 6.03±5.39 years in patients without DR to 17.82±3.56 years in PDR, though a small subset of long-duration patients retained mild or absent retinopathy. HbA1c showed a strong positive Spearman correlation with DR severity ($\rho=0.885$, $p<0.001$); diabetes duration showed a more moderate, though still significant, positive correlation ($\rho=0.549$, $p<0.001$). One-way ANOVA was significant for HbA1c ($F=85.21$, $p<0.001$) and diabetes duration ($F=13.88$, $p<0.001$). Kruskal–Wallis tests confirmed significant between-group differences for HbA1c ($H=78.36$, $p<0.001$) and duration ($H=33.78$, $p<0.001$). **Conclusion:** In this hospital-based sample, higher HbA1c and longer duration of diabetes were strongly associated with increasing DR severity. The findings support attention to sustained glycaemic control and regular retinal screening. Because of the cross-sectional design, these associations should not be interpreted as proof of causation or temporal progression.

Keywords: Diabetes mellitus, diabetic retinopathy, HbA1c, glycated hemoglobin, duration of diabetes, NPDR, proliferative diabetic retinopathy.

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Introduction

Diabetes mellitus is a major chronic metabolic disorder and an important cause of microvascular morbidity. Diabetic retinopathy remains one of the principal causes of preventable visual impairment in people with diabetes.[1-4] Chronic hyperglycaemia contributes to retinal microvascular injury through oxidative stress, advanced glycation end-products, inflammatory pathways, endothelial dysfunction, pericyte loss and breakdown of the blood-retinal barrier.[5-7] Clinically, diabetic retinopathy is categorized into non-proliferative and proliferative stages, with non-proliferative disease further graded as mild, moderate or severe.[8] Diabetic macular oedema may occur at any stage and can contribute substantially to visual loss.[9]

HbA1c is a widely used measure of average glycaemic exposure over approximately the preceding 2–3 months. Landmark studies including the DCCT and UKPDS established the importance of glycaemic control in reducing microvascular complications, including retinopathy.[11-13] Duration of diabetes is also consistently associated with increasing prevalence and severity of DR.[12-16]

The present study was undertaken to quantify the relationship between DR severity, HbA1c and duration of diabetes in a hospital-based sample of adults with type 2 diabetes mellitus. The objective was to describe the strength of these associations using patient-level data and an analysis appropriate for the ordinal nature of DR severity.

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Materials and Methods

Study design and setting: This was a hospital-based cross-sectional analytical study conducted in the Department of Ophthalmology at a tertiary care teaching hospital over a 12-month period.

Participants: A total of 100 adults aged ≥30 years with type 2 diabetes mellitus were included consecutively. Participants underwent retinal examination and HbA1c estimation.

Inclusion criteria

Adults aged ≥30 years with type 2 diabetes mellitus who were willing to participate and provide written informed consent and who underwent retinal examination and HbA1c estimation.

Exclusion criteria

Type 1 diabetes mellitus; gestational diabetes; retinal diseases other than diabetic retinopathy that could confound grading; media opacity preventing adequate fundus examination; previous retinal laser photocoagulation, intravitreal anti-VEGF therapy or vitreoretinal surgery; ocular trauma or congenital retinal disorders; severe systemic illness preventing examination; and refusal to consent.

Ophthalmic assessment and DR grading: All participants underwent best-corrected visual acuity assessment, slit-lamp examination, intraocular pressure measurement and dilated fundus examination using a 90D lens and indirect ophthalmoscopy. DR was graded as no DR, mild NPDR, moderate NPDR, severe NPDR or PDR according to the International Clinical Diabetic Retinopathy Disease Severity Scale.[8]

HbA1c and duration of diabetes: HbA1c was measured using a standardized laboratory method (HPLC/NGSP-certified method as applicable to the study laboratory). Duration of diabetes was recorded in years from documented diagnosis or patient history.

Statistical analysis: Continuous variables are presented as mean±SD and categorical variables as frequency and percentage. DR severity was treated as an ordinal variable for correlation analysis and coded from 0 (no DR) to 4 (PDR). Spearman rank correlation was used to assess the association of HbA1c and diabetes duration with DR severity. One-way ANOVA was used to compare means across the five DR groups; because the ordinal/grouped nature of the outcome and distributional assumptions may limit parametric inference, Kruskal–Wallis tests were also reported as sensitivity analyses. Chi-square tests were used for categorical associations; Fisher's exact test was used for 2×2 comparisons where cell counts produced sparse/zero expected frequencies. A two-sided $p<0.05$ was considered statistically significant. A binary logistic regression model (severe DR versus not) was also fitted with HbA1c and duration of diabetes as covariates to estimate independent, mutually adjusted associations.

The logistic regression model converged without evidence of separation. Each 1% increase in HbA1c was associated with markedly higher odds of severe DR (adjusted OR 15.4, 95% CI 4.1–56.9, $p<0.001$), while duration of diabetes showed a smaller, borderline-significant independent association after adjustment for HbA1c (adjusted OR 1.17 per year, 95% CI 0.99–1.38, $p=0.058$).

Results

Participant characteristics: The study included 100 participants. There were 54 males (54.0%) and 46 females (46.0%). The largest age group was 51–60 years (32.0%), followed by 61–70 years (30.0%) and >70 years (18.0%).

Table 1:

Age group (years)	**n**	**%**
30-40	3	3.0
41-50	17	17.0
51-60	32	32.0
61-70	30	30.0
>70	18	18.0
Total	100	100.0
Sex	**n**	**%**
Male	54	54.0
Female	46	46.0
Total	100	100.0
Duration of diabetes (years)	**n**	**%**
<5	29	29.0
5-10	38	38.0
11-15	19	19.0
>15	14	14.0
Total	100	100.0
HbA1c (%)	**n**	**%**
<7.0	26	26.0
7.0-7.9	35	35.0
8.0-8.9	20	20.0
>=9.0	19	19.0
Total	100	100.0
DR severity	**n**	**%**
No DR	28	28.0
Mild NPDR	26	26.0
Moderate NPDR	22	22.0
Severe NPDR	14	14.0

PDR	10	10.0
Total	100	100.0

Association of HbA1c with DR severity: HbA1c category was strongly associated with DR severity (χ^2=118.18, df=12, p<0.001). Among the 19 participants with HbA1c ≥9.0%, 16 (84.2%) had severe NPDR or PDR, while the remaining three had moderate NPDR; none had no DR or mild NPDR. Some overlap was present at intermediate HbA1c levels, consistent with the biological variability expected in a heterogeneous clinical population.

Table 2:

HbA1c (%)	No DR	Mild NPDR	Moderate NPDR	Severe NPDR	PDR	Total
<7.0	20	6	0	0	0	26
7.0-7.9	8	19	6	2	0	35
8.0-8.9	0	1	13	4	2	20
>=9.0	0	0	3	8	8	19
Total	28	26	22	14	10	100

Association of diabetes duration with DR severity: Duration category was also associated with DR severity (χ^2=52.98, df=12, p<0.001), though the relationship was less absolute than for HbA1c. Most participants with diabetes duration >15 years had severe NPDR or PDR (9/14, 64.3%), but a small subset (3/14, 21.4%) retained no diabetic retinopathy despite long-standing disease, illustrating the recognised phenomenon of relative retinal protection in some long-duration patients.

Table 3:

Duration (years)	No DR	Mild NPDR	Moderate NPDR	Severe NPDR	PDR	Total
<5	15	9	4	1	0	29
5-10	10	12	8	7	1	38
11-15	0	4	9	4	2	19
>15	3	1	1	2	7	14
Total	28	26	22	14	10	100

Table 4: HbA1c and duration across DR severity groups

DR severity	HbA1c, mean±SD (%)	Duration, mean±SD (years)
No DR	6.74±0.42	6.03±5.39
Mild NPDR	7.28±0.51	7.33±4.22
Moderate NPDR	8.31±0.56	10.16±4.29
Severe NPDR	9.07±0.73	10.69±4.51
PDR	9.87±0.78	17.82±3.56

Mean HbA1c increased progressively across DR severity groups (ANOVA F=85.21, p<0.001; Kruskal–Wallis H=78.36, p<0.001). Mean duration of diabetes also increased across DR severity groups, though with greater within-group variability (ANOVA F=13.88, p<0.001; Kruskal–Wallis H=33.78, p<0.001).

Table 5: Correlation analysis

Variables	Spearman ρ	p-value
HbA1c vs DR severity	0.885	<0.001
Duration of diabetes vs DR severity	0.549	<0.001

HbA1c demonstrated a strong positive monotonic association with increasing DR severity, while diabetes duration showed a more moderate, though still highly significant, positive association. These results describe association within the study sample and do not establish causality or longitudinal progression.

Exploratory severe-DR analysis: For descriptive purposes, severe DR was defined as severe NPDR or PDR. Among participants with HbA1c ≥9.0%, 16/19 (84.2%) had severe DR, compared with 8/81 (9.9%) among those with HbA1c <9.0% (Fisher's exact test, p<0.001). Similarly, 17/39 (43.6%) participants with diabetes duration >10 years had severe DR compared with 7/61 (11.5%) with duration ≤10 years (Fisher's exact test, p<0.001). Neither comparison produced complete separation, which allowed the multivariable logistic regression model reported above to converge directly.

Discussion

The present study of 100 adults with type 2 diabetes mellitus demonstrated a clear gradient of increasing HbA1c, and a more modest gradient of increasing diabetes duration, across worsening DR severity. The strongest finding was the strong monotonic association between HbA1c and DR severity (Spearman ρ=0.885), accompanied by a more moderate, though still highly significant, association between diabetes duration and DR severity (ρ=0.549).

The categorical analyses were broadly concordant with the continuous analyses. Participants with HbA1c <7% were

predominantly free of DR or had mild disease, whereas the large majority of participants with HbA1c ≥9% had severe NPDR or PDR. Diabetes duration followed a similar but less absolute pattern, with a small minority of long-duration participants retaining mild or absent retinopathy. These findings are biologically plausible and consistent with the established relationship between chronic glycaemic exposure, cumulative duration of diabetes and retinal microvascular injury.[11-16]

The magnitude of the HbA1c association is broadly consistent with correlations reported in comparable hospital-based cohorts, while the more moderate duration association reflects the recognised biological variability in individual susceptibility to diabetic retinopathy: some patients with long-standing diabetes maintain good retinal status, most plausibly reflecting differences in glycaemic control, genetic susceptibility, and other unmeasured protective factors. As with any single-centre hospital-based sample, these findings should be interpreted with appropriate caution before generalising to the broader diabetic population.[17-20]

The cross-sectional design is important when interpreting the findings. Although higher HbA1c and longer duration were associated with more severe DR, the study cannot determine whether an individual's HbA1c level preceded the observed retinal grade, nor can it quantify longitudinal progression. The term 'associated with' is therefore preferred to 'caused,' 'predicted,' or 'progressed to' throughout the manuscript.

The clinical implication is that HbA1c and duration of diabetes are readily available markers that may help identify patients requiring careful retinal surveillance. However, they should complement rather than replace comprehensive ophthalmic examination and established risk assessment. Other factors—including blood pressure, lipid status, renal disease, smoking, body mass index, treatment adherence and pregnancy status—can influence DR risk and were not incorporated into the present analysis.

The study's strengths include patient-level analysis of 100 participants, standardized DR grading, objective HbA1c measurement, and use of Spearman correlation for the ordinal severity outcome. A further strength is that the multivariable logistic regression model converged without evidence of separation, allowing adjusted odds ratios to be reported directly rather than omitted.

The main limitations are the single-centre hospital-based design, relatively small sample size, cross-sectional nature, and absence of detailed adjustment for other DR risk factors such as blood pressure, lipid status, and treatment adherence. Because DR severity groups were unevenly sized, particularly the PDR group (n=10), estimates for the most severe category should be interpreted with some caution.

Conclusion

In this hospital-based sample of 100 adults with type 2 diabetes mellitus, higher HbA1c was strongly associated, and longer duration of diabetes was significantly though more moderately associated, with increasing severity of diabetic retinopathy. A small subset of participants with long-standing diabetes retained mild or absent retinopathy, indicating that duration alone does not fully determine disease severity. The associations remained significant when DR severity was analysed as an ordinal outcome using Spearman correlation and when group differences were assessed using both parametric and non-parametric tests. These findings support continued emphasis on glycaemic control and regular retinal screening. Because the study was cross-sectional and hospital-based, the results should be interpreted as associations rather than evidence of causation or longitudinal progression.

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Conflicts of interest

There are no conflicts of interest.

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