Original Article

Association of Glycated Hemoglobin (HbA1c) Levels with Microvascular Complications in Patients with Type 2 Diabetes Mellitus: A Retrospective Observational Study

Kumari Priyanka[1], Manoj Kumar[2], Swati Sharma[1]

[1]Assistant Professor, Department of General Medicine, Rajarshi Dashrath Autonomous State Medical College, Ayodhya, Uttar Pradesh, India. [2]Associate Professor, Department of Physiology, Rajarshi Dashrath Autonomous State Medical College, Ayodhya, Uttar Pradesh, India.

Abstract

Background: Microvascular complications are major causes of morbidity among patients with type 2 diabetes mellitus (T2DM). Glycated hemoglobin (HbA1c) is an important marker of long-term glycemic control. This study aimed to evaluate the association between HbA1c levels and microvascular complications in patients with T2DM. **Material and Methods:** This retrospective observational study included 400 patients with T2DM at a tertiary care hospital in Ayodhya, Uttar Pradesh, during 2025–2026. Demographic characteristics, clinical parameters, HbA1c levels, and documented microvascular complications were evaluated. Patients were categorized into three groups according to HbA1c levels: <7%, 7–8.9%, and ≥9%. Statistical analysis included the Chi-square test and appropriate tests for continuous variables, with $p<0.05$ considered statistically significant. **Results:** The mean age of participants was 55.8 ± 11.6 years, with 58.0% males. The mean HbA1c level was 8.6 ± 1.9%. Overall, 224 patients (56.0%) had at least one microvascular complication. Peripheral neuropathy was observed in 37.0%, nephropathy in 31.0%, and retinopathy in 28.0%. The prevalence of microvascular complications increased significantly across HbA1c categories, from 33.3% among patients with HbA1c <7% to 77.1% among those with HbA1c ≥9% ($p<0.001$). Patients with complications demonstrated significantly higher mean HbA1c levels than those without complications (9.4 ± 1.8% versus 7.6 ± 1.5%; $p<0.001$). Increasing age, longer diabetes duration, higher BMI, hypertension, and dyslipidemia were also significantly associated with microvascular complications. **Conclusion:** Elevated HbA1c levels were associated with a higher prevalence of microvascular complications among patients with T2DM. Regular glycemic monitoring and early identification of complications may help improve long-term diabetes management.

Keywords: Type 2 diabetes mellitus, HbA1c, Glycemic control, Diabetic retinopathy, Diabetic nephropathy, Peripheral neuropathy, Microvascular complications.

Received: 17 October 2026 **Revised: 01 November 2026** **Accepted: 10 November 2026** **Published: 13 November 2026**

Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia, which contributes to progressive microvascular damage. Diabetic retinopathy, nephropathy, and peripheral neuropathy are major complications responsible for considerable morbidity and reduced quality of life. Glycated hemoglobin (HbA1c) is an established indicator of long-term glycemic control, and elevated HbA1c levels have been associated with an increased risk of microvascular complications.[1]

Chronic hyperglycemia promotes endothelial dysfunction, oxidative stress, and advanced glycation end-product formation, resulting in microvascular injury. Recent evidence suggests that both elevated HbA1c levels and long-term glycemic variability contribute to the development and progression of diabetic retinopathy.[2] The American Diabetes Association recommends an HbA1c target below 7% for many nonpregnant adults with diabetes, emphasizing individualized glycemic management to minimize complications.[3]

Diabetic kidney disease is another important consequence of prolonged hyperglycemia, characterized by albuminuria and progressive deterioration of renal function. Effective glycemic management plays a significant role in reducing the risk and progression of diabetic kidney disease.[4] Studies have also demonstrated that early glycemic control may provide long-term protection against microvascular complications, highlighting the importance of timely intervention.[5] Furthermore, the association between HbA1c levels and diabetic complications may vary according to renal function and other clinical characteristics.[6] Therefore, the present study aimed to evaluate the association between HbA1c levels and microvascular complications, including diabetic retinopathy, nephropathy, and peripheral neuropathy, among patients with type 2 diabetes mellitus.

Address for correspondence: Dr. Swati Sharma, Assistant Professor, Department of General Medicine, Rajarshi Dashrath Autonomous State Medical College, Ayodhya, Uttar Pradesh, India
E-mail: dr.swatisharma1289@gmail.com

DOI:
10.21276/amit.2026.v13.i3.1188

How to cite this article: Priyanka K, Kumar M, Sharma S. Association of Glycated Hemoglobin (HbA1c) Levels with Microvascular Complications in Patients with Type 2 Diabetes Mellitus: A Retrospective Observational Study. Acta Med Int. 2026;13(3):1014-1017.

Materials and Methods

Study Design and Setting: This retrospective observational study was designed to evaluate the association between HbA1c levels and microvascular complications among patients with type 2 diabetes mellitus. Medical records of 400 patients were selected for review from a tertiary care hospital in Ayodhya, Uttar Pradesh, India, covering a one-year period during 2025–2026.

Study Population: A total of 400 patients aged ≥18 years with an established diagnosis of type 2 diabetes mellitus and available HbA1c records were included in the study.

Inclusion Criteria

- Patients aged ≥18 years diagnosed with type 2 diabetes mellitus.
- Patients with documented HbA1c measurements.
- Patients with available clinical records regarding microvascular complications.
- Patients receiving regular diabetes-related medical care.

Exclusion Criteria

- Patients with type 1 diabetes mellitus or gestational diabetes.
- Patients with incomplete HbA1c or complication assessment records.
- Patients with documented non-diabetic causes of neuropathy.
- Patients with renal or retinal disorders clearly attributable to causes other than diabetes.

Data Collection: Relevant information was extracted from hospital medical records, including age, sex, duration of diabetes, body mass index (BMI), hypertension, dyslipidemia, antidiabetic treatment, fasting blood glucose, postprandial blood glucose, and HbA1c levels.

Patients were categorized into three groups according to HbA1c levels:

- Group I: HbA1c <7.0% (good glycemic control).
- Group II: HbA1c 7.0–8.9% (suboptimal glycemic control).
- Group III: HbA1c ≥9.0% (poor glycemic control).

The most recent HbA1c measurement within the predefined study period was considered for analysis.

Assessment of Microvascular Complications: The presence of diabetic microvascular complications was assessed using documented clinical findings and available investigations.

Diabetic Retinopathy: Retinopathy was identified from documented ophthalmological examinations, including fundus examination or retinal imaging findings.

Diabetic Nephropathy: Diabetic kidney disease was assessed using documented urinary albumin-to-creatinine ratio (UACR), serum creatinine, estimated glomerular filtration rate (eGFR), and clinical diagnosis. Persistent albuminuria (UACR ≥30 mg/g) and/or sustained eGFR <60 mL/min/1.73 m² supported the diagnosis when attributable to diabetes.

Diabetic Peripheral Neuropathy: Peripheral neuropathy was identified using documented clinical symptoms and examination findings, including vibration perception, pinprick sensation, ankle reflexes, and 10-g monofilament testing, wherever available.

Patients were classified according to the presence or absence of each microvascular complication. Multiple complications in the same patient were recorded separately.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The Chi-square test or Fisher's exact test was used to compare the prevalence of microvascular complications across HbA1c categories. One-way ANOVA or the Kruskal–Wallis test was applied to compare continuous variables among groups, depending on data distribution.

Multivariable logistic regression was used to evaluate the association between HbA1c levels and individual microvascular complications after adjustment for age, sex, duration of diabetes, BMI, hypertension, and dyslipidemia. Adjusted odds ratios with 95% confidence intervals were calculated. A p-value <0.05 was considered statistically significant.

Ethical Considerations: The study protocol was subject to approval by the Institutional Ethics Committee. Patient confidentiality was maintained, and identifying information was excluded from the analytical dataset. Requirements for informed consent or a waiver were determined according to institutional regulations.

Results

Table 1: Demographic and Clinical Characteristics of Study Participants (N=400)

Parameters	Values
Total patients	400
Mean age (years)	55.8 ± 11.6
Male	232 (58.0%)
Female	168 (42.0%)
Mean BMI (kg/m²)	27.6 ± 4.3
Mean duration of diabetes (years)	9.4 ± 5.8
Mean HbA1c (%)	8.6 ± 1.9
Mean fasting blood glucose (mg/dL)	162.8 ± 42.6
Mean postprandial blood glucose (mg/dL)	238.4 ± 58.7
Hypertension	184 (46.0%)
Dyslipidemia	156 (39.0%)
HbA1c <7%	96 (24.0%)
HbA1c 7–8.9%	164 (41.0%)
HbA1c ≥9%	140 (35.0%)
Diabetic retinopathy	112 (28.0%)

Diabetic nephropathy	124 (31.0%)
Diabetic peripheral neuropathy	148 (37.0%)
At least one microvascular complication	224 (56.0%)

The mean age of participants was 55.8 ± 11.6 years, with a male predominance (58.0%). The mean HbA1c level was 8.6 ± 1.9%, indicating suboptimal glycemic control in the population. Peripheral neuropathy was the most frequently observed microvascular complication (37.0%), followed by nephropathy (31.0%) and retinopathy (28.0%).

Table 2: Association Between HbA1c Categories and Microvascular Complications

Parameters	HbA1c <7% (n=96)	HbA1c 7–8.9% (n=164)	HbA1c ≥9% (n=140)	p-value
Mean age (years)	52.4 ± 10.8	55.6 ± 11.2	58.4 ± 12.1	<0.001
Duration of diabetes (years)	6.8 ± 4.3	9.1 ± 5.2	11.6 ± 6.4	<0.001
Diabetic retinopathy	12 (12.5%)	40 (24.4%)	60 (42.9%)	<0.001
Diabetic nephropathy	16 (16.7%)	44 (26.8%)	64 (45.7%)	<0.001
Diabetic peripheral neuropathy	20 (20.8%)	52 (31.7%)	76 (54.3%)	<0.001
At least one microvascular complication	32 (33.3%)	84 (51.2%)	108 (77.1%)	<0.001

The prevalence of all three microvascular complications increased progressively across higher HbA1c categories. Patients with HbA1c ≥9% demonstrated the highest prevalence of retinopathy (42.9%), nephropathy (45.7%), and peripheral neuropathy (54.3%). The association between HbA1c categories and each microvascular complication was statistically significant (p<0.001).

Table 3: Comparison of Clinical and Biochemical Parameters According to Microvascular Complication Status

Parameters	Complications present (n=224)	Complications absent (n=176)	p-value
Mean age (years)	59.2 ± 10.8	51.5 ± 11.2	<0.001
Duration of diabetes (years)	11.8 ± 5.9	6.3 ± 4.2	<0.001
BMI (kg/m²)	28.4 ± 4.5	26.6 ± 3.9	<0.001
HbA1c (%)	9.4 ± 1.8	7.6 ± 1.5	<0.001
Fasting blood glucose (mg/dL)	178.6 ± 44.2	142.7 ± 34.8	<0.001
Postprandial blood glucose (mg/dL)	259.8 ± 61.4	211.2 ± 45.6	<0.001
Hypertension	124 (55.4%)	60 (34.1%)	<0.001
Dyslipidemia	104 (46.4%)	52 (29.5%)	<0.001

Patients with microvascular complications had significantly higher HbA1c levels (9.4 ± 1.8% versus 7.6 ± 1.5%; p<0.001), longer diabetes duration, and higher fasting and postprandial blood glucose levels. Hypertension and dyslipidemia were also more prevalent among patients with complications.

Table 4: Association Between HbA1c Levels and Individual Microvascular Complications

Microvascular complication	Complication present (n)	Mean HbA1c with complication (%)	Mean HbA1c without complication (%)	p-value
Diabetic retinopathy	112	9.8 ± 1.7	8.1 ± 1.6	<0.001
Diabetic nephropathy	124	9.6 ± 1.8	8.2 ± 1.7	<0.001
Diabetic peripheral neuropathy	148	9.5 ± 1.9	8.1 ± 1.6	<0.001
At least one microvascular complication	224	9.4 ± 1.8	7.6 ± 1.5	<0.001

Higher HbA1c levels were significantly associated with the presence of individual microvascular complications. The highest mean HbA1c was observed among patients with diabetic retinopathy (9.8 ± 1.7%), followed by nephropathy (9.6 ± 1.8%) and peripheral neuropathy (9.5 ± 1.9%). All comparisons demonstrated statistical significance (p<0.001).

Discussion

The present retrospective observational study evaluated the association between HbA1c levels and microvascular complications among 400 patients with type 2 diabetes mellitus. The findings demonstrated that 56.0% of patients had at least one microvascular complication, with peripheral neuropathy (37.0%) being the most common, followed by nephropathy (31.0%) and retinopathy (28.0%). The prevalence of complications increased significantly with higher HbA1c levels (p<0.001). These observations support the importance of glycemic control and regular screening for diabetic microvascular complications, as emphasized by the American Diabetes Association.[7]

Diabetic nephropathy was observed in 31.0% of patients, with its prevalence increasing from 16.7% among patients with HbA1c <7% to 45.7% among those with HbA1c ≥9%. This association highlights the relationship between poor glycemic control and renal complications. Current diabetes management guidelines emphasize regular assessment of renal function and albuminuria for the early identification and management of diabetic kidney disease.[8] Similarly, Kunutsor et al,[9] in a systematic review and meta-analysis, examined the effects of intensive glycemic control on microvascular outcomes, supporting the clinical importance of glycemic management in type 2 diabetes.

The present study also demonstrated a significant association between elevated HbA1c levels and diabetic nephropathy. Wang et al,[10] reported that greater HbA1c variability was associated

with an increased risk of renal function decline, suggesting that long-term glycemic fluctuations may contribute to diabetic kidney disease. Sartore et al,[11] in their meta-analysis, identified significant associations between HbA1c variability and diabetic retinopathy and nephropathy, although the pooled association with neuropathy was not statistically significant.

Furthermore, patients with microvascular complications had significantly higher mean HbA1c levels than those without complications (9.4 ± 1.8% versus 7.6 ± 1.5%; p<0.001). Li et al,[12] demonstrated that visit-to-visit HbA1c variability was associated with increased risks of cardiovascular and microvascular complications among patients with newly diagnosed type 2 diabetes. Similarly, Cardoso et al,[13] identified long-term glycemic variability as an important predictor of vascular complications, emphasizing the significance of sustained glycemic management.

In the present study, increasing age, longer diabetes duration, elevated BMI, hypertension, and dyslipidemia were also associated with microvascular complications. These findings suggest that diabetic complications are influenced by multiple clinical and metabolic factors. Guo et al,[14] in their systematic review and meta-analysis, further examined the relationship between HbA1c variability and vascular complications, supporting the importance of comprehensive glycemic assessment.

The major limitations of the study included its retrospective design, reliance on existing medical records, potential selection bias, and the inability to establish causality. Additionally, a single HbA1c measurement may not adequately represent long-term glycemic variability. Nevertheless, the findings highlight the potential clinical value of HbA1c assessment and regular screening for diabetic microvascular complications.

Conclusion

Higher HbA1c levels were significantly associated with an increased prevalence of diabetic retinopathy, nephropathy, and peripheral neuropathy. Patients with poor glycemic control demonstrated a greater burden of microvascular complications, particularly those with longer diabetes duration and associated metabolic risk factors. Regular HbA1c monitoring, individualized glycemic management, and early screening for microvascular complications are essential components of comprehensive diabetes care.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Aldafas R, Vinogradova Y, Crabtree TSJ, Gordon J, Idris I. The long-term impact of early HbA1c control on nephropathy, neuropathy, and retinopathy in type 2 diabetes: findings from a large UK observational study. J Diabetes Complications. 2026;40(5):109292. doi:10.1016/j.jdiacomp.2026.109292.
2. Maiorino MI, Gesualdo C, Angelino S, Rossi S, Di Martino N, Iodice C, et al. HbA1c variability as an independent risk factor for diabetic retinopathy: results from a screening program. Acta Diabetol. 2026;63(8):1395-1402. doi:10.1007/s00592-026-02711-7.
3. American Diabetes Association Professional Practice Committee for Diabetes. 6. Glycemic goals, hypoglycemia, and hyperglycemic crises: Standards of Care in Diabetes—2026. Diabetes Care. 2026;49(Suppl 1):S132-S149. doi:10.2337/dc26-S006.
4. American Diabetes Association Professional Practice Committee for Diabetes. 11. Chronic kidney disease and risk management: Standards of Care in Diabetes—2026. Diabetes Care. 2026;49(Suppl 1):S246-S260. doi:10.2337/dc26-S011.
5. Aldafas R, Vinogradova Y, Crabtree TSJ, Gordon J, Idris I. The legacy effect of early HbA1c control on microvascular complications and hospital admissions in type 2 diabetes: findings from a large UK study. Ther Adv Endocrinol Metab. 2025. doi:10.1177/20420188251350897.
6. Kofod DH, Carlson N, Almdal TP, Bomholt T, Torp-Pedersen C, Nørgaard K, et al. The association between hemoglobin A1c and complications among individuals with diabetes and severe chronic kidney disease. Diabetes Care. 2025;48(8):1400-1409. doi:10.2337/dc25-0339.
7. American Diabetes Association Professional Practice Committee. 12. Retinopathy, neuropathy, and foot care: Standards of Care in Diabetes—2025. Diabetes Care. 2025;48(Suppl 1):S252-S265. doi:10.2337/dc25-S012.
8. American Diabetes Association Professional Practice Committee. 11. Chronic kidney disease and risk management: Standards of Care in Diabetes—2025. Diabetes Care. 2025;48(Suppl 1):S239-S251. doi:10.2337/dc25-S011.
9. Kunutsor SK, Balasubramanian VG, Zaccardi F, Gillies CL, Aroda VR, Seidu S, et al. Glycaemic control and macrovascular and microvascular outcomes: a systematic review and meta-analysis of trials investigating intensive glucose-lowering strategies in people with type 2 diabetes. Diabetes Obes Metab. 2024;26(6):2069-2081. doi:10.1111/dom.15511.
10. Wang S, Song S, Gao J, Duo Y, Gao Y, Fu Y, et al. Glycated haemoglobin variability and risk of renal function decline in type 2 diabetes mellitus: an updated systematic review and meta-analysis. Diabetes Obes Metab. 2024;26(11):5167-5182. doi:10.1111/dom.15861.
11. Sartore G, Ragazzi E, Caprino R, Lapolla A. Long-term HbA1c variability and macro-/micro-vascular complications in type 2 diabetes mellitus: a meta-analysis update. Acta Diabetol. 2023;60(6):721-738. doi:10.1007/s00592-023-02037-8.
12. Li S, Nemeth I, Donnelly L, Hapca S, Zhou K, Pearson ER. Visit-to-visit HbA1c variability is associated with cardiovascular disease and microvascular complications in patients with newly diagnosed type 2 diabetes. Diabetes Care. 2020;43(2):426-432. doi:10.2337/dc19-0823.
13. Cardoso CRL, Leite NC, Moram CBM, Salles GF. Long-term visit-to-visit glycemic variability as predictor of micro- and macrovascular complications in patients with type 2 diabetes: the Rio de Janeiro Type 2 Diabetes Cohort Study. Cardiovasc Diabetol. 2018;17:33. doi:10.1186/s12933-018-0677-0.
14. Guo K, Zhao Q, Wang M, et al. The scope of HbA1c variability and risk of vascular complications among patients with type 2 diabetes: a systematic review and meta-analysis of prospective studies. Horm Metab Res. 2022;54:94-103. doi:10.1055/a-1730-4904.