

CORRELATIONAL EVALUATION OF HBA1C WITH DIABETIC COMPLICATIONS AMONG DIABETICS: AN INSTITUTIONAL BASED STUDY

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ABSTRACT

Background: Diabetes mellitus is a chronic metabolic disorder associated with persistent hyperglycaemia and a wide spectrum of long-term complications affecting multiple organ systems. Glycated hemoglobin (HbA1c) serves as a reliable indicator of long-term glycaemic control and plays a crucial role in predicting the risk of diabetic complications. Understanding the relationship between HbA1c levels and the occurrence of microvascular and macrovascular complications is essential for effective disease management and prevention strategies. **Aim:** To correlational evaluation of HbA1c with diabetic complications among diabetics. **Materials and Methods:** This hospital-based observational analytical study included 125 diagnosed diabetic patients attending the outpatient and inpatient departments of Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India. Detailed clinical history, demographic data, and physical examination findings were recorded using a structured proforma. Biochemical investigations included HbA1c, fasting blood sugar, postprandial blood sugar, serum urea, serum creatinine, and lipid profile. Diabetic complications such as retinopathy, nephropathy, neuropathy, coronary artery disease, cerebrovascular disease, and peripheral vascular disease were assessed clinically and through relevant investigations. **Results:** The majority of patients had poor glycaemic control, with 40.00% having HbA1c levels >9%. Diabetic neuropathy (44.00%) was the most common complication, followed by retinopathy (38.40%) and nephropathy (33.60%). A significant association was observed between higher HbA1c levels and most diabetic complications, particularly retinopathy, nephropathy, neuropathy, coronary artery disease, and peripheral vascular disease ($p < 0.05$). HbA1c also showed a strong positive correlation with fasting and postprandial blood glucose levels, serum creatinine, and lipid parameters, while a negative correlation was observed with HDL cholesterol. **Conclusion:** Elevated HbA1c levels are significantly associated with increased risk of diabetic complications and adverse biochemical profiles. HbA1c can be considered a valuable predictor of disease severity and complication burden. Effective glycaemic control may help in reducing the progression of diabetes-related complications.

INTRODUCTION

Diabetes mellitus is one of the most important chronic metabolic disorders worldwide and continues to impose a major clinical, social, and economic burden. The disease is characterized by persistent hyperglycaemia resulting from defects in insulin secretion, insulin action, or both, and over time it affects multiple organ systems. The current global burden of diabetes remains high, with continuing

growth in the number of affected adults, making it a major public health challenge. Beyond its prevalence, the real concern lies in its chronic, progressive, and multisystem nature, because prolonged exposure to hyperglycaemia predisposes individuals to vascular, neurologic, renal, retinal, and cardiovascular damage.^[1]

Among the biochemical tools available for monitoring long-term glycaemic status, glycated hemoglobin (HbA1c) has a central place in diabetes

care. HbA1c reflects the average blood glucose level over the preceding two to three months and is widely used for diagnosis, therapeutic monitoring, and assessment of metabolic control. It is convenient, standardized, and clinically meaningful because it provides an integrated estimate of chronic glycaemic exposure rather than a single time-point glucose value. At the same time, HbA1c is not entirely free from limitations, as its interpretation may be influenced by factors such as anemia, hemoglobinopathies, altered erythrocyte turnover, renal impairment, and certain clinical states.^[2,3]

The importance of HbA1c extends beyond simple assessment of glucose control. Chronic hyperglycaemia promotes nonenzymatic glycation of proteins, oxidative stress, endothelial dysfunction, inflammation, and activation of several metabolic pathways that ultimately damage both small and large blood vessels. Through these mechanisms, diabetes may lead to microvascular complications such as retinopathy, nephropathy, and neuropathy, as well as macrovascular complications including coronary artery disease, cerebrovascular disease, and peripheral vascular disease. Thus, HbA1c is not only a marker of glycaemic exposure but also a clinically relevant biochemical indicator that may parallel the burden of diabetic complications.^[4] Glycaemic control remains one of the major therapeutic goals in diabetes management, and modern recommendations continue to emphasize individualized HbA1c targets. For many nonpregnant adults, an HbA1c target of less than 7% remains an appropriate goal, although more or less stringent targets may be considered depending on age, comorbidities, duration of disease, risk of hypoglycaemia, and life expectancy. Because HbA1c represents long-term metabolic control, persistently elevated levels often indicate inadequate control and a greater probability of tissue injury. Therefore, assessment of HbA1c in relation to clinical complications has considerable value in identifying patients at higher risk and in guiding treatment intensification. Macrovascular disease constitutes a major cause of morbidity and mortality among diabetic patients. Chronic hyperglycaemia accelerates atherosclerosis and interacts with hypertension, dyslipidemia, obesity, inflammation, and insulin resistance to worsen cardiovascular risk. In patients with diabetes, coronary artery disease, stroke, and peripheral arterial disease frequently coexist and contribute substantially to disability and premature death. Because cardiovascular involvement often develops silently over years, biochemical markers that reflect long-term glycaemic burden are especially relevant in risk stratification. The relationship between HbA1c and macrovascular outcomes therefore remains an important area of study in tertiary care populations where multiple risk factors often cluster together.^[5]

Microvascular complications are equally important because they directly affect quality of life and functional independence. Diabetic retinopathy remains a leading cause of preventable vision loss,

diabetic kidney disease is a major contributor to chronic kidney disease and renal failure, and diabetic neuropathy predisposes patients to pain, sensory loss, foot ulceration, and amputation. Contemporary standards recommend regular screening for albuminuria, estimated glomerular filtration rate, retinal disease, peripheral neuropathy, and foot problems in patients with diabetes. Since hyperglycaemia is a fundamental pathogenic driver of these complications, studying HbA1c in relation to them is clinically meaningful and may help clarify how strongly long-term glycaemic exposure aligns with organ damage in routine hospital practice.^[6]

MATERIALS AND METHODS

This hospital-based observational analytical study was conducted among 125 diagnosed diabetic patients attending the outpatient and inpatient departments of Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India.

The study population included adult male and female patients with established diabetes mellitus who were evaluated for the correlation of glycated hemoglobin (HbA1c) with various diabetic complications. Patients who were willing to participate and gave informed consent were included in the study. Subjects with serious acute illness, pregnancy, hemoglobinopathies, recent blood transfusion, chronic liver disease, or other conditions known to interfere with HbA1c estimation were excluded from the study.

A detailed clinical evaluation was carried out in all enrolled subjects using a predesigned and structured proforma. Information regarding age, sex, duration of diabetes, family history of diabetes, treatment history, body mass index (BMI), blood pressure, lifestyle factors, and history suggestive of diabetic complications was recorded. A thorough general physical examination and systemic examination were performed. Particular attention was given to symptoms and signs suggestive of microvascular and macrovascular complications, including diabetic retinopathy, nephropathy, neuropathy, ischemic heart disease, cerebrovascular disease, and peripheral vascular disease.

For biochemical assessment, venous blood samples were collected under aseptic precautions. HbA1c was estimated using a standardized laboratory method aligned with accepted quality control procedures. In addition to HbA1c, relevant biochemical parameters were assessed to provide a comprehensive metabolic profile. These included fasting blood sugar (FBS), postprandial blood sugar (PPBS), serum urea, serum creatinine, lipid profile [total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), very low-density lipoprotein (VLDL)], and urine albumin/protein assessment. Renal involvement was evaluated using serum creatinine and urinary protein parameters, while dyslipidemia was assessed through the lipid

profile. These investigations were performed in the central biochemistry laboratory of the hospital using standard operating procedures and internal quality control measures.

Assessment of diabetic complications was done based on clinical examination and relevant supportive investigations from patient records and hospital evaluation. Diabetic retinopathy was identified from ophthalmologic examination/fundus evaluation findings. Diabetic nephropathy was assessed using urinary albumin/protein status and renal function parameters. Diabetic neuropathy was evaluated clinically by symptoms such as numbness, tingling, burning sensation, and impaired peripheral sensation on examination. Macrovascular complications such as coronary artery disease, cerebrovascular accident, and peripheral vascular disease were identified based on documented clinical history, examination findings, and available relevant investigations. The primary variable of interest in the study was HbA1c, and its correlation with the presence and pattern of diabetic complications was analyzed. Patients were also evaluated with respect to glycaemic status and associated biochemical derangements. The relationship between poor glycaemic control and occurrence of complications was examined to determine the biochemical significance of HbA1c as an indicator of diabetic burden and end-organ involvement.

The collected data were entered in Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 27.0. Continuous variables were expressed as mean \pm standard deviation, and categorical variables were presented as frequency and percentage. The association between HbA1c levels and diabetic complications was assessed using appropriate statistical tests such as the independent t-test, chi-square test, and Pearson's correlation coefficient wherever applicable. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The present study included a total of 125 diabetic patients, and their demographic and clinical characteristics are summarized in Table 1. The majority of the study population belonged to the 40–60 years age group (53.60%), followed by those aged >60 years (32.00%), while only 14.40% were below 40 years of age. This indicates that diabetes was more prevalent among middle-aged and elderly individuals in the study population. In terms of gender distribution, males (57.60%) outnumbered females (42.40%), suggesting a slightly higher burden of diabetes among male subjects in this cohort. Regarding the duration of diabetes, the largest proportion of patients had a disease duration of 5–10 years (40.80%), followed by those with more than 10 years (32.00%) and less than 5 years (27.20%). This reflects that a significant number of patients had longstanding diabetes, which is an important factor in the development of complications. Assessment of

nutritional status revealed that 48.80% of patients were overweight and 28.00% were obese, while only 23.20% had a normal BMI, highlighting the strong association between increased body weight and diabetes. Additionally, 60.80% of patients had coexisting hypertension, indicating a high prevalence of cardiovascular risk factors among the study population.

The distribution of patients according to glycaemic control, as assessed by HbA1c levels (Table 2), showed that a substantial proportion of patients had poor glycaemic control. Only 22.40% of patients had HbA1c levels below 7%, indicating good control, while 37.60% had moderate control (HbA1c 7–9%). Notably, the largest group, comprising 40.00% of patients, had HbA1c levels greater than 9%, reflecting poor glycaemic control.

The prevalence of diabetic complications among the study subjects is presented in Table 3. Among microvascular complications, diabetic neuropathy was the most common (44.00%), followed by diabetic retinopathy (38.40%) and diabetic nephropathy (33.60%). This indicates that nerve involvement was the predominant complication in this cohort. Among macrovascular complications, coronary artery disease (28.80%) was the most frequently observed, followed by peripheral vascular disease (16.80%) and cerebrovascular disease (11.20%).

Table 4 demonstrates the association between HbA1c levels and diabetic complications. A clear increasing trend in the prevalence of complications was observed with rising HbA1c levels. For diabetic retinopathy, the prevalence increased from 14.29% in patients with HbA1c <7% to 56.00% in those with HbA1c >9%, and this association was statistically significant ($p = 0.001$). Similarly, diabetic nephropathy showed a significant increase from 10.71% in the good control group to 50.00% in the poor control group ($p = 0.002$). Diabetic neuropathy also demonstrated a significant rise with increasing HbA1c levels, from 21.43% to 58.00% ($p = 0.003$). Among macrovascular complications, coronary artery disease showed a statistically significant association with HbA1c levels ($p = 0.045$), with prevalence increasing across the categories. Peripheral vascular disease also showed a significant association ($p = 0.039$). However, although cerebrovascular disease showed an increasing trend with higher HbA1c levels, the association was not statistically significant ($p = 0.081$).

The correlation between HbA1c and various biochemical parameters is presented in Table 5. HbA1c showed a strong positive correlation with fasting blood sugar ($r = 0.68$, $p < 0.001$) and postprandial blood sugar ($r = 0.72$, $p < 0.001$), indicating that higher HbA1c levels are closely associated with elevated blood glucose levels. A moderate positive correlation was observed with serum creatinine ($r = 0.51$, $p < 0.001$), suggesting a relationship between poor glycaemic control and declining renal function. HbA1c also showed

significant positive correlations with lipid parameters, including total cholesterol ($r = 0.46$, $p = 0.002$), triglycerides ($r = 0.49$, $p = 0.001$), and LDL cholesterol ($r = 0.44$, $p = 0.002$). In contrast, a

significant negative correlation was observed with HDL cholesterol ($r = -0.41$, $p = 0.003$), indicating that higher HbA1c levels are associated with lower protective HDL levels.

Table 1: Distribution of Study Population According to Demographic and Clinical Characteristics (n = 125)

| Variable | Category | Frequency (n) | Percentage (%) |
|--------------------------|------------|---------------|----------------|
| Age (years) | <40 | 18 | 14.40 |
| | 40–60 | 67 | 53.60 |
| | >60 | 40 | 32.00 |
| Gender | Male | 72 | 57.60 |
| | Female | 53 | 42.40 |
| Duration of Diabetes | <5 years | 34 | 27.20 |
| | 5–10 years | 51 | 40.80 |
| | >10 years | 40 | 32.00 |
| BMI (kg/m ²) | Normal | 29 | 23.20 |
| | Overweight | 61 | 48.80 |
| | Obese | 35 | 28.00 |
| Hypertension | Present | 76 | 60.80 |
| | Absent | 49 | 39.20 |

Table 2: Distribution of Patients According to HbA1c Levels (n = 125)

| HbA1c Category | Frequency (n) | Percentage (%) |
|-------------------------|---------------|----------------|
| <7% (Good control) | 28 | 22.40 |
| 7–9% (Moderate control) | 47 | 37.60 |
| >9% (Poor control) | 50 | 40.00 |

Table 3: Prevalence of Diabetic Complications Among Study Subjects (n = 125)

| Complication | Present (n) | Percentage (%) |
|-----------------------------|-------------|----------------|
| Diabetic Retinopathy | 48 | 38.40 |
| Diabetic Nephropathy | 42 | 33.60 |
| Diabetic Neuropathy | 55 | 44.00 |
| Coronary Artery Disease | 36 | 28.80 |
| Cerebrovascular Disease | 14 | 11.20 |
| Peripheral Vascular Disease | 21 | 16.80 |

Table 4: Association Between HbA1c Levels and Diabetic Complications

| Complication | HbA1c <7% (n=28) | HbA1c 7–9% (n=47) | HbA1c >9% (n=50) | p-value |
|--------------|------------------|-------------------|------------------|---------|
| Retinopathy | 4 (14.29%) | 16 (34.04%) | 28 (56.00%) | 0.001* |
| Nephropathy | 3 (10.71%) | 14 (29.79%) | 25 (50.00%) | 0.002* |
| Neuropathy | 6 (21.43%) | 20 (42.55%) | 29 (58.00%) | 0.003* |
| CAD | 5 (17.86%) | 12 (25.53%) | 19 (38.00%) | 0.045* |
| CVD | 1 (3.57%) | 5 (10.64%) | 8 (16.00%) | 0.081 |
| PVD | 2 (7.14%) | 7 (14.89%) | 12 (24.00%) | 0.039* |

(*Statistically significant)

Table 5: Correlation of HbA1c with Biochemical Parameters

| Parameter | Mean ± SD | Correlation Coefficient (r) with HbA1c | p-value |
|----------------------------------|----------------|--|---------|
| Fasting Blood Sugar (mg/dL) | 168.42 ± 42.15 | 0.68 | <0.001* |
| Postprandial Blood Sugar (mg/dL) | 242.36 ± 58.27 | 0.72 | <0.001* |
| Serum Creatinine (mg/dL) | 1.34 ± 0.48 | 0.51 | <0.001* |
| Total Cholesterol (mg/dL) | 212.55 ± 36.18 | 0.46 | 0.002* |
| Triglycerides (mg/dL) | 189.62 ± 44.73 | 0.49 | 0.001* |
| HDL (mg/dL) | 38.44 ± 6.52 | -0.41 | 0.003* |
| LDL (mg/dL) | 132.27 ± 28.11 | 0.44 | 0.002* |

(*Statistically significant)

DISCUSSION

In the present study, most patients were middle-aged or elderly, with 53.60% in the 40–60 year group and 32.00% above 60 years; males constituted 57.60% of cases. In addition, 40.80% had diabetes for 5–10 years, 32.00% had disease duration beyond 10 years, 48.80% were overweight, 28.00% were obese, and 60.80% had hypertension. These findings indicate that the study population carried a substantial burden of established cardiometabolic risk. A broadly

comparable pattern was reported by Arambewela et al. (2018), where overweight/obesity was present in 80.00% and hypertension in 77.60% of patients attending a tertiary diabetic clinic, with age and duration emerging as major determinants of chronic complications. Compared with that report, our study showed a slightly lower burden of excess body weight and hypertension, but the same overall trend that longer-standing diabetes clusters with other vascular risk factors.^[7] With regard to glycaemic control, only 22.40% of our patients had HbA1c

<7%, whereas 37.60% had HbA1c 7–9% and as many as 40.00% had HbA1c >9%, showing that poor glycaemic control predominated. This observation is in line with the TEMD study by Sonmez et al. (2018), in which glycaemic control was achieved in only 40.20% of patients with type 2 diabetes and the mean HbA1c was $7.7 \pm 1.7\%$. Our proportion with good control was even lower, suggesting that the study population in the present hospital-based series may have represented a more metabolically uncontrolled group, which could partly explain the higher complication burden observed in subsequent tables.^[8] The prevalence pattern of diabetic complications in our study showed that neuropathy was the commonest complication (44.00%), followed by retinopathy (38.40%) and nephropathy (33.60%) among microvascular lesions, while coronary artery disease was the leading macrovascular complication (28.80%), followed by peripheral vascular disease (16.80%) and cerebrovascular disease (11.20%). These rates are higher than those reported by Dias et al. (2016) from a tertiary care registry, where retinopathy, nephropathy, and neuropathy were each around 16% to 17%, and CAD, stroke, and PVD were 21.30%, 6.60%, and 6.70%, respectively. The greater frequencies in our series may reflect poorer glycaemic control, a higher proportion of overweight patients, and a larger share of subjects with longer diabetes duration. Nevertheless, both studies agree that chronic diabetic complications are common in tertiary-care populations and increase with advancing age and duration of disease.^[9] The association between HbA1c and retinopathy in our study was particularly striking: retinopathy increased from 14.29% in patients with HbA1c <7% to 34.04% in those with HbA1c 7–9%, reaching 56.00% in subjects with HbA1c >9% ($p=0.001$). This supports the concept that worsening glycaemic exposure contributes directly to retinal microvascular damage. A similar relationship was documented by Almutairi et al. (2021), who found diabetic retinopathy in 26.90% of diabetic patients and showed a significant association between DR and HbA1c ($p=0.040$), with duration of diabetes also remaining significant ($p=0.001$). Our study demonstrated a stronger gradient across HbA1c categories, which may be because we analyzed complications across clearly stratified glycaemic groups rather than only overall prevalence.^[10] Nephropathy in the present study also rose markedly with poor glycaemic control, from 10.71% in the HbA1c <7% group to 29.79% in the HbA1c 7–9% group and 50.00% in the HbA1c >9% group ($p=0.002$). This finding is biologically plausible and consistent with intervention evidence. In the ADVANCE trial, Patel et al. (2008) showed that intensive glucose control reduced the incidence of nephropathy to 4.10% compared with 5.20% in the standard-control group, with a 21% relative reduction in nephropathy. Although the ADVANCE population and design differed from our cross-sectional hospital study, the direction of effect is the same: better glycaemic control is associated with less renal

involvement. The stronger difference seen in our data across HbA1c bands may reflect cumulative long-term uncontrolled diabetes rather than short-term treatment separation alone.^[11] Neuropathy was the most frequent microvascular complication in our study, affecting 44.00% overall, and it increased from 21.43% in the good-control group to 42.55% in the moderate-control group and 58.00% in the poor-control group ($p=0.003$). This supports a close relationship between chronic hyperglycaemia and neural injury. D'Souza et al. (2015) reported diabetic peripheral neuropathy prevalences of 18.30% by history and 32.20% by examination among tertiary-care patients, and identified male sex, smoking, and age >40 years as important determinants. Our prevalence was higher than their examination-based estimate, possibly because our sample included a considerable proportion of older subjects, overweight/obese individuals, hypertensives, and patients with suboptimal HbA1c, all of which may amplify neuropathic burden.^[12] Macrovascular complications in our study also tended to increase with worsening HbA1c. Coronary artery disease rose from 17.86% in the HbA1c <7% group to 38.00% in the HbA1c >9% group ($p=0.045$), and peripheral vascular disease increased from 7.14% to 24.00% ($p=0.039$), whereas cerebrovascular disease rose from 3.57% to 16.00% but did not reach statistical significance ($p=0.081$). This pattern is comparable with the UKPDS 35 findings reported by Stratton et al. (2000), where each 1% reduction in mean HbA1c was associated with a 14% reduction in myocardial infarction risk and a 37% reduction in microvascular complications. Our failure to show statistical significance for cerebrovascular disease may be related to the relatively small number of stroke events in a sample of 125 patients, whereas the broader macrovascular trend still supports the role of chronic hyperglycaemia in vascular injury.^[13] The present study showed a strong positive correlation of HbA1c with fasting blood sugar ($r=0.68$, $p<0.001$) and an even stronger correlation with postprandial blood sugar ($r=0.72$, $p<0.001$). These findings suggest that both fasting and postprandial hyperglycaemia contribute importantly to long-term glycaemic exposure in our patients. Monnier et al. (2003) demonstrated that the relative contribution of postprandial glucose was highest in lower HbA1c ranges, falling from 69.70% in the lowest HbA1c quintile to 30.50% in the highest quintile, while the contribution of fasting glucose rose from 30.30% to 69.50% as HbA1c worsened. Our results fit well with this model, as HbA1c in our cohort tracked strongly with both fasting and postprandial glucose, indicating that day-to-day glycaemic excursions as well as basal hyperglycaemia are relevant in poorly controlled diabetes.^[14] HbA1c in our study also correlated significantly with biochemical markers of renal dysfunction and dyslipidemia: serum creatinine showed a moderate positive correlation ($r=0.51$, $p<0.001$), while total cholesterol ($r=0.46$, $p=0.002$), triglycerides ($r=0.49$, $p=0.001$), and LDL ($r=0.44$,

p=0.002) correlated positively; HDL correlated negatively ($r=-0.41$, $p=0.003$). These findings indicate that poor glycaemic control coexists with an atherogenic lipid pattern and worsening renal status. Comparable results were reported by Hussain et al. (2017), who found significant positive correlations of HbA1c with total cholesterol, triglycerides, LDL-C, and LDL-C/HDL-C ratio, while the relationship with HDL-C was negative. Their study also showed that patients with HbA1c >7.0% had significantly higher cholesterol and LDL-C values than those with HbA1c ≤7.0%. Thus, our biochemical data reinforce the value of HbA1c not only as a marker of glycaemic control but also as an indicator of broader metabolic and vascular risk.^[15]

CONCLUSION

The present study demonstrates that poor glycaemic control, as reflected by elevated HbA1c levels, is strongly associated with an increased prevalence of both microvascular and macrovascular diabetic complications. A significant correlation was observed between HbA1c and various biochemical parameters, including blood glucose levels, renal function, and lipid profile. These findings highlight the importance of HbA1c as a reliable indicator of long-term glycaemic status and complication risk. Early detection and effective control of HbA1c may play a crucial role in preventing or delaying the progression of diabetic complications.

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