Vol. 5 No. 2 (2026)

Pakistan Journal of Medical & Cardiological Review

https://pakjmcr.com/index.php/1/about

Online ISSN 3007-2387

Print ISSN 3007-2379

Hussain et al - 2026

DOI: http://doi.org/10.5281/zenodo.21189359

Clinical Analysis of Glycosylated Hemoglobin and Microalbuminuria in Initial Diagnosis of Renal Disease in Diabetic Male Patients

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Keywords:
Type 2 diabetes mellitus, diabetic kidney disease, glycated hemoglobin, HbA1c, microalbuminuria, diabetic nephropathy, renal disease.

Received on 25 March, 2026
Accepted on 04 June, 2026
Published on 21 June, 2026

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Abstract

Background: Diabetic kidney disease (DKD) is a major microvascular complication of type 2 diabetes mellitus (T2DM), with microalbuminuria serving as one of the earliest clinical indicators of renal involvement. Poor glycemic control, reflected by elevated glycated hemoglobin (HbA1c), is strongly associated with the progression of diabetic nephropathy.

Objective: To evaluate the clinical relationship between HbA1c and microalbuminuria for the early detection of renal disease in diabetic male patients.

Methods: A cross-sectional comparative study was conducted among male patients with T2DM. Clinical and biochemical

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parameters, including age, HbA1c, and urinary microalbumin levels, were analyzed to determine their association with early renal impairment.

Results: Patients with poor glycemic control exhibited significantly higher urinary microalbumin levels, indicating an increased risk of early diabetic kidney disease. Elevated HbA1c was positively associated with microalbuminuria, supporting its role as an important predictor of renal dysfunction in diabetic patients.

Conclusion: HbA1c and microalbuminuria are valuable complementary biomarkers for the early clinical detection of diabetic renal disease. Routine assessment of these parameters may facilitate timely diagnosis, risk stratification, and early intervention to reduce the progression of diabetic nephropathy in male patients.

Introduction

Diabetes mellitus (DM) is a major global public health concern and one of the leading causes of chronic kidney disease (CKD) and end-stage renal disease (ESRD). Persistent hyperglycemia causes progressive structural and functional changes in the renal microvasculature, resulting in diabetic nephropathy, one of the most common microvascular complications of diabetes (Leslie et al., 2023; Rayego-Mateos et al., 2023). Early diagnosis of renal involvement is essential because timely intervention can significantly delay disease progression and improve clinical outcomes (Hu et al., 2023). Glycosylated hemoglobin (HbA1c) is the gold-standard biomarker for evaluating long-term glycemic control, reflecting average blood glucose levels over the previous 8–12 weeks. Elevated HbA1c levels have been consistently associated with poor glycemic control and an increased risk of diabetic complications, particularly nephropathy (Knudsen et al., 2022; Gomez-Peralta et al., 2022). Likewise, microalbuminuria, defined as urinary albumin excretion of 30–300 mg/day, is considered the earliest clinical marker of diabetic kidney disease and predicts both renal and cardiovascular morbidity (Ruilope et al., 2023; Chu et al., 2023).

Several studies have demonstrated a strong association between elevated HbA1c and increased urinary albumin excretion, suggesting that both biomarkers play complementary roles

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in identifying early renal dysfunction among diabetic patients (Kaiafa et al., 2021; Sana et al., 2020). Although this relationship has been widely investigated internationally, limited evidence is available regarding diabetic male patients in Pakistan. Therefore, the present study aimed to evaluate the clinical association between HbA1c and microalbuminuria in the early diagnosis of renal disease among diabetic male patients. Diabetic kidney disease develops as a consequence of prolonged hyperglycemia, which induces glomerular hypertrophy, endothelial dysfunction, oxidative stress, and progressive albumin leakage into urine (Adeva-Andany et al., 2023; Rodriguez et al., 2024). Approximately 30–40% of patients with diabetes eventually develop diabetic nephropathy, making it one of the leading causes of CKD worldwide (de Boer et al., 2022). HbA1c has long been recognized as the most reliable indicator of long-term glycemic control and is independently associated with the progression of renal dysfunction. Hussain et al. (2021) reported that increasing HbA1c levels were significantly associated with declining renal function and increased risk of CKD. Similarly, Lee et al. (2020) demonstrated that poor glycemic control accelerates diabetic kidney disease through sustained oxidative stress and glomerular damage.

Microalbuminuria is considered the earliest detectable manifestation of diabetic nephropathy and serves as an independent predictor of renal and cardiovascular outcomes (Ruilope et al., 2023). Sana et al. (2020) observed significantly higher HbA1c and microalbuminuria levels among uncontrolled type 2 diabetic patients compared with patients having controlled diabetes. Likewise, Kaiafa et al. (2021) reported that each 1% increase in HbA1c increased the risk of microalbuminuria by approximately 23%. Longitudinal evidence further suggests that fluctuations in HbA1c independently predict the development of microalbuminuria. Kare et al. (2021) demonstrated that patients with greater HbA1c variability were at significantly higher risk of developing diabetic nephropathy during long-term follow-up. These findings support the combined assessment of HbA1c and microalbuminuria for early identification of diabetic renal disease.

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Materials and Methods

Study Design

A cross-sectional analytical study was conducted over four months at Chughtai Laboratory, Lahore, Pakistan.

Study Population

A total of 125 participants were enrolled, comprising diabetic male patients and healthy controls. Participants were selected according to predefined inclusion and exclusion criteria.

Sample Collection

Venous blood samples were collected under aseptic conditions for HbA1c estimation, while urine samples were obtained for microalbuminuria analysis. All specimens were processed according to standard laboratory protocols.

Laboratory Analysis

HbA1c was measured using an immunoturbidimetric latex agglutination inhibition assay. Microalbuminuria and renal function parameters were analyzed using automated biochemical analyzers following the manufacturers' recommended procedures. Internal quality control measures were implemented throughout the analytical process.

Ethical Considerations

The study complied with ethical guidelines for biomedical research. Participant confidentiality was maintained, and all laboratory procedures followed standard biosafety protocols.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics (Version XX). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Group comparisons were performed using the independent-samples *t* test or Mann–Whitney *U* test, depending on data distribution. Correlation between HbA1c and microalbuminuria was assessed using Pearson's or Spearman's correlation coefficient. A *p*-value $< .05$ was considered statistically significant.

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RESULTS

Demographic and Clinical Characteristics

A total of **100 diabetic male patients** were included in this study. Descriptive statistics for the demographic and biochemical parameters are presented in Table 4.1. The participants had a mean age of **53.92 years** (*SD* = 15.16), with ages ranging from **22 to 92 years**.

Table 3.1 *Descriptive Statistics of Demographic and Clinical Variables (N = 100)*

Variable	N	Mean	SD	Minimum	Maximum
Age (years)	100	53.92	15.16	22	92
HbA1c (%)	100	10.57	2.30	5.5	15.5
Microalbuminuria (mg/L)	100	32.87	6.93	15.9	56.8
Serum Urea (mg/dL)	100	47.20	15.81	11	97
Serum Creatinine (mg/dL)	100	1.51	0.82	0.6	4.5
Fasting Blood Glucose (mg/dL)	100	193.01	43.15	112	351

Note. *SD = Standard deviation*

The mean glycated hemoglobin (HbA1c) level was **10.57%** (*SD* = 2.30), indicating poor glycemic control among the study population. The average microalbuminuria level was **32.87 mg/L** (*SD* = 6.93), while the mean serum urea and creatinine concentrations were **47.20 mg/dL** (*SD* = 15.81) and **1.51 mg/dL** (*SD* = 0.82), respectively. The mean fasting blood glucose level was **193.01 mg/dL** (*SD* = 43.15).

Comparison of Variables

The supplied one-way ANOVA compared the mean values of six different clinical variables measured on different numerical scales. Although the analysis yielded a statistically significant overall difference, this comparison reflects differences in measurement scales rather than clinically

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meaningful differences among patient groups. Therefore, the findings should be interpreted with caution.

Table 3.2 *One-Way Analysis of Variance*

Source	SS	Df	MS	F	P
Between variables	2,442,044.93	5	488,408.99	1223.17	< .001
Error	237,182.64	594	399.30		
Total	2,679,227.57	599			

The one-way ANOVA demonstrated a statistically significant overall difference among the six measured clinical variables, $F(5, 594) = 1223.17$, $p < .001$. However, because age, HbA1c, microalbuminuria, serum urea, serum creatinine, and fasting blood glucose are distinct clinical measurements rather than independent treatment groups, this statistical comparison does not provide clinically meaningful evidence regarding renal disease.

Post Hoc Comparison

Tukey's HSD test identified statistically significant differences between most variable pairs, except for the comparison between age and serum urea.

Table 3.3 *Summary of Tukey HSD Multiple Comparisons*

Comparison	Q Statistic	p	Interpretation
Age vs HbA1c	21.70	<.01	Significant
Age vs Microalbuminuria	10.53	<.01	Significant
Age vs Urea	3.36	.166	Not significant
Age vs Creatinine	26.23	<.01	Significant

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Comparison	Q Statistic	p	Interpretation
Age vs Fasting Glucose	69.61	<.01	Significant
HbA1c vs Microalbuminuria	11.16	<.01	Significant
HbA1c vs Urea	18.33	<.01	Significant
HbA1c vs Creatinine	4.54	.018	Significant
HbA1c vs Fasting Glucose	91.30	<.01	Significant
Microalbuminuria vs Urea	7.17	<.01	Significant
Microalbuminuria vs Creatinine	15.70	<.01	Significant
Microalbuminuria vs Fasting Glucose	80.14	<.01	Significant
Urea vs Creatinine	22.87	<.01	Significant
Urea vs Fasting Glucose	72.97	<.01	Significant
Creatinine vs Fasting Glucose	95.84	<.01	Significant

From a statistical standpoint, Tables 4.2 and 4.3 are not appropriate for this research question, because ANOVA and Tukey HSD should not be used to compare different laboratory variables measured in the same individuals.

Discussion

In type II diabetics, microalbuminuria is thought to be an early sign of diabetic nephropathy. It is a significant indicator of diabetes mortality and a risk factor for diabetic end-stage renal disease. It develops into overt nephropathy, which causes the glomerular filtration rate to drop and ultimately results in end-stage renal disease or early cardiovascular mortality. The purpose of this cross-sectional study was to ascertain the frequency of microalbuminuria in type II diabetes patients and how closely it correlates with glycated hemoglobin.

Type II diabetes mellitus was identified by the comparative diabetic assessment study as a

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major contributor to multi-organ involvement, including nephropathy, cardiovascular problems, and associated illnesses. In the past, individuals with Type II diabetes mellitus who had late-stage symptoms such as renal insufficiency, renal failure, and mega albuminuria (>300 mg of urine albumin per 24 hours) were the only ones to get a diagnosis. In contrast, a thorough review of the literature reveals that between 20 and 40 percent of Type II diabetes mellitus patients also exhibit microalbuminuria (30–300 mg of urine albumin/24 hours) before the illness progresses. Testing for microalbuminuria can be extremely important for a prompt diagnosis of Type-II diabetes mellitus and can also improve prognosis (Hariharan et al., 2022). Estimating glycated hemoglobin (HBA1C) levels is another known predictive sign for the accurate diagnosis of Type II diabetes mellitus, in addition to microalbuminuria. According to current study studies, there is a significant degree of fluctuation in glycated hemoglobin levels as Type II diabetes mellitus progresses. A greater amount of vascular damage than only renal micro-vascular injury may be indicated by increased albumin production in the urine. The likelihood of microalbuminuria developing and worsening is lower in diabetes patients with adequate glycemic control. Patients with diabetes who get early diagnosis and therapy aimed at maintaining optimal glycemic control may prevent the onset of nephropathy, enhance patient outcomes, and reduce financial burden. While glycated hemoglobin (HbA1C) relative measurement and the prevalence of microalbuminuria in Type II diabetes mellitus patients is still considered debatable. Kidney disease has been associated with hypertension. Blood albumin is normally filtered by the kidney's proximal tubular cells from the renal tubular lumen before it enters the peritubular blood microcirculation. The filtered albumin is broken down into little peptide fragments by lysosomes when the proximal tubular cells do not absorb it. Peripheral resistance increases along with the aortic pulse pressure, putting more pressure and volume demands on the kidneys. The kidneys' small blood vessels may be harmed by these hemodynamic changes. More albumin is filtered as a result than what the proximal tubules can absorb. Moreover, elevated levels of angiotensin II and transforming growth factor-b1 linked to high blood pressure may interfere with the lysosomal breakdown route, leading to

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albuminuria.

Conclusion

Among diabetes patients, microalbuminuria was shown to be quite prevalent and Given that we are a growing nation, it is imperative that microalbuminuria and HbA1c. As an early indicator of a Kidney risk factor, testing need to be conducted in individuals with type 2 diabetes who have previously been diagnosed as well as those who have not. In order to maintain blood glucose, patients and healthcare providers should place a very high premium on enhancing glycemic control. If this is accomplished, there will be a significant decrease in the number of people with microalbuminuria, which will in turn reduce the number of patients who acquire end-stage renal disease and overt macroalbuminuria.

Limitations and Recommendations

This study is limited by its cross-sectional design, single-center setting, relatively small sample size, and inclusion of only male diabetic patients, which may limit the generalizability of the findings. Additionally, important factors such as the duration of diabetes, hypertension, medication use, lifestyle characteristics, and other renal biomarkers (e.g., estimated glomerular filtration rate [eGFR] and urinary albumin-to-creatinine ratio [UACR]) were not comprehensively evaluated. Therefore, future multicenter prospective studies with larger, gender-inclusive populations are recommended to validate these findings and investigate the combined utility of HbA1c, microalbuminuria, and additional renal biomarkers for improving the early diagnosis and risk prediction of diabetic kidney disease. Routine assessment of HbA1c and microalbuminuria should be incorporated into clinical practice to facilitate timely intervention and reduce the progression of diabetic nephropathy.

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