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Correlation of Glycemic Control and Renal Function in Type 2 Diabetes Mellitus: A Cross-Sectional Study

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ABSTRACT

Background: Type 2 Diabetes Mellitus (T2DM) is a global health concern marked by chronic hyperglycemia, which contributes to oxidative stress and subsequent diabetic complications, particularly nephropathy. Glycated hemoglobin (HbA1c) serves as a standard marker for glycemic control, while renal function tests (RFTs) such as serum creatinine, blood urea, and uric acid provide insight into renal status and potential oxidative burden.
Objective: To evaluate biochemical markers of glycemic control and renal function in T2DM patients and assess the correlation between HbA1c and renal parameters.
Methods: A cross-sectional comparative study was conducted involving 100 T2DM patients and 100 age- and sex-matched healthy controls. HbA1c was measured using the ion-exchange resin method. Serum creatinine, urea, and uric acid were estimated using standard enzymatic methods. Statistical analysis was performed using SPSS 26.0.
Results: Diabetic patients showed significantly higher levels of HbA1c (8.6 ± 1.4%), serum creatinine (1.4 ± 0.3 mg/dL), blood urea (49 ± 8 mg/dL), and uric acid (5.8 ± 1.2 mg/dL) compared to controls ($p < 0.001$ for all). A positive correlation was observed between HbA1c and serum creatinine ($r = +0.63$), urea ($r = +0.59$), and uric acid ($r = +0.55$), indicating a strong link between poor glycemic control and renal dysfunction.
Conclusion: Poor glycemic control in T2DM patients is significantly associated with early renal impairment. Monitoring HbA1c alongside renal function markers can aid in the early detection of diabetic nephropathy and may reflect underlying oxidative stress. Future studies incorporating direct oxidative stress biomarkers are warranted for a more comprehensive assessment.

Keywords: Type 2 Diabetes Mellitus, HbA1c, Oxidative Stress, Renal Function Tests, Serum Creatinine, Blood Urea, Uric Acid

INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder characterized by hyperglycemia resulting from insulin resistance and/or insufficient insulin secretion. It is one of the most prevalent

non-communicable diseases globally, significantly contributing to morbidity and mortality, especially in low- and middle-income countries [1]. The International Diabetes Federation estimates that by 2045, approximately 783 million individuals will be affected by diabetes worldwide [2].

Glycemic control plays a pivotal role in the management and prognosis of T2DM. **Glycated Hemoglobin (HbA1c)** is the most reliable marker for long-term glycemic control, reflecting the average blood glucose concentration over the previous 2–3 months [3]. Persistent hyperglycemia is known to induce **oxidative stress**, which is a major contributor to the development of diabetes-associated complications, including nephropathy, neuropathy, and cardiovascular diseases [4].

Oxidative stress arises due to an imbalance between the production of reactive oxygen species (ROS) and the antioxidant defense system. In diabetic patients, prolonged hyperglycemia leads to auto-oxidation of glucose, activation of the polyol pathway, and formation of advanced glycation end products (AGEs), all of which contribute to ROS generation [5].

Several biochemical markers have been explored for their role in assessing renal function and oxidative stress status in diabetic patients. These include **serum creatinine**, **blood urea**, and **serum uric acid**—parameters that not only indicate renal involvement but may also reflect increased oxidative load and endothelial dysfunction [6][7]. Therefore, evaluating the correlation between glycemic control and renal function tests (RFTs) can provide insight into early renal involvement and potential oxidative stress in T2DM patients.

This study aims to assess the biochemical markers of glycemic control and renal function in patients with T2DM and compare them with healthy individuals. It also evaluates the correlation between HbA1c and renal markers to highlight their interrelationship.

MATERIAL AND METHODS

Study Design and Duration

This was a comparative cross-sectional study conducted over a period of one year, from January 2024 to December 2024, in the Department of Biochemistry, Lyallpur Khalsa College, Jalandhar.

Study Population

A total of 200 participants were included in the study, comprising: 100 diagnosed cases of Type 2 Diabetes Mellitus (T2DM) attending regular health check-ups.

100 age- and sex-matched healthy individuals with no history of diabetes or renal dysfunction, serving as the control group.

Inclusion Criteria

1. Adults aged **30–65 years**.
2. Diabetic patients diagnosed with **Type 2 Diabetes Mellitus** as per **ADA criteria**.
3. Patients willing to provide informed consent.

Exclusion Criteria

1. Patients with Type 1 Diabetes Mellitus.
2. Individuals with chronic kidney disease (CKD), cardiovascular disease, liver dysfunction, or other systemic illnesses.
3. Pregnant and lactating women.
4. Patients on antioxidant supplements or nephrotoxic drugs.

Ethical Consideration

Prior to initiation, the study protocol was reviewed and approved by the Institutional Ethics Committee of Lyallpur Khalsa College, Jalandhar. Written informed consent was obtained from all participants.

Sample Collection

Fasting venous blood samples (5 mL) were collected under aseptic conditions. Blood was collected in both **plain vials** for biochemical assays and **EDTA vials** for HbA1c estimation.

Biochemical Parameters Assessed

1. **Glycemic Control: Glycated Hemoglobin (HbA1c):** Measured using **ion-exchange resin method**.
2. **Renal Function Tests (RFTs): Serum Creatinine:** Estimated using the **Jaffe's kinetic method**.
3. **Blood Urea:** Assessed using the **urease-glutamate dehydrogenase (GLDH) method**.
4. **Serum Uric Acid:** Measured using the **uricase-peroxidase method**.

All biochemical analyses were carried out using **semi-automated chemistry analyzers** following standard operating procedures and internal quality control protocols.

STATISTICAL ANALYSIS

Data were expressed as **mean ± standard deviation (SD)**. **Independent t-test** was used to compare means between diabetic and control groups. **ANOVA** was applied to assess variations in RFT parameters across different HbA1c categories. **Pearson correlation coefficient (r)** was used to evaluate the correlation between HbA1c and renal function parameters. A **p-value < 0.05** was considered statistically significant. Analysis was done using **SPSS version 26.0**.

RESULTS AND OBSERVATIONS

Table 1: Comparison of Mean RFT Parameters Between Diabetic and Control Group

Parameter	Diabetic Patients (n=100)	Control Group (n=100)	p-value	Statistical Significance
HbA1c (%)	8.6 ± 1.4	5.2 ± 0.4	< 0.001	Highly Significant
Serum Creatinine (mg/dL)	1.4 ± 0.3	0.9 ± 0.2	< 0.001	Highly Significant
Blood Urea (mg/dL)	49 ± 8	33 ± 5	< 0.001	Highly Significant
Serum Uric Acid (mg/dL)	5.8 ± 1.2	4.5 ± 1.0	< 0.001	Highly Significant

Table 2: Distribution of Diabetic Patients According to HbA1c Ranges

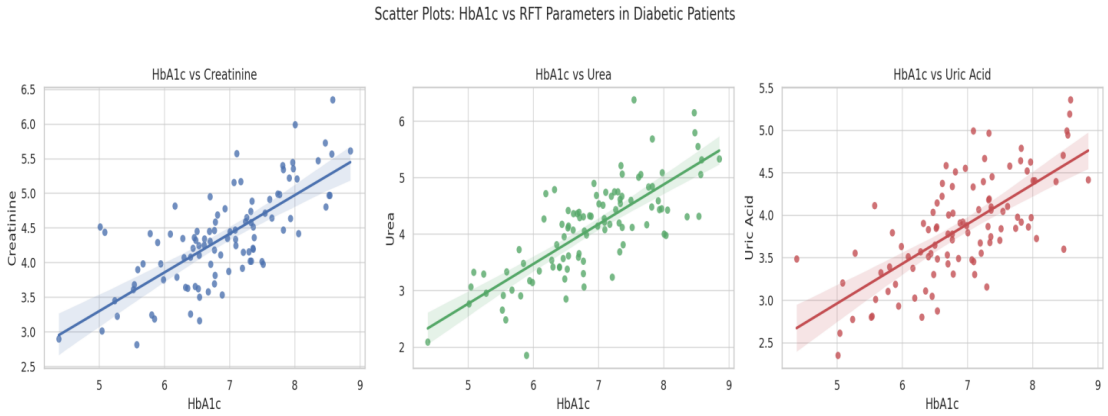
HbA1c Range (%)	Number of Patients	Percentage (%)
< 7.0 (Good control)	12	12%
7.0 – 8.9 (Moderate)	47	47%
≥ 9.0 (Poor control)	41	41%
Total	100	100%

Table 3: Renal Function Parameters Across HbA1c Categories in Diabetic Patients

HbA1c Range (%)	Mean Creatinine (mg/dL)	Mean Urea (mg/dL)	Mean Uric Acid (mg/dL)
< 7.0 (Good control)	1.1 ± 0.2	42 ± 5	5.2 ± 1.0
7.0 – 8.9 (Moderate)	1.3 ± 0.3	48 ± 6	5.6 ± 1.1
≥ 9.0 (Poor control)	1.5 ± 0.3	53 ± 7	6.2 ± 1.2

Table 4: Correlation Matrix Between HbA1c and RFT Parameters in Diabetic Patients

Correlation Pair	Pearson's r	p-value	Interpretation
HbA1c vs Creatinine	+0.63	< 0.001	Moderate to Strong Positive
HbA1c vs Urea	+0.59	< 0.001	Moderate Positive
HbA1c vs Uric Acid	+0.55	< 0.001	Moderate Positive
Creatinine vs Urea	+0.67	< 0.001	Strong Positive
Creatinine vs Uric Acid	+0.60	< 0.001	Moderate to Strong Positive
Urea vs Uric Acid	+0.58	< 0.001	Moderate Positive



DISCUSSION

The present study aimed to evaluate glycemic control and its correlation with renal function parameters in patients with Type 2 Diabetes Mellitus (T2DM). The findings demonstrate significantly elevated levels of **HbA1c**, **serum creatinine**, **blood urea**, and **serum uric acid** in diabetic patients compared to age- and sex-matched healthy controls (Table 1). These results are consistent with previous studies suggesting that poor glycemic control is associated with deteriorating renal function and increased oxidative stress [8,9].

In this study, the **mean HbA1c** in diabetic patients was **8.6%**, indicating suboptimal glycemic control. According to the **American Diabetes Association (ADA)**, an HbA1c level ≥7.0% is considered poorly controlled and associated with an increased risk of microvascular complications, particularly diabetic nephropathy [1,10]. As shown in **Table 2**, 41% of patients fell into the poor glycemic control category (HbA1c ≥9.0%), further underlining the need for stricter management protocols.

Renal function tests (RFTs) showed significantly higher serum creatinine, blood urea, and uric acid levels in diabetics, indicating early signs of renal impairment. This aligns with studies by Shankar et al. and Saran et al., who reported progressive elevation in these parameters in uncontrolled diabetics [11,12].

Furthermore, when RFT parameters were analyzed across different **HbA1c categories (Table 3)**, a clear upward trend in mean serum creatinine, urea, and uric acid was observed with increasing HbA1c levels. This indicates that poor glycemic control may contribute directly to the deterioration of renal function, potentially via mechanisms involving **advanced glycation end-products (AGEs)** and **oxidative stress-induced endothelial injury** [13].

The **Pearson correlation analysis (Table 4)** revealed significant **positive correlations** between HbA1c and renal markers, particularly serum creatinine (r = +0.63) and blood urea (r = +0.59). These correlations suggest that as glycemic control worsens, renal function parameters also deviate from normal, reinforcing the idea of HbA1c as a useful surrogate marker not only for glycemic control but also for early nephropathy in T2DM [14,15].

The observed elevation in **serum uric acid** in diabetic patients may reflect **increased oxidative stress**, as hyperuricemia has been linked with enhanced free radical production and reduced nitric oxide bioavailability [16]. Studies suggest that uric acid itself may act both as a **marker and mediator** of oxidative stress, playing a role in the pathogenesis of diabetic complications, especially nephropathy and hypertension [17].

These findings underline the importance of regular monitoring of **HbA1c and renal function parameters** in diabetic patients to identify early signs of nephropathy and manage complications proactively. Moreover, this study supports integrating oxidative stress assessment into routine diabetic care to better understand disease progression and therapeutic responses.

However, the study is limited by the lack of direct oxidative stress markers (e.g., MDA, SOD, GSH), which could have further elucidated the link between glycemic control and oxidative burden. Future research should include these biomarkers to establish a more comprehensive biochemical profile in T2DM.

CONCLUSION

This study demonstrates a significant positive correlation between poor glycemic control (high HbA1c) and elevated renal function parameters (creatinine, urea, uric acid) in Type 2 Diabetes Mellitus patients. These findings emphasize the need for regular monitoring of HbA1c and renal markers to detect early renal impairment. Improved glycemic control may help prevent or delay diabetic nephropathy and related complications.

Declaration by Authors

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Conflict of Interest: The authors declare no conflict of interest.

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