Original Article

# Study of Correlation Between Duration of Diabetes, atherogenic Index, and albuminuria in Type 2 Diabetic Subjects

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## Abstract

**Background:** Type 2 diabetes mellitus has emerged as one of the most significant non-communicable diseases of the present century, posing a sustained burden on healthcare systems worldwide. Objective: Study of Correlation Between Duration of Diabetes, atherogenic Index, and albuminuria In Type 2 Diabetic Subjects. **Material and Methods:** This cross-sectional, observational, analytical study was conducted in the outpatient department (OPD) and inpatient department (IPD) of the Department of General Medicine at K.R. Hospital, Mysore Medical College and Research Institute (MMCRI), Mysore. **Results:** The prevalence of microalbuminuria was high, indicating a considerable burden of early renal involvement among patients with type 2 diabetes mellitus. A statistically significant association was observed between duration of diabetes and the presence of microalbuminuria, demonstrating that patients with longer disease duration were more likely to develop early renal complications. Although HbA1c levels were slightly higher in patients with microalbuminuria, the association between glycaemic control and microalbuminuria was not statistically significant in this study. The atherogenic index of plasma (AIP) showed slightly higher mean values among patients with microalbuminuria, but the relationship did not reach statistical significance. **Conclusion:** Patients with longer disease duration had significantly higher prevalence of albuminuria, underscoring the cumulative effects of prolonged hyperglycaemia and metabolic stress on renal microvascular structures. Although the mean HbA1c levels and atherogenic index values were slightly higher among patients with microalbuminuria, these associations were not statistically significant in the present study.

**Keywords:** Duration of Diabetes, atherogenic Index, and albuminuria in T2 Diabetes Subjects.

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## Introduction

Type 2 diabetes mellitus has an impact that extends far beyond persistent hyperglycaemia, influencing multiple metabolic pathways and organ systems over time. What makes type 2 diabetes particularly challenging is not merely the elevation of blood glucose levels but the silent and progressive nature of its complications, especially those affecting the cardiovascular system and kidneys.[1] These complications often develop insidiously, remaining clinically unapparent until significant and sometimes irreversible damage has occurred. In this context, identifying reliable biochemical markers that reflect metabolic control, vascular risk, and early organ injury is crucial for timely intervention and risk stratification in individuals living with diabetes.[1,2]

Glycated hemoglobin, commonly known as HbA1c, has long been established as a cornerstone in the assessment of long-term glycaemic control in patients with type 2 diabetes mellitus. Unlike fasting or postprandial glucose measurements that capture glucose levels at a single point in time, HbA1c provides an integrated picture of average blood glucose over the preceding two to three months.[2] This reflects the non-enzymatic glycation of hemoglobin within erythrocytes, a process that is directly proportional to ambient glucose concentration and the lifespan of red blood cells. Numerous landmark clinical trials have demonstrated that elevated HbA1c levels are strongly associated with the development and progression of microvascular complications such as retinopathy, nephropathy, and neuropathy. Beyond microvascular damage, sustained poor glycaemic control has also been implicated in accelerating macrovascular disease, underscoring the broader clinical relevance of HbA1c beyond a mere monitoring tool.[2,3]

In patients with type 2 diabetes mellitus, the atherogenic index assumes particular importance due to the heightened risk of cardiovascular disease, which remains the leading cause of morbidity and mortality in this population. Chronic

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hyperglycaemia contributes to oxidative stress, low-grade inflammation, and lipoprotein glycation, thereby exacerbating lipid abnormalities and promoting atherosclerosis. Elevated HbA1c levels have been associated with worsening lipid profiles, suggesting a close metabolic link between poor glycaemic control and increased atherogenicity. Consequently, studying HbA1c alongside the atherogenic index provides valuable insight into the combined burden of glycaemic and lipid- related cardiovascular risk in individuals with diabetes.[4,5]

While cardiovascular complications account for a substantial proportion of adverse outcomes in type 2 diabetes mellitus, diabetic kidney disease remains one of its most feared microvascular complications. Albuminuria, defined by the abnormal excretion of albumin in urine, is widely regarded as an early and sensitive marker of diabetic nephropathy. The presence of albumin in urine reflects increased glomerular permeability resulting from structural and functional changes within the renal microvasculature. Importantly, albuminuria is not only a marker of renal involvement but also a surrogate indicator of generalized endothelial dysfunction. Its presence has been consistently linked to an increased risk of cardiovascular events and mortality, even at relatively low levels of urinary albumin excretion.[5,6]

The relationship between glycaemic control and albuminuria has been extensively studied, with higher HbA1c levels being associated with the onset and progression of diabetic nephropathy. Persistent hyperglycaemia leads to glomerular hyperfiltration, advanced glycation end-product formation, and activation of inflammatory and fibrotic pathways within the kidney.[6] These mechanisms collectively contribute to the development of albuminuria and eventual decline in renal function. However, emerging evidence suggests that dyslipidaemia and atherogenic lipid patterns may also play a contributory role in renal injury. Lipid accumulation within renal tissues, oxidative modification of lipoproteins, and lipid-induced inflammation have been implicated in the progression of diabetic kidney disease.[6,7]

Comparing HbA1c levels and the atherogenic index with albuminuria in patients with type 2 diabetes mellitus allows for a more integrated assessment of disease burden. Such a comparison acknowledges that diabetes is not a disorder of isolated pathways but a complex systemic condition in which glucose and lipid metabolism, vascular health, and organ function are inextricably linked. Understanding how these parameters relate to one another may help identify patients at higher risk of developing complications even before overt clinical manifestations arise. This is particularly relevant in resource-limited settings, where simple and cost-effective markers are essential for early risk prediction and preventive strategies.[8]

Patients with poorly controlled HbA1c, a high atherogenic index, and evidence of albuminuria represent a subgroup with significant metabolic and vascular vulnerability, warranting aggressive and multifaceted management. Conversely, identifying discordance among these markers may also provide insight into individual variations in disease progression and response to therapy.[8,9]

This study aimed to evaluate HbA1c levels and the atherogenic index, and to compare them with albuminuria in patients with type 2 diabetes mellitus.

## Materials and Methods

This cross-sectional, observational, analytical study was conducted in the outpatient department (OPD) and inpatient department (IPD) of the Department of General Medicine at K.R. Hospital, Mysore Medical College and Research Institute (MMCRI), Mysore. K.R. Hospital is a tertiary care teaching hospital serving a diverse patient population from urban and rural areas of Karnataka. The study was conducted over 18 months, from April 2024 to September 2025.

**Inclusion Criteria:**

Patients diagnosed with Type 2 Diabetes Mellitus as per the American Diabetes Association (ADA) guidelines.

Age above 18 years.

Willing to provide written informed consent.

**Exclusion Criteria:**

Patients with known kidney disease or impaired renal function.

Patients with liver disorders.

Pregnant women.

Patients with active urinary tract infections.

Patients with anemia.

Patients on lipid-lowering drugs, steroids, or antiretroviral therapy (ART).

Patients with other systemic illnesses that could affect lipid metabolism or urinary albumin excretion.

**Study Sampling:** A simple random sampling technique was employed.

**Study Sample Size:** The sample size was calculated using the formula for cross-sectional studies:

$$S = \frac{Z^2 \times P \times Q}{D^2}$$

Where:

- $Z$ = 1.96 (standard value at 95% confidence level)
- $P$ = Prevalence of microalbuminuria in diabetic patients (7.2% or 0.072, based on prior studies)
- $Q = 1 - P = 0.928$
- $D$ = Margin of error (5% or 0.05)

$$S = \frac{(1.96)^2 \times 0.072 \times 0.928}{(0.05)^2} \approx 103$$

Thus, a minimum sample size of 103 participants was required. To account for potential dropouts or incomplete data, a final sample of 110 participants was targeted.

**Study Parameters**

**The following parameters were assessed:**

Demographic and clinical details: Age, sex, occupation, duration of diabetes, treatment history, past medical history, family history, personal habits (smoking, alcohol).

Physical examination findings: Pulse, blood pressure, respiratory rate, temperature, systemic examination of cardiovascular, respiratory, abdominal, and nervous systems.

Laboratory investigations:

- Complete blood count (CBC)
- Renal function test (serum creatinine)
- Liver function test (LFT)
- Fasting blood sugar (FBS), postprandial blood sugar (PPBS)

- Glycated hemoglobin (HbA1c)
- Lipid profile: Total cholesterol, triglycerides, HDL, LDL
- Atherogenic Index of Plasma (AIP): calculated as log(TG/HDL)
- Urine routine analysis
- Urinary albumin-creatinine ratio (UACR)
- Fundoscopy for diabetic retinopathy assessment

**Study Procedure:** After obtaining ethical clearance, eligible patients were approached during their hospital visit. The nature, purpose, and procedures of the study were explained in detail. Written informed consent was obtained from each participant. A detailed history was taken, and a thorough clinical examination was performed. Relevant laboratory investigations were ordered as per the study protocol. Blood samples were collected under aseptic precautions for CBC, RFT, LFT, HbA1c, FBS, PPBS, and lipid profile. A spot urine sample was collected for UACR estimation. An ophthalmologist performed Fundoscopy. All data were recorded in a structured proforma.

**Study Data Collection:** Data were collected using a pre-designed, standardized pro forma that included all study variables: demographic details, clinical history, examination findings, and laboratory results. Data collection was performed by the principal investigator under the supervision of the guide. All laboratory reports were obtained from the hospital's central laboratory, ensuring standardized methods and quality control. Data were initially recorded on paper forms and later transferred to a digital spreadsheet for analysis.

**Data Analysis:** Data were entered into Microsoft Excel and analyzed using SPSS software version 28. Descriptive statistics were presented as mean ± standard deviation for continuous variables and frequency (percentage) for categorical variables. The association between categorical variables (e.g., presence of microalbuminuria and glycemic control) was assessed using the Chi-square test. Correlation between continuous variables (e.g., HbA1c, AIP, and UACR) was analyzed using Pearson's correlation coefficient. For non-normally distributed data, non-parametric tests (Spearman's correlation) were applied. An independent-samples t-test was used to compare group means. A p-value of less than 0.05 was considered statistically significant.

## Results

A total of 103 patients with type 2 diabetes mellitus were included in the study. The majority of participants belonged to the 46–60 years age group, accounting for 49 patients (47.57%). Patients aged 60 years or older comprised 46 individuals (44.66%), representing the second-largest group in the study population. In contrast, only 8 participants (7.77%) were aged 30-45. Overall, the findings indicate that the study cohort predominantly consisted of middle-aged and elderly individuals, with more than 92% aged 45 years or older, reflecting the higher prevalence of type 2 diabetes mellitus in older age groups.

The study included 103 patients with type 2 diabetes mellitus. Among them, 57 participants (55.34%) were male, while 46 participants (44.66%) were female. The results indicate a slight male predominance in the study population. The male-to-female ratio was approximately 1.24:1. Both sexes were well represented in the cohort, allowing for balanced evaluation of clinical and biochemical parameters across genders.

Participants in the study represented a diverse occupational background. The most common occupations were business (14 patients, 13.59%), engineering (13 patients, 12.62%), and shopkeeping (13 patients, 12.62%). Teachers accounted for 12 patients (11.65%), while drivers represented 11 patients (10.68%). Farmers constituted 10 patients (9.71%), and homemakers accounted for 9 patients (8.74%). Clerks, laborers, and retired individuals each comprised 7 patients (6.8%). The occupational distribution demonstrates that the study population included individuals from varied socioeconomic and professional backgrounds.

Urine albumin was present in 57 patients (55.34%) and absent in 46 patients (44.66%). Urine sugar was detected in 88 participants (85.44%) and was absent in 15 participants (14.56%). Urine ketones were present in only 3 patients (2.91%), whereas the majority of participants (100 patients, 97.09%) did not demonstrate ketonuria. These findings suggest a high prevalence of glycosuria among study participants, while ketonuria was relatively uncommon.

**Prevalence of Microalbuminuria:** Microalbuminuria was present in 54 patients (52.43%) and absent in 49 patients (47.57%). The results indicate that more than half of the study participants exhibited microalbuminuria, suggesting a substantial burden of early diabetic nephropathy within the study population.

**Table 1: Prevalence of microalbuminuria among study participants**

| Microalbuminuria | Frequency (n) | Percentage (%) |
|---|---|---|
| No | 49 | 47.57 |
| Yes | 54 | 52.43 |

**Association Between Duration of Diabetes and Microalbuminuria:** The duration of diabetes was significantly longer in participants with microalbuminuria than in those without. Patients without microalbuminuria had a mean diabetes duration of 8.31 ± 5.56 years, whereas those with microalbuminuria had a longer mean duration of 11.54 ± 5.17 years. The difference was statistically significant (p = 0.0029), indicating that longer diabetes duration was associated with microalbuminuria among the study participants.

**Table 2: Comparison of duration of diabetes between patients with and without microalbuminuria**

| Duration of diabetes (years) | Mean ± SD | Mean ± SD | p-value |
|---|---|---|---|
| | No microalbuminuria | Microalbuminuria present | |
| Duration of diabetes | 8.31 ± 5.56 | 11.54 ± 5.17 | 0.0029 |

**Comparison of HbA1c Levels According to Microalbuminuria Status:** The mean HbA1c level among patients without microalbuminuria was 8.36 ± 0.68%, whereas patients with microalbuminuria had a mean HbA1c level of 8.45 ± 0.74%. Statistical analysis showed that the difference between the two groups was not significant (p = 0.5024). These findings suggest that HbA1c levels were comparable between participants with and without microalbuminuria in the present study.

**Table 3: Comparison of HbA1c levels between patients with and without microalbuminuria**

| HbA1c (%) | Mean ± SD | Mean ± SD | p-value |
|---|---|---|---|
| | No microalbuminuria | Microalbuminuria present | |
| HbA1c | 8.36 ± 0.68 | 8.45 ± 0.74 | 0.5024 |

**Comparison of Atherogenic Index of Plasma According to Microalbuminuria Status:** The mean atherogenic index of plasma (AIP) among patients without microalbuminuria was 0.62 ± 0.14, while the mean AIP among patients with microalbuminuria was 0.64 ± 0.12. The difference between the two groups was not statistically significant (p = 0.5703). These findings indicate that AIP values were comparable between patients with and without microalbuminuria in the study population.

**Table 4: Comparison of atherogenic index of plasma between patients with and without microalbuminuria**

| Atherogenic index (AIP) | Mean ± SD | Mean ± SD | p-value |
|---|---|---|---|
| | No microalbuminuria | Microalbuminuria present | |
| AIP | 0.62 ± 0.14 | 0.64 ± 0.12 | 0.5703 |

## Discussion

The present study evaluated the demographic, clinical, and biochemical characteristics of patients with type 2 diabetes mellitus and explored their relationship with albuminuria and atherogenic dyslipidaemia. The study population consisted predominantly of middle-aged and elderly individuals, with the majority of participants in the 46–60-year age group, followed closely by those aged 60 years or older. Only a small proportion of participants were below 45 years of age.

The findings of the present study are consistent with those reported by Jawad A Al-Lawati et al., who evaluated glycaemic control across different age groups in patients with type 2 diabetes mellitus.

The sex distribution in the present study showed a slight male predominance, although both sexes were well represented. Gender differences in diabetes prevalence and complications have been reported in several epidemiological studies. In the study by Al-Lawati et al., female gender was independently associated with better glycaemic control after adjustment for confounding variables, suggesting that gender-specific behavioral and biological factors may influence metabolic outcomes in diabetic populations.[10]

**Prevalence of Microalbuminuria and Diabetic Microvascular Complications:** In the present study, microalbuminuria was observed in a substantial proportion of the study population, indicating a significant burden of early renal involvement among patients with type 2 diabetes mellitus. More than half of the participants demonstrated evidence of microalbuminuria, while a small subset exhibited macroalbuminuria. These findings highlight the progressive nature of diabetic nephropathy and underscore the importance of early detection of renal injury in individuals with long-standing diabetes. Albuminuria is widely recognized as one of the earliest clinical markers of diabetic kidney disease. It reflects underlying glomerular endothelial dysfunction, increased permeability of the glomerular basement membrane, and progressive structural alterations within the renal microvasculature.

Persistent hyperglycaemia in diabetes leads to several pathological mechanisms that contribute to renal injury. Chronic elevation of blood glucose promotes the formation of advanced glycation end products, activation of protein kinase C pathways, and increased oxidative stress within the vascular endothelium. These molecular disturbances cause thickening of the glomerular basement membrane, mesangial expansion, and loss of podocyte integrity. As a result, the filtration barrier becomes increasingly permeable, allowing albumin molecules to pass into the urine. Microalbuminuria, therefore, represents not only an early indicator of nephropathy but also a marker of generalized vascular injury in individuals with diabetes.

The high prevalence of microalbuminuria observed in the present study is consistent with previous findings on the relationship between metabolic indices and renal involvement in diabetes. Licui Qi et al. investigated the predictive value of metabolic indices, such as the visceral adiposity index and lipid accumulation product, in patients with newly diagnosed type 2 diabetes. Their study demonstrated that patients with microalbuminuria had significantly higher metabolic risk scores compared to those without renal involvement, indicating that metabolic disturbances play a key role in the development of early nephropathy.[11]

The relationship between AIP and diabetic nephropathy has also been confirmed by meta-analytic evidence. Danyan Min et al. conducted a systematic review and meta-analysis involving more than twenty-five thousand patients with type 2 diabetes mellitus. Their pooled analysis demonstrated that elevated AIP values were significantly associated with an increased risk of diabetic nephropathy, with a pooled risk ratio indicating a meaningful increase in renal complication risk among patients with higher AIP levels.[12] Notably, the association was stronger among older individuals, further emphasizing the cumulative impact of metabolic stress on vascular tissues over time.

**Relationship Between Duration of Diabetes and Microalbuminuria:** One of the key findings of the present study

was a statistically significant association between diabetes duration and the presence of microalbuminuria. Patients with microalbuminuria demonstrated a significantly longer duration of diabetes compared with those without microalbuminuria. This observation suggests that the length of time an individual lives with diabetes plays a crucial role in the development of renal microvascular damage. Diabetes is a chronic metabolic disorder characterized by prolonged exposure to hyperglycaemia, and the cumulative metabolic burden over time progressively affects multiple organ systems, particularly the microvasculature of the kidney.

The relationship between disease duration and diabetic complications has been widely documented in the literature. Jawad A Al-Lawati et al. demonstrated that longer duration of diabetes was inversely associated with achieving optimal glycaemic control. Their study found that patients with diabetes for more than 5 years were significantly less likely to maintain HbA1c levels below recommended targets.[10] This finding highlights the progressive nature of metabolic dysregulation in diabetes. It suggests that patients with longer disease duration are more likely to experience sustained hyperglycaemia, which in turn accelerates the development of microvascular complications such as nephropathy. The findings of the present study, therefore, align with the broader body of evidence demonstrating that longer diabetes duration is a major determinant of microvascular complications. The statistically significant difference observed between patients with and without microalbuminuria highlights the cumulative impact of chronic metabolic disturbances on renal structure and function. These observations emphasize the importance of early diagnosis and aggressive metabolic control in patients with newly diagnosed diabetes. Effective glycaemic management during the early stages of the disease may help delay the onset of microvascular complications and reduce the long-term burden of diabetic nephropathy. In clinical practice, monitoring diabetes duration alongside biochemical markers of metabolic control may provide valuable insight into the risk of renal involvement. Patients with longer disease duration should be considered at higher risk for microvascular complications and may benefit from more frequent screening for albuminuria and other indicators of renal dysfunction. Early identification of such changes enables clinicians to initiate timely therapeutic interventions to slow the progression of diabetic kidney disease and improve long-term patient outcomes.

**Association of Glycaemic Control and Atherogenic Index of Plasma with Microalbuminuria:** The present study also examined the relationships among glycaemic control, atherogenic dyslipidaemia, and microalbuminuria in patients with type 2 diabetes mellitus. Glycaemic control was assessed using glycated hemoglobin (HbA1c), while the atherogenic index of plasma (AIP) was used as a marker of lipid-related cardiovascular and metabolic risk. Although the mean HbA1c and AIP values were slightly higher in patients with microalbuminuria than in those without albuminuria, the differences were not statistically significant. These findings suggest that while glycaemic and lipid abnormalities are central components of diabetic metabolic dysfunction, their relationship with early renal involvement may be influenced by multiple interacting factors, including disease duration, genetic susceptibility, and coexisting metabolic disturbances.

Persistent hyperglycaemia is a fundamental driver of diabetic microvascular complications. Elevated HbA1c reflects long-term exposure to high glucose concentrations, which promotes the activation of several pathological biochemical pathways. Chronic hyperglycaemia leads to increased production of advanced glycation end products, oxidative stress, and activation of inflammatory signaling within vascular endothelial cells. These molecular events contribute to structural alterations in the glomerular basement membrane and to podocyte damage, ultimately increasing glomerular permeability and allowing albumin to leak into the urine. Therefore, poor glycaemic control has traditionally been considered a major determinant in the development of diabetic nephropathy.

Previous research has demonstrated that glycaemic status plays an important role in metabolic disturbances associated with diabetes. Hagos Amare Gebreyesus et al. reported that a large proportion of patients with type 2 diabetes exhibited poor glycaemic control, with HbA1c levels exceeding recommended targets in the majority of participants.[13]

Several studies have demonstrated a significant association between elevated AIP levels and diabetic complications. Emin Murat Akbas et al. reported a strong correlation between AIP, serum uric acid levels, and albuminuria in patients with diabetes mellitus.[14] Their findings indicated that patients with higher AIP values exhibited significantly greater levels of albuminuria, suggesting that lipid-related metabolic disturbances may contribute to renal microvascular damage. The authors emphasized that AIP may serve as a useful marker for identifying patients at increased risk of both renal and cardiovascular complications. Recent research has also explored the predictive value of AIP for diabetic kidney disease. Han Yan et al. reported that elevated AIP levels were independently associated with an increased risk of diabetic kidney disease in patients with type 2 diabetes mellitus.[15] Similarly, Yue-Yang Zhang et al. demonstrated a dose-response relationship between increasing AIP levels and the risk of diabetic kidney disease, highlighting the potential role of dyslipidaemia in the pathogenesis of renal complications.[16] These findings collectively suggest that AIP may serve as an important metabolic indicator for identifying patients at risk of renal involvement. Although the present study did not demonstrate a statistically significant association between AIP or HbA1c and microalbuminuria, the slightly higher values observed among patients with albuminuria may still reflect underlying metabolic trends. The lack of statistical significance may be attributed to factors such as sample size, cross-sectional study design, and variability in metabolic parameters among individuals. Nevertheless, the overall findings remain consistent with the broader understanding that dyslipidaemia and poor glycaemic control contribute to the complex metabolic environment that predisposes diabetic patients to renal microvascular injury. Overall, evaluating glycaemic and lipid parameters alongside renal markers provides a more comprehensive understanding of metabolic risk in patients with type 2 diabetes mellitus. Monitoring indices such as HbA1c and A1P may therefore help identify individuals at increased risk of developing diabetic complications, enabling earlier therapeutic

intervention and improved long-term disease management.

## Conclusion

Microalbuminuria is a common early manifestation of renal involvement in diabetic individuals and reflects the underlying microvascular damage associated with chronic metabolic disturbances. More than half of the study participants exhibited microalbuminuria, highlighting the considerable burden of early diabetic nephropathy among patients receiving care at tertiary healthcare facilities.

One of the most important findings of the study was the significant association between diabetes duration and the presence of microalbuminuria. Patients with longer disease duration showed a significantly higher prevalence of albuminuria, emphasizing the cumulative effect of prolonged hyperglycaemia and metabolic stress on renal microvascular structures. Although the mean HbA1c levels and atherogenic index values were slightly higher among patients with microalbuminuria, these associations were not statistically significant in the present study. In conclusion, the present study reinforces the clinical significance of microalbuminuria as an early indicator of renal involvement in type 2 diabetes mellitus. Early detection of albuminuria, along with careful monitoring of metabolic parameters such as glycaemic status and lipid indices, may facilitate timely therapeutic intervention and help prevent the progression of diabetic nephropathy and associated cardiovascular complications.

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### Conflicts of interest

There are no conflicts of interest.

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