International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article *DOI: 10.61336/im/26-2-12*

To Study The Association Of Microalbuminuria With Asymptomatic Left Ventricular Diastolic Dysfunction In Type 2 Diabetes Mellitus Patients.

Dr. Deeksha Merchant[1]*, Dr. suma D[2].

[1]post graduate in department of general medicine. The oxford medical college hospital and research centre, bangalore

[2]Department of general medicine. The oxford medical college hospital and research centre, Bangalore.

Correspondence:
Dr. Deeksha Merchant.
post graduate in department of general medicine. The oxford medical college hospital and research centre, bangalore.

Received: 04-04-2026
Revised: 22-04-2026
Accepted: 07-05-2026
Published: 23-05-2026

Abstract

Background: Type 2 diabetes mellitus is associated with various microvascular and macrovascular complications. Microalbuminuria, an early marker of diabetic nephropathy, has been linked to cardiovascular dysfunction, particularly diabetic cardiomyopathy. Left ventricular diastolic dysfunction is often the earliest sign of cardiac involvement in diabetes. This study was conducted to evaluate the association between microalbuminuria and asymptomatic left ventricular diastolic dysfunction in patients with type 2 diabetes mellitus. ***Objectives:*** The primary objective was to determine whether microalbuminuria is associated with subclinical left ventricular diastolic dysfunction in asymptomatic type 2 diabetes mellitus patients. Secondary objectives included assessing the relationship between glycemic control, duration of diabetes, and echocardiographic parameters of diastolic function. ***Methods:*** A cross-sectional study was carried out at Oxford Medical College Hospital and Research Centre in Bangalore from August 2024 to January 2025. Seventy-five patients with type 2 diabetes mellitus were enrolled and divided into two groups: normoalbuminuric (n=40) and microalbuminuric (n=35). Urinary microalbumin levels were measured using the Erba-Mannheim 360 Automated Clinical Chemistry Analyzer, while left ventricular function was evaluated via two-dimensional echocardiography using the GE Vivid E machine. Key parameters, including the E/A ratio and left ventricular ejection fraction (LVEF), were recorded. Statistical analyses were performed using descriptive statistics, chi-square tests, t-tests, and multivariate logistic regression, with a p-value of <0.05 considered statistically significant. ***Results:*** The study population had a mean age of 55.2 ± 8.6 years with a male predominance (56%). The average duration of diabetes was 8.1 ± 3.2 years, with the microalbuminuric group showing a slightly longer duration compared to the normoalbuminuric group. Glycemic control, indicated by HbA1c values, was significantly poorer in the microalbuminuric group (8.5 ± 1.2% vs 8.0 ± 1.0%; p=0.04). Urinary microalbumin levels were significantly elevated in the microalbuminuric patients (78.5 ± 25.3 mg/day) compared to those with normoalbuminuria (<30 mg/day; p<0.001). Echocardiographic evaluation revealed a significantly reduced E/A ratio in the microalbuminuric group (1.0 ± 0.2 vs 1.2 ± 0.2; p=0.002) and a modest reduction in LVEF (59 ± 5% vs 61 ± 4%; p=0.03). Additionally, slight increases in interventricular septum thickness and left ventricular posterior wall thickness were noted in the microalbuminuric group. Multivariate logistic regression analysis identified microalbuminuria as an independent predictor of left ventricular diastolic dysfunction (odds ratio [OR] = 2.5, 95% confidence interval [CI]: 1.20–5.20, p=0.01) after adjusting for age, duration of diabetes, and HbA1c levels. ***Conclusion:*** The findings of this study indicate that microalbuminuria is significantly associated with subclinical left ventricular diastolic dysfunction in asymptomatic patients with type 2 diabetes mellitus. Elevated urinary microalbumin levels, poorer glycemic control, and longer duration of diabetes were all linked with worsening echocardiographic parameters. These results suggest that routine screening for microalbuminuria, combined with echocardiographic evaluation, could facilitate early detection of diabetic cardiomyopathy, thereby enabling timely intervention and potentially reducing cardiovascular morbidity in this high-risk population.

Keywords: Type 2 Diabetes Mellitus, Microalbuminuria, Left Ventricular Diastolic Dysfunction, Echocardiography, Diabetic Cardiomyopathy.

INTRODUCTION

Diabetes mellitus represents a major global health challenge with its prevalence escalating at an alarming rate, particularly in developing nations, and its complications imposing a heavy burden on healthcare systems worldwide [1]. Type 2 diabetes

mellitus (T2DM) is the most common form of diabetes in adults, characterized by chronic hyperglycemia that leads to a multitude of metabolic disturbances, eventually resulting in both microvascular and macrovascular complications. One of the earliest indicators of diabetic microvascular damage is microalbuminuria, defined as the excretion of 30–300 mg of albumin per 24 hours in the urine. This condition reflects early glomerular injury and is considered a harbinger of diabetic nephropathy [3]. The pathogenesis of microalbuminuria is multifactorial, involving increased glomerular permeability due to endothelial dysfunction, oxidative stress, and low-grade inflammation, all of which contribute to damage of the glomerular basement membrane [3,7]. Importantly, microalbuminuria is not only an early marker of renal impairment but also a powerful predictor of cardiovascular events, highlighting the systemic nature of the vascular damage induced by diabetes [8].

In parallel, diabetic cardiomyopathy has emerged as a distinct clinical entity in T2DM patients, characterized by myocardial dysfunction that occurs independently of coronary artery disease and hypertension [2]. The earliest manifestation of diabetic cardiomyopathy is typically left ventricular (LV) diastolic dysfunction, which precedes the development of systolic dysfunction and symptomatic heart failure. Diastolic dysfunction in the diabetic heart results primarily from myocardial fibrosis, abnormal calcium handling, and the accumulation of advanced glycation end-products, which collectively impair ventricular relaxation and filling [2,6]. Several studies have reported that even subtle increases in urinary albumin excretion are associated with structural and functional cardiac abnormalities, including left ventricular hypertrophy and impaired diastolic filling, suggesting a close pathophysiological relationship between renal and cardiac involvement in diabetes [4,8]. The interrelationship between microalbuminuria and LV diastolic dysfunction is of significant clinical interest because both conditions reflect an underlying generalized vasculopathy. The chronic hyperglycemic state in T2DM induces endothelial dysfunction and promotes inflammatory cascades that affect not only the kidneys but also the myocardium, leading to interstitial fibrosis and impaired myocardial relaxation [3]. This shared pathological pathway provides a compelling rationale for using microalbuminuria as a surrogate marker to identify patients at risk of developing subclinical cardiac dysfunction. Early detection of these asymptomatic changes through noninvasive screening modalities such as urinary albumin measurement and echocardiography could allow for timely intervention, potentially slowing the progression to overt heart failure and reducing cardiovascular morbidity and mortality in diabetic patients [5,9].

Despite the well-documented associations between microalbuminuria and cardiovascular disease, there remains a paucity of data specifically addressing the relationship between microalbuminuria and asymptomatic LV diastolic dysfunction in T2DM. Variations in study design, sample size, and patient selection criteria have contributed to inconsistent findings in the literature, underscoring the need for further research in this area [4]. The present study is designed as a cross-sectional analysis to evaluate the prevalence of microalbuminuria in patients with T2DM and to determine its association with subclinical LV diastolic dysfunction as detected by advanced echocardiographic techniques. By focusing on asymptomatic individuals, the study aims to capture the early stages of diabetic cardiomyopathy before clinical manifestations become apparent.

A comprehensive assessment combining biochemical markers, such as urinary albumin levels measured by automated analyzers, with detailed echocardiographic evaluation of LV function, including parameters like the E/A ratio, will provide robust insights into the interplay between renal and cardiac dysfunction in diabetes [5]. This integrative approach is expected to enhance the early identification of patients at high risk for cardiovascular events, thereby facilitating the initiation of therapeutic strategies aimed at preserving cardiac function. Strategies such as optimizing glycemic control, implementing renin-angiotensin system inhibition, and encouraging lifestyle modifications have all been shown to confer benefits in mitigating the progression of both renal and cardiac complications in diabetic individuals [2,7].

Furthermore, elucidating the molecular and hemodynamic mechanisms that link microalbuminuria to LV diastolic dysfunction could pave the way for the development of novel therapeutic interventions that target the common pathways underlying both diabetic nephropathy and cardiomyopathy. Such advances would be particularly valuable in resource-limited settings, where cost-effective screening and early intervention could have a substantial impact on patient outcomes and healthcare expenditures [1]. Ultimately, understanding the association between microalbuminuria and subclinical LV diastolic dysfunction in T2DM patients has the potential to refine risk stratification models and guide clinical decision-making, ultimately improving long-term cardiovascular outcomes in this vulnerable population [3,10]. The aim of the study was to investigate the association between microalbuminuria and asymptomatic left ventricular diastolic dysfunction in patients with type 2 diabetes mellitus. Additionally, the study sought to evaluate how factors such as glycemic control and disease duration influence these subclinical cardiac changes.

MATERIALS AND METHODS

Study Design

The study was designed as a cross-sectional analysis that aimed to assess the association between microalbuminuria and asymptomatic left ventricular diastolic dysfunction in patients with type 2 diabetes mellitus. This design was chosen

because it allowed for the evaluation of both biochemical and echocardiographic parameters at a single point in time. The design enabled the identification of correlations between urinary albumin excretion and specific echocardiographic indices indicative of left ventricular diastolic function, thereby offering a snapshot of early cardiac involvement in diabetes.

Study Setting

The investigation was conducted at the Oxford Medical College Hospital and Research Centre in Bangalore. This tertiary care hospital provided a diverse patient population and had the requisite facilities, including a fully equipped clinical laboratory and an advanced echocardiography unit. The setting was ideal because it catered to a large number of patients with type 2 diabetes mellitus, and the hospital's infrastructure allowed for standardized laboratory and imaging assessments. All data collection was carried out in dedicated clinical areas to ensure patient privacy and adherence to research protocols.

Study Duration

The study was carried out over a six-month period from August 2024 to January 2025. During this time, all procedures including patient enrollment, sample collection, echocardiographic evaluation, and data recording were completed. The chosen duration allowed for the recruitment of an adequate number of participants and provided sufficient time for the thorough evaluation of each patient. It also ensured that seasonal variations or other temporal factors did not significantly influence the study outcomes.

Participants – Inclusion and Exclusion Criteria

Participants were selected based on clearly defined criteria to ensure the reliability of the findings. The inclusion and exclusion criteria were listed as follows:

Inclusion Criteria:

- Patients diagnosed with type 2 diabetes mellitus for more than 5 years.
- Individuals aged above 18 years.
- Patients who presented to the general medicine outpatient department and agreed to participate after a thorough explanation of the study procedures.

Exclusion Criteria:

- Patients with chronic kidney disease.
- Individuals with a history of hypertension.
- Patients with urinary tract infection at the time of examination.
- Subjects with documented ischemic heart disease.
- Individuals with known valvular heart disease.
- Patients with chronic liver disease.
- Patients diagnosed with type 1 diabetes mellitus.

Study Sampling

The study employed a non-probability purposive sampling technique. Patients with type 2 diabetes mellitus who attended the general medicine outpatient department and met the inclusion criteria were approached consecutively. This approach was adopted because it ensured that only individuals relevant to the research objective were included, while also being pragmatic given the clinical setting. By using this method, the study minimized sampling bias and allowed for the efficient identification of eligible participants.

Study Sample Size

The sample size was determined using a formula based on previous studies that reported the prevalence of microalbuminuria in patients with type 2 diabetes mellitus. Using data from an earlier study where the prevalence of positive microalbuminuria was reported as 24.7%, and considering a margin of error of 10%, the minimum sample size was calculated to be 75 patients. This calculation ensured that the study had sufficient power to detect statistically significant associations between microalbuminuria and left ventricular diastolic dysfunction.

Study Groups

Participants were categorized into two distinct groups based on the presence or absence of microalbuminuria. Group 1 consisted of patients who were normoalbuminuric, and Group 2 comprised patients who demonstrated microalbuminuria, defined as a urinary albumin excretion rate between 30 and 300 mg/24 hours. This categorization enabled comparative analysis of the echocardiographic findings between the two groups, thereby facilitating the evaluation of the potential association between renal and cardiac abnormalities in asymptomatic diabetic patients.

Study Parameters

The study parameters included both biochemical and echocardiographic assessments. Urinary microalbumin levels were quantified using an Erba-Mannheim 360 Automated Clinical Chemistry Analyzer, and these values were recorded as milligrams per day. In addition, echocardiographic evaluations were performed using the GE Vivid E machine. Parameters such as the E/A ratio, left ventricular ejection fraction (LVEF), and measures of left ventricular hypertrophy (including interventricular septum and posterior wall thickness) were systematically recorded. Demographic data including age, gender, duration of diabetes, and glycemic control indices were also collected to adjust for potential confounders.

Study Procedure

All study procedures were conducted in a systematic and standardized manner. Initially, eligible patients were identified and provided with detailed information regarding the study. Written informed consent was obtained prior to enrollment. After consent, participants were asked to complete a pretested questionnaire that captured socio-demographic data, medical history, and cardiovascular risk factors. Following the questionnaire, patients were instructed to provide a mid-stream urine sample (minimum 10 mL) for the assessment of microalbuminuria. Thereafter, each participant underwent a comprehensive two-dimensional echocardiographic examination. During the echocardiography, parameters such as the E/A ratio, left ventricular wall thickness, and ejection fraction were carefully measured. All procedures were carried out by trained medical personnel under standardized conditions to ensure consistency across evaluations.

Study Data Collection

Data collection was performed using a meticulously designed data collection sheet. The sheets were created in an Excel format and included fields for demographic details, clinical history, laboratory results, and echocardiographic findings. Every parameter was recorded immediately after its assessment to minimize errors. The data collection process was supervised by senior investigators to ensure completeness and accuracy. The information was anonymized and securely stored in a password-protected database to maintain confidentiality.

Data Analysis

The collected data were compiled and analyzed using statistical software. Descriptive statistics were generated to represent the frequency and proportion of categorical variables, while continuous variables were summarized as means and standard deviations. Comparative analyses between the normoalbuminuric and microalbuminuric groups were performed using the Chi-square test for categorical variables and t-tests for continuous variables. A p-value of less than 0.05 was considered statistically significant. In addition, multivariate logistic regression analysis was employed to adjust for potential confounding factors and to identify independent predictors of left ventricular diastolic dysfunction.

Ethical Considerations

Ethical considerations were rigorously addressed throughout the study. Ethical clearance was obtained from the institutional ethics committee of the Oxford Medical College Hospital and Research Centre. All study procedures were carried out in strict adherence to ethical guidelines and the principles of the Declaration of Helsinki. Informed consent was obtained from every participant, and they were assured that their participation was voluntary and that they could withdraw from the study at any time without any impact on their subsequent medical care. Confidentiality was maintained by anonymizing the data and ensuring that patient identifiers were not included in any published reports or presentations. The potential risks to participants were minimal, as the study involved routine clinical assessments and non-invasive investigations only. All patients were provided with adequate information regarding the study aims, procedures, and their rights, ensuring that they were fully informed before giving consent.

RESULTS

A total of 75 patients with type 2 diabetes mellitus were enrolled in the study. Among these, 40 patients were identified as normoalbuminuric and 35 patients as microalbuminuric. The analysis was performed on data collected over a six-month period, during which demographic, clinical, biochemical, and echocardiographic parameters were systematically recorded. The following sections and tables describe the detailed findings.

The study population had a mean age of 55.2 ± 8.6 years. Males comprised 56% (42/75) of the patients, and females constituted 44% (33/75). The age distribution and gender proportions were comparable between the normoalbuminuric and microalbuminuric groups, with no statistically significant differences noted.

Table1: Demographic Characteristics.

Variable	Total (n=75)	Normoalbuminuric (n=40)	Microalbuminuric (n=35)
Mean Age (years)	55.2 ± 8.6	54.8 ± 8.2	55.7 ± 9.1
Gender (M:F)	42:33	23:17	19:16

Baseline clinical parameters were recorded to assess the overall health status of the participants. The mean duration of diabetes was 8.1 ± 3.2 years, with normoalbuminuric patients having a slightly shorter duration (7.8 ± 2.9 years) than the microalbuminuric group (8.5 ± 3.5 years). Body mass index (BMI), blood pressure, and glycemic control were also compared between groups.

Table2:Baseline Clinical Characteristics

Parameter	Total (n=75)	Normoalbuminuric (n=40)	Microalbuminuric (n=35)	p-value
Duration of Diabetes (yr)	8.1 ± 3.2	7.8 ± 2.9	8.5 ± 3.5	0.28
BMI (kg/m²)	26.5 ± 3.1	26.2 ± 2.9	26.9 ± 3.3	0.15
Systolic BP (mmHg)	122 ± 10	121 ± 9	123 ± 11	0.20
Diastolic BP (mmHg)	78 ± 6	78 ± 5	78 ± 7	0.95
HbA1c (%)	8.2 ± 1.1	8.0 ± 1.0	8.5 ± 1.2	0.04*

*Significant at $p < 0.05$

Biochemical evaluations revealed that serum creatinine levels were slightly higher in the microalbuminuric group (1.0 ± 0.2 mg/dL) compared to the normoalbuminuric group (0.9 ± 0.2 mg/dL). Urinary microalbumin levels were, by definition, within normal limits (<30 mg/day) in normoalbuminuric patients, while the microalbuminuric group showed a mean value of 78.5 ± 25.3 mg/day. Estimated glomerular filtration rate (eGFR) was marginally lower in microalbuminuric patients.

Table3: Biochemical Parameters.

Parameter	Total (n=75)	Normoalbuminuric (n=40)	Microalbuminuric (n=35)	p-value
Serum Creatinine (mg/dL)	0.9 ± 0.2	0.9 ± 0.2	1.0 ± 0.2	0.08
Urinary Microalbumin (mg/day)	– (Normal <30)	<30	78.5 ± 25.3	<0.001*
eGFR (mL/min/1.73 m²)	90 ± 12	92 ± 11	88 ± 13	0.09

*Significant at $p < 0.05$

Echocardiographic assessment was performed to evaluate cardiac structure and function. The E/A ratio was significantly lower in the microalbuminuric group (1.0 ± 0.2) compared to the normoalbuminuric group (1.2 ± 0.2), indicating impaired diastolic function. Left ventricular ejection fraction (LVEF) was within normal limits for both groups, though a subtle decrease was observed in microalbuminuric patients. Additionally, the interventricular septum (IVS) and left ventricular (LV) posterior wall thickness were marginally greater in the microalbuminuric group.

Table4: Echocardiographic Parameters

Parameter	Total (n=75)	Normoalbuminuric (n=40)	Microalbuminuric (n=35)	p-value
E/A Ratio	1.1 ± 0.2	1.2 ± 0.2	1.0 ± 0.2	0.002*
LVEF (%)	60 ± 5	61 ± 4	59 ± 5	0.03*
IVS Thickness (mm)	10.2 ± 1.1	10.0 ± 1.0	10.5 ± 1.2	0.05
LV Posterior Wall Thickness (mm)	10.1 ± 1.0	10.0 ± 0.9	10.3 ± 1.1	0.12

*Significant at $p < 0.05$

A direct comparison of the echocardiographic indices revealed statistically significant differences, particularly in the E/A ratio and LVEF, which suggested the presence of subclinical left ventricular diastolic dysfunction in microalbuminuric patients.

Table5: Comparison of Echocardiographic Parameters Between Groups

Echocardiographic Parameter	Normoalbuminuric (n=40)	Microalbuminuric (n=35)	p-value
E/A Ratio	1.2 ± 0.2	1.0 ± 0.2	0.002*
LVEF (%)	61 ± 4	59 ± 5	0.03*
IVS Thickness (mm)	10.0 ± 1.0	10.5 ± 1.2	0.05
LV Posterior Wall Thickness (mm)	10.0 ± 0.9	10.3 ± 1.1	0.12

*Significant at $p < 0.05$

In the microalbuminuric group, left ventricular diastolic dysfunction was categorized into three grades based on echocardiographic criteria. Grade I dysfunction was the most common, followed by Grade II and Grade III dysfunction.

Table 6: Frequency Distribution of LV Diastolic Dysfunction Grades among Microalbuminuric Patients

LV Diastolic Dysfunction Grade	Frequency (n=35)	Percentage (%)
Grade I	20	57.1
Grade II	10	28.6
Grade III	5	14.3

Table 6B presents the distribution of urinary microalbumin levels stratified by the severity grades of left ventricular diastolic dysfunction among patients with microalbuminuria. Although mean microalbumin levels were higher in patients with moderate dysfunction (55.7 ± 43.6 mg/day) compared to those with mild (37.6 ± 43.2 mg/day) and severe (42.7 ± 50.4 mg/day) dysfunction, with statistical significance (p = 0.002). These findings suggest a trend toward higher albuminuria with increasing severity, although variability limits definitive conclusions.

Table 6B: Urinary Microalbumin Levels Stratified by LV Diastolic Dysfunction Grade in Microalbuminuric Patients

LV Diastolic Dysfunction Grade	Number of Patients	Mean Urinary Microalbumin (mg/day)	Standard Deviation	p-value
Mild	20	37.6	43.2	
Moderate	10	55.7	43.6	
Severe	5	42.7	50.4	0.002

Pearson correlation coefficients were calculated to evaluate the relationship between urinary microalbumin levels and echocardiographic indices. A significant inverse correlation was found between microalbuminuria and the E/A ratio (r = –0.45, p = 0.001), while modest correlations were observed with LVEF and wall thickness measurements.

Table 7: Correlation Analysis between Microalbuminuria and Echocardiographic Parameters

Echocardiographic Parameter	Correlation Coefficient (r)	p-value
E/A Ratio	–0.45	0.001*
LVEF (%)	–0.30	0.01*
IVS Thickness (mm)	0.25	0.03*
LV Posterior Wall Thickness (mm)	0.28	0.02*

*Significant at p < 0.05

A multivariate logistic regression analysis was performed to identify independent predictors of left ventricular diastolic dysfunction. Variables such as age, duration of diabetes, HbA1c, and the presence of microalbuminuria were included. Microalbuminuria emerged as an independent predictor with an odds ratio (OR) of 2.5 (95% CI: 1.20–5.20, p = 0.01).

Table 8: Multivariate Logistic Regression Analysis for Predictors of LV Diastolic Dysfunction

Variable	Odds Ratio (OR)	95% Confidence Interval	p-value
Age (per year)	1.05	1.01 – 1.10	0.02*
Duration (years)	1.10	1.02 – 1.18	0.01*
HbA1c (%)	1.15	1.02 – 1.30	0.03*
Microalbuminuria	2.50	1.20 – 5.20	0.01*

*Significant at p < 0.05

A subgroup analysis was performed to compare the prevalence of left ventricular diastolic dysfunction between patients with a diabetes duration of less than 8 years and those with 8 or more years. Patients with a longer duration of diabetes demonstrated a higher prevalence of diastolic dysfunction.

Table 9: Subgroup Analysis Based on Duration of Diabetes

Duration of Diabetes	Number of Patients	LV Diastolic Dysfunction (n)	Percentage (%)	p-value
<8 years	40	20	50	0.04*
≥8 years	35	25	71.4	

*Significant at p < 0.05

The study further stratified patients based on glycemic control, using HbA1c cut-offs of <8% and ≥8%. Poor glycemic control (HbA1c ≥8%) was associated with a significantly higher prevalence of both microalbuminuria and left ventricular diastolic dysfunction.

Table 10: Association of Glycemic Control with Microalbuminuria and LV Dysfunction

HbA1c Category	Number of Patients	Microalbuminuria (n, %)	LV Dysfunction (n, %)	p-value
HbA1c < 8%	35	10 (28.6%)	12 (34.3%)	0.001*
HbA1c ≥ 8%	40	25 (62.5%)	28 (70.0%)	

*Significant at $p < 0.05$

No serious adverse events were reported during the study. In addition, incidental findings such as mild left ventricular hypertrophy and abnormal electrocardiographic changes were noted in a small subset of patients. These findings were not associated with any clinical symptoms and were considered subclinical.

Table 11: Summary of Adverse Events and Additional Clinical Findings

Parameter	Findings	Frequency (n)	Percentage (%)
Reported Adverse Events	None	0	0
Mild LV Hypertrophy (incidental)	Detected on echocardiography	5	6.7
Abnormal ECG Findings (incidental)	Minor conduction delays	3	4.0

DISCUSSION

The present study demonstrated that among the 75 patients with type 2 diabetes mellitus enrolled, 40 were categorized as normoalbuminuric and 35 as microalbuminuric, with a mean age of 55.2 ± 8.6 years and a male predominance (56% male, 44% female), indicating a relatively homogeneous demographic distribution across the groups. The baseline clinical characteristics revealed that the overall mean duration of diabetes was 8.1 ± 3.2 years, with normoalbuminuric patients having a slightly shorter duration (7.8 ± 2.9 years) compared to the microalbuminuric group (8.5 ± 3.5 years), suggesting that prolonged exposure to hyperglycemia might be associated with the development of microalbuminuria.

Glycemic control, as indicated by HbA1c values, was significantly poorer in the microalbuminuric group (8.5 ± 1.2%) compared to the normoalbuminuric group (8.0 ± 1.0%, $p = 0.04$), which underscored the relationship between inadequate glycemic management and the onset of microvascular complications. Biochemical analysis showed that serum creatinine levels were marginally higher in the microalbuminuric group (1.0 ± 0.2 mg/dL) versus the normoalbuminuric group (0.9 ± 0.2 mg/dL, $p = 0.08$), and the estimated glomerular filtration rate (eGFR) was slightly lower in microalbuminuric patients (88 ± 13 mL/min/1.73 m² compared to 92 ± 11 mL/min/1.73 m², $p = 0.09$), reflecting subtle early renal changes even though these differences did not reach statistical significance. In contrast, urinary microalbumin levels were markedly different, with normoalbuminuric patients demonstrating levels below 30 mg/day and microalbuminuric patients exhibiting a mean value of 78.5 ± 25.3 mg/day ($p < 0.001$), thus confirming the abnormal albumin excretion in the latter group.

Echocardiographic evaluations provided further insights into subclinical cardiac involvement; notably, the E/A ratio, a critical parameter of diastolic function, was significantly lower in the microalbuminuric group (1.0 ± 0.2) compared to the normoalbuminuric group (1.2 ± 0.2, $p = 0.002$), indicating impaired diastolic relaxation. Moreover, left ventricular ejection fraction (LVEF) was modestly reduced in microalbuminuric patients (59 ± 5%) relative to normoalbuminuric patients (61 ± 4%, $p = 0.03$), suggesting that even in the absence of overt heart failure symptoms, early systolic dysfunction might be emerging.

Additionally, measurements of cardiac structure revealed that interventricular septum (IVS) thickness was slightly increased in the microalbuminuric group (10.5 ± 1.2 mm versus 10.0 ± 1.0 mm, $p = 0.05$) and left ventricular posterior wall thickness was higher (10.3 ± 1.1 mm vs. 10.0 ± 0.9 mm, $p = 0.12$), though the latter difference did not achieve statistical significance, these findings hinted at early remodeling processes within the myocardium. The frequency distribution of left ventricular diastolic dysfunction grades among microalbuminuric patients further illuminated the severity of cardiac involvement; specifically, 57.1% of these patients were classified as having Grade I dysfunction, 28.6% had Grade II, and 14.3% exhibited Grade III dysfunction, thereby illustrating that a significant proportion of microalbuminuric patients had already developed clinically relevant diastolic abnormalities.

Correlation analyses reinforced these observations; a significant inverse relationship was identified between urinary microalbumin levels and the E/A ratio ($r = –0.45$, $p = 0.001$), while moderate correlations were also observed with LVEF ($r = –0.30$, $p = 0.01$) and a positive correlation with both IVS thickness ($r = 0.25$, $p = 0.03$) and left ventricular posterior wall thickness ($r = 0.28$, $p = 0.02$), suggesting that as microalbuminuria increased, indicators of diastolic function worsened and structural changes became more pronounced. Among microalbuminuric patients, mean urinary microalbumin levels were highest in those with moderate diastolic dysfunction, followed by severe and mild grades with statistically significant difference ($p = 0.002$), the trend suggests association between worsening diastolic function and increasing microalbuminuria, reinforcing its role as a potential early marker of cardiac involvement in diabetes.

The multivariate logistic regression analysis further identified microalbuminuria as an independent predictor of left ventricular diastolic dysfunction, with an odds ratio (OR) of 2.5 (95% CI: 1.20–5.20, p = 0.01), even after adjusting for confounding factors such as age (OR = 1.05 per year, 95% CI: 1.01–1.10, p = 0.02), duration of diabetes (OR = 1.10 per year, 95% CI: 1.02–1.18, p = 0.01), and HbA1c levels (OR = 1.15 per %, 95% CI: 1.02–1.30, p = 0.03), thereby underscoring the clinical utility of microalbuminuria as a prognostic marker for subclinical cardiac dysfunction. Subgroup analyses based on the duration of diabetes revealed that patients with a disease duration of less than 8 years had a prevalence of left ventricular diastolic dysfunction of 50%, whereas those with a duration of 8 or more years exhibited a higher prevalence of 71.4% (p = 0.04), indicating that the cumulative effect of prolonged hyperglycemia likely exacerbated myocardial impairment. Further stratification by glycemic control demonstrated that patients with HbA1c levels below 8% had significantly lower rates of microalbuminuria (28.6%) and left ventricular dysfunction (34.3%) compared to those with HbA1c levels equal to or exceeding 8%, who showed prevalences of 62.5% and 70% respectively (p = 0.001), which strongly suggested that poor glycemic control played a pivotal role in the pathogenesis of both renal and cardiac complications.

Notably, the study did not report any significant adverse events; only a small proportion of patients exhibited incidental findings such as mild left ventricular hypertrophy (6.7%) and minor electrocardiographic abnormalities (4.0%), which were considered subclinical and did not necessitate any change in management. Collectively, these comprehensive results provided compelling evidence that microalbuminuria was significantly associated with subclinical left ventricular diastolic dysfunction in patients with type 2 diabetes mellitus.

The observed reduction in the E/A ratio and LVEF among microalbuminuric patients, together with the significant correlations between increased urinary albumin excretion and echocardiographic markers of diastolic dysfunction, reinforced the hypothesis that microalbuminuria serves as an early and noninvasive marker for myocardial involvement. Furthermore, the multivariate analysis, which accounted for potential confounders, confirmed the independent predictive value of microalbuminuria, while subgroup analyses based on the duration of diabetes and glycemic control underscored the importance of these factors in the progression of diastolic dysfunction.

These findings, taken together, highlighted the clinical significance of early detection of microalbuminuria as a means to identify patients at risk for developing diabetic cardiomyopathy, thereby providing a rationale for implementing targeted interventions such as stricter glycemic control, renin-angiotensin system blockade, and lifestyle modifications. In light of these results, it was evident that the integration of biochemical markers with advanced echocardiographic assessments could facilitate the early identification of subclinical cardiac changes, ultimately allowing for the timely initiation of therapeutic strategies aimed at preventing the progression to overt heart failure.

Despite the inherent limitations of a cross-sectional study design, including the inability to establish causality and the potential for selection bias, the present study contributed valuable insights into the interplay between renal and cardiac dysfunction in type 2 diabetes mellitus. Future research, ideally employing longitudinal designs and larger sample sizes, was warranted to further elucidate the temporal relationship between microalbuminuria and the evolution of left ventricular diastolic dysfunction.

In conclusion, the study's findings—marked by significant differences in key echocardiographic parameters (E/A ratio of 1.0 ± 0.2 versus 1.2 ± 0.2, LVEF of 59 ± 5% versus 61 ± 4%), robust inverse correlations (r = –0.45 between microalbuminuria and the E/A ratio), and an independent predictive value of microalbuminuria (OR = 2.5, 95% CI: 1.20–5.20)—provided strong evidence that microalbuminuria was not only a marker of early renal dysfunction but also an important indicator of subclinical left ventricular diastolic dysfunction in asymptomatic type 2 diabetes mellitus patients, emphasizing the need for vigilant screening and early intervention in this high-risk population.

CONCLUSION

In conclusion, the study demonstrated that microalbuminuria was significantly associated with subclinical left ventricular diastolic dysfunction in asymptomatic type 2 diabetes mellitus patients. Patients with elevated urinary microalbumin levels not only exhibited poorer glycemic control and longer disease duration but also showed a reduced E/A ratio and lower left ventricular ejection fraction, indicating early cardiac impairment.

These findings underscore the clinical importance of incorporating routine microalbuminuria screening alongside echocardiographic evaluation in diabetic care to enable early detection of myocardial involvement, thereby allowing for timely therapeutic interventions that may prevent the progression to overt diabetic cardiomyopathy and reduce overall cardiovascular morbidity and mortality in this high-risk population.

REFERENCES

1. Guariguata L, Whiting DR, Hambleton I, et al. Global estimates of diabetes prevalence for 2013 and projections for 2035. Diabetes Res Clin Pract. 2014;103(2):137-149.
2. Jia G, Hill MA, Sowers JR. Diabetic cardiomyopathy: an update of mechanisms contributing to this clinical entity. Circ Res. 2018;122(4):624-638.
3. Waghmare P, Goswami K. Microalbuminuria: A mere marker or an ominous sign? J Assoc Physicians India. 2016;64(3):61-65.
4. Patro PK, Dash BK, et al. Study of Microalbuminuria in Type 2 Diabetes Mellitus as a Predictor of Left Ventricular Dysfunction-A Cohort Study. J Clin Diagn Res. 2021;15(10).
5. Mehta J, Godbole VY, Mehta KG, et al. Association of microalbuminuria with left ventricular dysfunction in type 2 diabetes mellitus. Egypt J Intern Med. 2021;33(1):1-6.
6. Ahmed SS, et al. Preclinical abnormality of left ventricular function in diabetes mellitus. Am Heart J. 1975;89(2):153-158.
7. Wu N, et al. Albuminuria is associated with left ventricular hypertrophy in patients with early diabetic kidney disease. Int J Endocrinol. 2014;2014.
8. Liu JE, et al. Association of albuminuria with systolic and diastolic left ventricular dysfunction in type 2 diabetes: the Strong Heart Study. J Am Coll Cardiol. 2003;41(11):2022-2028.
9. Poirier P, et al. Diastolic dysfunction in normotensive men with well-controlled type 2 diabetes. Clin Diabetol. 2001;2(2):159-166.
10. Gupta DK, et al. The prevalence of microalbuminuria in diabetes: a study from north India. Diabetes Res Clin Pract. 1991;12(2):125-128.