Original Article

Assessment of Estimated Glomerular Filtration Rate and Total Kidney Volume in Newly Diagnosed Type 2 Diabetes Mellitus: A Case–Control Study

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Abstract

Background: Type 2 Diabetes Mellitus (T2DM) is a major public health concern and a leading cause of diabetic kidney disease. Renal structural and functional alterations may develop early in the course of diabetes, even before the appearance of overt nephropathy. Assessment of estimated glomerular filtration rate (eGFR) and total kidney volume (TKV) may facilitate early detection of diabetic renal involvement. The objective is to assess estimated glomerular filtration rate and total kidney volume in newly diagnosed Type 2 Diabetes Mellitus patients and compare them with healthy controls, and to evaluate their relationship with glycemic parameters. **Material and Methods:** This hospital-based case–control study was conducted over one year from March 2025 to February 2026 at a tertiary care teaching hospital. A total of 320 participants were enrolled, comprising 160 newly diagnosed T2DM patients and 160 age- and sex-matched healthy controls. Clinical evaluation, anthropometric measurements, biochemical investigations, and ultrasonographic assessment of kidney dimensions were performed. eGFR was calculated using the CKD-EPI equation, and total kidney volume was determined using the ellipsoid formula. Statistical analysis was performed using SPSS version 26.0, with a p-value <0.05 considered statistically significant. **Results:** Newly diagnosed T2DM patients demonstrated significantly higher fasting blood glucose, postprandial blood glucose, HbA1c levels, serum creatinine, and total kidney volume compared with controls ($p<0.001$). Mean eGFR was significantly lower among cases (94.6 ± 15.3 mL/min/1.73 m²) than controls (103.8 ± 13.1 mL/min/1.73 m²; $p<0.001$). Total kidney volume was significantly higher in cases (290.1 ± 38.6 cm³) compared with controls (260.7 ± 34.8 cm³; $p<0.001$). HbA1c showed a significant negative correlation with eGFR and a positive correlation with total kidney volume. **Conclusion:** Newly diagnosed T2DM patients exhibit significant early renal structural and functional alterations characterized by increased kidney volume and reduced eGFR. These parameters may serve as useful early markers of diabetic kidney involvement and aid in timely intervention to prevent progression of diabetic kidney disease.

Keywords: Type 2 Diabetes Mellitus, Estimated Glomerular Filtration Rate, Total Kidney Volume, Diabetic Kidney Disease, Renal Hypertrophy, CKD-EPI.

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Introduction

Type 2 Diabetes Mellitus (T2DM) is one of the most common chronic metabolic diseases in the world and is a public health issue owing to the rise in its prevalence rates and its associated health complications. The International Diabetes Federation estimates that in 2021 there were about 537 million adults living with diabetes, and that this will grow to 783 million by 2045. India is one of the countries having high prevalence of diabetes, and it is also known as a "diabetes capital of the world" due to its high prevalence of T2DM.[1,2]

Diabetes mellitus is a disorder in which the blood glucose level is too high (hyperglycemia) due to decreased production of insulin, decreased sensitivity to insulin or both. Over a long period of time, hyperglycemia causes damage to the microvascular and macrovascular systems in various organ tissue systems, especially to the kidneys, eyes, nerves and cardiovascular system2. Diabetic kidney disease (DKD) is one of the most common types of chronic kidney disease (CKD) and end-stage renal disease (ESRD) in the world.[3]

In the early stage of diabetes, the kidneys' structure and function change in a few ways. Renal involvement can occur before proteinuria is detected or renal function is severely affected. One of the earliest manifestation is glomerular hyperfiltration: increase in GFR because of adaptive hemodynamic changes resulting from hyperglycemia.[4] While this hyperfiltration

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activity at first was thought to be a compensatory mechanism, continuing hyperfiltration leads to progressive glomerular damage and progressive renal damage.[5]

The best overall measure of kidney function is glomerular filtration rate. The use of exogenous GFR markers for direct measurement of GFR is often impractical in routine clinical practice due to its complexity, cost and limited availability.

Consequently, estimated glomerular filtration rate (eGFR), calculated using serum creatinine-based equations such as the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation, has become the preferred method for assessing renal function in both clinical practice and research settings.[6] Changes in eGFR may reflect early renal dysfunction even in newly diagnosed diabetic patients who are otherwise asymptomatic.[7]

In addition to functional alterations, structural changes in the kidneys occur early in the course of diabetes. Renal hypertrophy, manifested by an increase in kidney size and volume, is a well-recognized feature of early diabetic nephropathy.[8] Experimental and clinical studies have shown that hyperglycemia induces renal cellular hypertrophy, renal extracellular matrix expansion and renal blood flow in these cells, which leads to renal enlargement and total kidney volume.[9] One non-invasive tool that is easy to perform, cost-effective, and reproducible is the ultrasonographic determination of kidney volume, which measures these structural changes.[10]

Diabetic patients have been reported to have significantly larger kidney volume than non-diabetic, especially in the early phase of the disease when renal hypertrophy dominates.[11] Moreover, greater kidney volume has been linked to glycemic control, albuminuria, and lower renal function, thus making it a potential early sign of diabetic kidney involvement.[12] Few studies have been conducted, however, in newly diagnosed T2DM patients and limited data is available on renal structural and functional changes in these patients.

Improved knowledge of the changes in eGFR and total kidney volume at the onset of diabetes diagnosis could offer insights into the early physiological changes in diabetic kidneys and help to identify early signs for timely intervention to prevent progression to diabetic kidney disease. Moreover, the association of renal morphology and function could be enhanced to help stratify risk and identify patients that are at higher risk for future renal dysfunction.

Therefore, the present case–control study was undertaken to assess estimated glomerular filtration rate and total kidney volume in newly diagnosed Type 2 Diabetes Mellitus patients and to compare these parameters with those of age- and sex-matched healthy controls. The study also aimed to determine the relationship between eGFR, total kidney volume, and glycemic indices in newly diagnosed T2DM patients.

Materials and Methods

This hospital-based case–control study was conducted in the Department of General Medicine in collaboration with the Department of Radiodiagnosis and the Central Clinical Laboratory of a tertiary care teaching hospital over a period of one year, from March 2025 to February 2026. The study aimed to assess estimated glomerular filtration rate (eGFR) and total kidney volume (TKV) in newly diagnosed Type 2 Diabetes Mellitus (T2DM) patients and compare these parameters with those of healthy controls. A total of 320 participants were enrolled, comprising 160 newly diagnosed T2DM patients (cases) and 160 age- and sex-matched healthy individuals (controls). Newly diagnosed T2DM was defined according to the criteria of the American Diabetes Association. Patients aged 30–65 years who had been diagnosed with T2DM within the preceding six months and had not initiated antidiabetic treatment were included as cases. Healthy individuals with fasting plasma glucose levels below 100 mg/dL, HbA1c levels below 5.7%, and no history of diabetes mellitus, hypertension, or kidney disease were recruited as controls.

Participants with Type 1 diabetes mellitus, gestational diabetes mellitus, previously diagnosed diabetes mellitus, chronic kidney disease, polycystic kidney disease, congenital renal anomalies, renal malignancy, nephrolithiasis, previous renal surgery, hypertension, cardiovascular disease, chronic liver disease, malignancy, systemic inflammatory disorders, pregnancy, lactation, or current use of nephrotoxic medications were excluded from the study. Individuals with inadequate ultrasonographic visualization of the kidneys or those unwilling to provide informed consent were also excluded.

Demographic, clinical data, such as age, sex, occupation, family history of diabetes, duration of diabetes symptoms, smoking status, alcohol consumption, blood pressure and anthropometric measures were collected on a predesigned case record form, after written informed consent was obtained. The height and the weight were measured in a standard manner and their ratio (BMI) was determined as kg/m².

Venous blood samples were drawn after a 8-12 hour overnight fast for the estimation of fasting blood glucose (FBG), postprandial blood glucose (PPBG), glycated hemoglobin (HbA1c), serum creatinine, blood urea nitrogen (BUN). Serum creatinine was determined by isotope dilution mass spectrometry (IDMS)-traceable enzymatic method. The Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation was used to estimate GFR, which was reported as mL/min/1.73 m².

An experienced radiologist blinded to the diabetic status of the participants performed the ultrasonographic assessment of both kidneys with a high-resolution ultrasound machine using a convex transducer with a frequency of 3.5–5 MHz. The length (max longitudinal), width (transverse), and thickness (anteroposterior) of each kidney were measured. The volume of kidney was measured using the formula of Ellipsoid kidney (Volume (cm^3) = Length × Width × Thickness × 0.523). The total kidney volume was obtained by summing the volumes of the right and left kidneys. The three measurements were taken for each dimension to reduce measurement error and the mean value were analyzed.

In advance of starting the study, the protocol was examined and approved by the Institutional Ethics Committee. Informed written consent was requested for all participants and the study was performed according to the ethical principles of the Helsinki Declaration. Confidentiality and anonymity of all participant information was observed throughout the study.

Statistical Analysis

The primary outcome measures were eGFR and TKV. Correlation between eGFR and TKV and its correlation with fasting blood glucose, HbA1c, BMI and blood pressure were secondary outcomes. The data was input into Microsoft Excel and analysed using IBM SPSS statistics version 26.0. Continuous variables were reported as mean ± SD and categorical as frequencies and percentages. Shapiro–Wilk test was used to determine the normality of data distribution. Independent Student's t test was used to compare continuous variables and Chi square test was used to compare categorical variables between cases and controls. Pearson's correlation coefficient was computed to assess the correlation between eGFR and TKV and between eGFR, TKV and glycemic parameters. Multivariate linear regression analysis was conducted to determine eGFR and TKV independent predictors. P values <.05 were considered statistically significant.

Results

A total of 320 participants were included in the study, comprising 160 newly diagnosed Type 2 Diabetes Mellitus (T2DM) patients (cases) and 160 age- and sex-matched healthy controls. All enrolled participants completed clinical evaluation, laboratory investigations, and ultrasonographic assessment of kidney dimensions and were included in the final analysis.

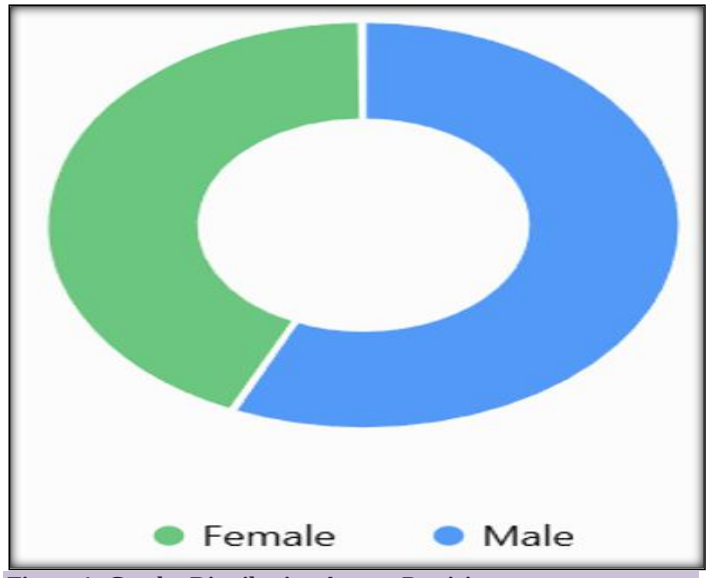

Figure 1: Gender Distribution Among Participants

Table 1: Baseline Characteristics of Study Participants

Variable	Cases (n=160)	Controls (n=160)	p-value
Age (years)	51.2 ± 8.7	50.4 ± 8.3	0.421
Male, n (%)	92 (57.5)	90 (56.3)	0.823
Female, n (%)	68 (42.5)	70 (43.7)	0.823
BMI (kg/m²)	28.4 ± 3.8	24.1 ± 3.1	<0.001
Systolic BP (mmHg)	128.6 ± 10.8	119.4 ± 9.2	<0.001
Diastolic BP (mmHg)	82.3 ± 6.9	77.1 ± 5.7	<0.001

The two groups were comparable with respect to age and sex distribution. Cases demonstrated significantly higher BMI and blood pressure values compared with controls.

Table 2: Glycemic Profile of Study Participants

Parameter	Cases (n=160)	Controls (n=160)	p-value
Fasting Blood Glucose (mg/dL)	168.4 ± 35.2	89.6 ± 8.4	<0.001
Postprandial Blood Glucose (mg/dL)	257.8 ± 52.6	118.3 ± 15.9	<0.001
HbA1c (%)	8.4 ± 1.2	5.2 ± 0.4	<0.001

Newly diagnosed T2DM patients exhibited significantly elevated fasting blood glucose, postprandial blood glucose, and HbA1c levels compared with healthy controls.

Table 3: Renal Function Parameters

Parameter	Cases (n=160)	Controls (n=160)	p-value
Serum Creatinine (mg/dL)	1.04 ± 0.21	0.89 ± 0.16	<0.001
Blood Urea Nitrogen (mg/dL)	20.8 ± 5.1	16.4 ± 3.8	<0.001
eGFR (mL/min/1.73m²)	94.6 ± 15.3	103.8 ± 13.1	<0.001

Cases demonstrated significantly higher serum creatinine and BUN levels along with lower eGFR compared with controls, indicating early alterations in renal function at the time of diabetes diagnosis.

Table 4: Ultrasonographic Renal Measurements

Parameter	Cases (n=160)	Controls (n=160)	p-value
Right Kidney Volume (cm³)	142.3 ± 20.4	128.1 ± 18.5	<0.001
Left Kidney Volume (cm³)	147.8 ± 22.1	132.6 ± 19.2	<0.001
Total Kidney Volume (cm³)	290.1 ± 38.6	260.7 ± 34.8	<0.001

Newly diagnosed T2DM patients exhibited significantly larger kidney volumes than controls, suggesting renal hypertrophy occurring early in the course of diabetes.

Table 5: Distribution of eGFR Categories Among Cases

eGFR Category	Frequency	Percentage
≥90 mL/min/1.73m²	102	63.8
60–89 mL/min/1.73m²	52	32.5
30–59 mL/min/1.73m²	6	3.7
<30 mL/min/1.73m²	0	0

Nearly two-thirds of diabetic patients had preserved renal function, while approximately one-third demonstrated mild reduction in eGFR, suggesting subclinical renal involvement at diagnosis.

Table 6: Correlation of eGFR with Clinical Parameters in Cases

Variable	Correlation Coefficient (r)	p-value
HbA1c (%)	-0.482	<0.001
Fasting Blood Glucose	-0.417	<0.001
BMI	-0.281	0.001
Total Kidney Volume	-0.356	<0.001

Estimated GFR showed a significant negative correlation with HbA1c, fasting blood glucose, BMI, and total kidney volume. Poor glycemic control was associated with lower renal function.

Table 7: Correlation of Total Kidney Volume with Clinical Parameters in Cases

Variable	Correlation Coefficient (r)	p-value
HbA1c (%)	0.523	<0.001
Fasting Blood Glucose	0.448	<0.001
BMI	0.301	<0.001
eGFR	-0.356	<0.001

Total kidney volume demonstrated a significant positive correlation with HbA1c, fasting blood glucose, and BMI. Patients with poorer glycemic control tended to have larger kidneys.

Table 8: Multivariate Linear Regression Analysis for Predictors of eGFR

Variable	β Coefficient	Standard Error	p-value
Age	-0.21	0.06	0.002
HbA1c	-0.39	0.08	<0.001
BMI	-0.18	0.05	0.011
Total Kidney Volume	-0.27	0.07	<0.001

Multivariate analysis identified HbA1c and total kidney volume as significant independent predictors of reduced eGFR among newly diagnosed T2DM patients.

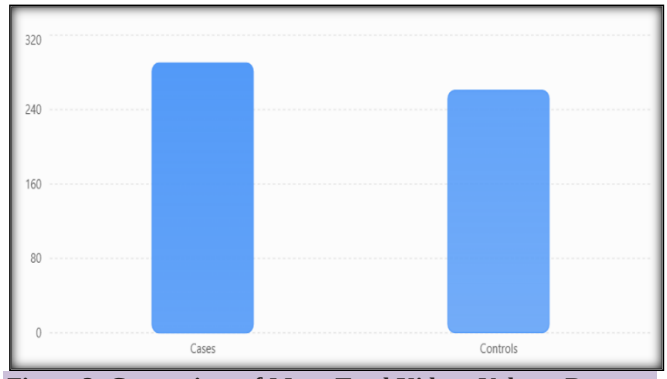

Figure 2: Comparison of Mean Total Kidney Volume Between Cases and Controls

Discussion

The estimated glomerular filtration rate (eGFR) and the total kidney volume (TKV) were measured in newly diagnosed Type 2 Diabetes Mellitus (T2DM) patients and also compared with healthy controls in the present case–control study. The results showed that newly diagnosed patients with T2DM had significantly lower levels of eGFR and significantly higher total kidney volumes compared to age- and sex-matched controls. Moreover, the poor glycemic control was linked to the higher renal volume and lower renal function, indicating that renal structural and functional changes may occur prior to the diagnosis of diabetes.

Demographic factors were similar between cases and controls in this study, as age and sex distribution were comparable, reducing the risk of demographic factors affecting renal parameters. The body mass index (BMI) was, however, significantly higher among diabetic patients. This finding was in line with earlier epidemiological research which showed that obesity is a significant risk factor for insulin resistance, diabetic kidney disease and T2DM.[12] Renal hypertrophy, increased adiposity and progressive nephron injury occur due to activation of inflammatory and metabolic pathways.[9]

Newly diagnosed T2DM patients had significant elevation of glycemic parameters (Fasting blood glucose, Postprandial blood glucose, HbA1c) compared to controls. This is expected and in line with the American Diabetes Association3 diagnostic criteria for diabetes mellitus. Chronic hyperglycemia is established as the major initiating event in diabetic nephropathy, which is mediated by the production of advanced glycation end products, activation of protein kinase C, oxidative stress and intraglomerular hypertension.[3]

One of the key findings of this study was the significantly decreased eGFR in newly diagnosed diabetic patients as compared to the controls. A large percentage of patients had a mild decrease of renal function, even though most had eGFR

values in the normal range. The results confirm that renal dysfunction could occur as early as the onset of the diabetes, and even prior to the onset of clinically apparent nephropathy. Ruggenenti et al. have also showed that slight changes in GFR can be detected as early as the onset of T2DM and can predict renal deterioration.[7] Similarly, Magee et al. demonstrated that earlier renal evaluation of abnormalities in glomerular hemodynamics and hyperfiltration, were linked to future renal decline5.The present study also demonstrated significantly increased total kidney volume in newly diagnosed T2DM patients. Renal hypertrophy is a well-recognized hallmark of early diabetic kidney involvement and is believed to result from increased renal plasma flow, glomerular hyperfiltration, tubular hypertrophy, and expansion of extracellular matrix components8. Experimental studies have shown that hyperglycemia stimulates renal growth through activation of growth factors such as transforming growth factor-β and insulin-like growth factor pathways.[9] The larger kidney volumes observed among diabetic patients in the present study are therefore consistent with the pathophysiological changes known to occur during the early stages of diabetic nephropathy.

The findings of this study are in agreement with those reported by Ahmed et al., who observed significantly larger renal volumes among patients with T2DM compared with healthy individuals.[11] Similarly, Zerbini et al. reported persistent renal hypertrophy in diabetic subjects and suggested that increased kidney size may represent an early manifestation of diabetic renal involvement.[8] In the present study, as in previous reports, the enlarged kidney in newly diagnosed diabetic patients lends further support to the hypothesis that structural changes in the kidney precede the onset of clinical symptoms of diabetic kidney disease.

One of the main findings of this study was that eGFR was significantly correlated with HbA1c, with a negative correlation. Patients with poor glycemic control had lower eGFR levels suggestive of early deterioration in renal function. These have also been observed in other studies in which chronic hyperglycemia was shown to promote the progression of glomerular injury and the loss of nephrons.[3-5] The correlation of glycemic control and renal function indicates the need to start to improve glucose control as early in the diagnosis as possible to prevent future renal complications from the disease.

Other significant results was that there was a positive relationship between total kidney volume and HbA1c. Patients with elevated HbA1c levels had larger renal enlargements. This is biologically-acceptable because the chronic hyperglycemia causes renal blood flow and cellular hypertrophy which results in the enlargement of renal structures. Other previous studies also indicated that glycemic control is a risk factor for larger kidney size and progression of diabetic nephropathy.[11,12] Kidney volume can thus be used as an early imaging marker to identify the group of diabetic patients who are prone to renal complications.

The study also showed that there was a strong negative correlation between total kidney volume and eGFR. Patients with larger-sized kidneys had lower eGFR values suggesting that renal hypertrophy may not just be a benign adaptive process but a continuous pathological process that contributes to progression of the renal function decline. This finding is in line with previous reports that reported that chronic renal enlargement is linked to progression of diabetic kidney disease and poor renal outcome.[8,12]

Multivariate regression analysis revealed that HbA1c and total kidney volume were independent factors of eGFR. Results indicate that, both metabolic control index and structural kidney changes are important contributors to early kidney dysfunction in newly identified T2DM patients. In line with these findings, Tonneijck et al. emphasized the intricate relationship between hyperglycemia, hyperfiltration and renal structural remodeling in the pathogenesis of diabetic kidney disease (DKD)4.

The present clinical observations are of interest. The findings that the kidney (kidney volume and eGFR) is involved earlier than previously thought in the newly diagnosed T2DM patients suggest that this involvement may start earlier than this. Regular checks of eGFR in combination with ultrasonographic measurement of kidney size can help to identify patients with an increased risk for diabetic nephropathy at an early stage. Early intervention with strict glycemic control and therapeutic interventions to lower blood pressure and prevent high blood sugar may help prevent or delay the progression to chronic kidney disease and end-stage renal disease.

The advantage of this study is that it had relatively large numbers of patients, had the participation of newly diagnosed, untreated diabetics, and used both functional and structural renal parameters. But there are some restrictions which need to be recognised. The case–control design does not allow for the determination of causality. The study involved only one tertiary care center, and the results may not be generalizable. Moreover, there would be no assessment of albuminuria and long term follow up data. Additional longitudinal studies are warranted to see if higher kidney size or volume is associated with renal function deterioration and progression of diabetic kidney disease in the future.

Conclusion

This study showed that early structural and functional changes in kidney are significant in patients with newly diagnosed Type 2 Diabetes Mellitus (T2DM) compared to healthy controls. The diabetic patients had significantly greater total kidney volume and reduced estimated glomerular filtration rate (eGFR), indicating that renal involvement is early in the disease process as early as the time when nephropathy develops. High HbA1c and fasting blood glucose levels were strongly correlated with elevated kidney volume and decreased eGFR and therefore are important for the onset of early diabetic renal changes. Moreover, the negative correlation between total kidney volume and eGFR implies that renal hypertrophy could be a sign of progressive renal dysfunction. This highlights the need for a detailed renal assessment when Type 2 Diabetes Mellitus is diagnosed. Periodic eGFR measurement with kidney ultrasonographic evaluation of kidney volume may help to detect the early involvement of the diabetic kidney and implement early preventive and therapeutic measures for maintaining renal

function. Thus, total kidney volume and eGFR may be useful initial markers of the risk for diabetic kidney disease and for long-term diabetic complications in diabetics.

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Conflicts of interest
There are no conflicts of interest.

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