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Original Research Article

Association Between Kidney Size and Estimated Glomerular Filtration Rate (eGFR) in Diabetic Nephropathy

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Conflict of interest: Nil

Abstract

Background: Diabetic nephropathy is one of the leading causes of chronic kidney disease (CKD) and end-stage kidney disease worldwide. Early identification of renal structural changes may facilitate timely intervention and improve clinical outcomes. Ultrasonography provides a non-invasive method for assessing renal morphology, while estimated glomerular filtration rate (eGFR) remains the standard indicator of renal function.

Aim: To evaluate the association between kidney size measured by ultrasonography and estimated glomerular filtration rate (eGFR) in patients with diabetic nephropathy.

Methods & Materials: This hospital-based observational cross-sectional study was conducted in the Departments of Nephrology and Radiodiagnosis of a tertiary care teaching hospital. A total of 110 adult patients with diabetic nephropathy were enrolled. Clinical and laboratory parameters, including serum creatinine, HbA1c, and eGFR, were recorded. Ultrasonographic measurements included kidney length, width, cortical thickness, and renal volume. Pearson correlation analysis was used to evaluate the relationship between renal dimensions and eGFR. One-way ANOVA was used to compare renal parameters across CKD stages, and multiple linear regression analysis was performed to identify independent predictors of eGFR.

Results: The mean age of participants was 58.42 ± 9.76 years, and 61.8% were male. Mean eGFR was 52.18 ± 24.37 mL/min/1.73 m², while mean HbA1c was 8.26 ± 1.34%. Mean renal volume was 116.48 ± 26.32 cm³. Significant positive correlations were observed between eGFR and right kidney length ($r = 0.512$, $p < 0.001$), left kidney length ($r = 0.538$, $p < 0.001$), right cortical thickness ($r = 0.701$, $p < 0.001$), left cortical thickness ($r = 0.724$, $p < 0.001$), and mean renal volume ($r = 0.615$, $p < 0.001$). Renal dimensions progressively decreased with advancing CKD stage ($p < 0.001$). Multiple linear regression analysis identified cortical thickness as the strongest independent predictor of eGFR ($\beta = 0.472$, $p < 0.001$), followed by renal length ($\beta = 0.294$, $p = 0.002$) and renal volume ($\beta = 0.238$, $p = 0.006$). Increasing age and longer duration of diabetes were independently associated with lower eGFR.

Conclusion: Ultrasonographic renal dimensions are significantly associated with renal function in patients with diabetic nephropathy. Cortical thickness demonstrated the strongest correlation with eGFR and emerged as the most important independent predictor of renal function. Renal ultrasonography, particularly assessment of cortical thickness, may serve as a valuable non-invasive tool for evaluating disease severity and monitoring progression in diabetic nephropathy.

Keywords: Diabetic nephropathy; Chronic kidney disease; eGFR; Cortical thickness; Renal volume; Diabetic kidney disease.

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Introduction

Diabetes mellitus (DM) remains one of the most important public health challenges worldwide and is the leading cause of chronic kidney disease (CKD) and end-stage kidney disease (ESKD). The global increase in the prevalence of type 2 diabetes has been accompanied by a substantial rise in diabetic nephropathy, which contributes significantly to cardiovascular morbidity, mortality, and healthcare expenditure [1, 2]. Early detection of renal involvement is therefore essential to delay disease progression and improve patient outcomes.

Estimated glomerular filtration rate (eGFR) is the most widely used indicator of renal function and serves as the cornerstone for the diagnosis, staging, and monitoring of CKD. The recent kidney disease: Improving Global Outcomes (KDIGO) 2024

Clinical Practice Guideline emphasizes the importance of eGFR assessment in conjunction with structural kidney abnormalities for comprehensive evaluation of kidney disease [3]. However, eGFR primarily reflects functional status and may not fully capture the underlying structural alterations occurring in diabetic kidneys.

Renal ultrasonography is a non-invasive, readily available, and cost-effective imaging modality that provides valuable information regarding renal morphology. Parameters such as renal length, cortical thickness, parenchymal thickness, renal volume, and cortical echogenicity have been increasingly investigated as markers of kidney damage and disease progression [4]. Structural changes in diabetic nephropathy include glomerular hypertrophy, tubular enlargement, interstitial fibrosis, and progressive nephron loss, all of which may influence kidney size and morphology [5].

Recent studies have highlighted the clinical significance of renal morphometric measurements in assessing kidney function. Araújo et al. (2020) demonstrated that sonographically determined kidney measurements combined with cortical echogenicity were significantly associated with reduced CKD-EPI eGFR and histopathological changes in patients with chronic kidney disease [6].

Their findings suggested that ultrasound-derived renal parameters may provide important information beyond conventional laboratory markers. In patients with diabetic kidney disease, ultrasonographic assessment has gained increasing attention as a potential prognostic tool. Ham et al. (2023) developed an ultrasound renal scoring system in patients with diabetic kidney disease and reported that renal cortical thickness, parenchymal thickness, and renal length were significantly associated with renal prognosis and declining kidney function [7]. Similarly, Kalfaoglu (2023) reported that renal ultrasonographic abnormalities correlated with the severity of diabetic nephropathy and reflected progressive renal impairment, highlighting the utility of imaging-based assessment in diabetic patients [8].

Aim & Objectives

Aim: To evaluate the association between kidney size measured by ultrasonography and estimated glomerular filtration rate (eGFR) in patients with diabetic nephropathy.

Objectives

- To determine the renal dimensions, including kidney length, width, cortical thickness, and renal volume, in patients with diabetic nephropathy using ultrasonography.
- To assess renal function by estimating glomerular filtration rate (eGFR) using serum creatinine-based calculations.
- To evaluate the correlation between renal size parameters and eGFR in patients with diabetic nephropathy.
- To compare renal morphological parameters across different stages of chronic kidney disease (CKD) based on eGFR.
- To identify independent ultrasonographic predictors of renal function using multivariable regression analysis.
- To evaluate the utility of renal size measurements as non-invasive markers of renal functional impairment in diabetic nephropathy.

Materials & Methods

Study Design: This hospital-based observational cross-sectional study was conducted to evaluate the association between kidney size measured by ultrasonography and estimated glomerular filtration rate (eGFR) in patients with diabetic nephropathy.

Study Place: The study was conducted in the Department of General Medicine at Swamy Vivekanandha Medical College Hospital & Research Institute, Namakkal, Tamilnadu, India.

Study Period: The study was carried out over a period of 12 months from October 2024 to September 2025.

Study Population: The study population comprised adult patients diagnosed with diabetic nephropathy attending the Nephrology Outpatient Department (OPD) or admitted to the inpatient wards during the study period.

Sample Size: A total of 110 patients with diabetic nephropathy fulfilling the eligibility criteria were enrolled consecutively during the study period.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee prior to commencement of the study. Written informed consent was obtained from all participants before enrollment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Confidentiality of patient information was maintained throughout the study, and all collected data were used solely for research purposes.

Inclusion Criteria

Patients meeting the following criteria were included:

- Adults aged ≥18 years.
- Patients diagnosed with Type 1 or Type 2 diabetes mellitus.

- Patients with diabetic nephropathy diagnosed on the basis of persistent albuminuria/proteinuria, reduced eGFR, and clinical evaluation consistent with diabetic kidney disease.
- Patients willing to provide written informed consent.

Exclusion Criteria

Patients fulfilling any of the following criteria were excluded:

- Known chronic kidney disease due to causes other than diabetic nephropathy.
- Polycystic kidney disease, congenital renal anomalies, or solitary kidney.
- Renal malignancy or renal mass lesions.
- Acute kidney injury at the time of enrollment.
- Obstructive uropathy or hydronephrosis.
- History of renal transplantation.
- Pregnant women.
- Patients with incomplete clinical or radiological data.

Methodology

Eligible patients were recruited consecutively after obtaining informed consent. A detailed clinical history was recorded, including age, sex, duration of diabetes mellitus, history of hypertension, medication use, and other relevant comorbidities.

A comprehensive physical examination was performed. Demographic and clinical data were documented using a structured case record form.

All participants underwent laboratory investigations and ultrasonographic assessment of both kidneys. Renal dimensions obtained from ultrasonography were correlated with renal function as assessed by eGFR.

Clinical and Laboratory Investigations: The following investigations were performed for all enrolled patients: complete blood count (CBC), fasting and postprandial blood glucose levels, glycated hemoglobin (HbA1c), serum urea, serum creatinine, serum electrolytes, urine routine microscopy, urinary albumin/protein estimation, and lipid profile.

These investigations were conducted using standard laboratory methods to assess glycemic status, renal function, and associated metabolic abnormalities. Serum creatinine was measured using a standardized enzymatic method. Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation and expressed as mL/min/1.73 m².

Based on eGFR values, patients were categorized according to KDIGO CKD staging:

- Stage 1: eGFR ≥90 mL/min/1.73 m²
- Stage 2: eGFR 60–89 mL/min/1.73 m²
- Stage 3a: eGFR 45–59 mL/min/1.73 m²
- Stage 3b: eGFR 30–44 mL/min/1.73 m²
- Stage 4: eGFR 15–29 mL/min/1.73 m²
- Stage 5: eGFR <15 mL/min/1.73 m²

Ultrasonographic Procedure: Renal ultrasonography was performed using a high-resolution ultrasound machine equipped with a 3.5–5.0 MHz curvilinear transducer. All examinations were conducted by experienced radiologists who were blinded to the patients' eGFR values.

Patients were examined in the supine and lateral decubitus positions. Longitudinal and transverse scans of both kidneys were obtained.

The following renal parameters were measured:

Kidney Length: Maximum bipolar renal length was measured in the longitudinal plane from the upper pole to the lower pole.

Kidney Width: Maximum transverse renal width was measured in the transverse plane.

Cortical Thickness: Cortical thickness was measured from the renal capsule to the base of the medullary pyramid at the mid-pole region of each kidney.

Renal Volume: Renal volume was calculated using the ellipsoid formula:

Renal Volume (cm³) = Length × Width × Thickness × 0.523

The average values of both kidneys were used for analysis whenever appropriate.

Outcome Measures

Primary Outcome Measure: To determine the association between ultrasonographic renal size parameters and estimated glomerular filtration rate (eGFR) in patients with diabetic nephropathy.

Secondary Outcome Measures

- To assess renal dimensions including kidney length, width, cortical thickness, and renal volume.
- To evaluate the correlation between renal morphometric parameters and renal function.
- To compare renal dimensions across different CKD stages.
- To identify independent predictors of eGFR using multivariable regression analysis.

Statistical Analysis: Data were entered into Microsoft Excel 365 and subsequently analyzed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA). Continuous

variables were tested for normality using the Shapiro–Wilk test. Normally distributed continuous variables were expressed as mean ± standard deviation (SD), whereas non-normally distributed variables were presented as median and interquartile range (IQR). Categorical variables were expressed as frequencies and percentages. Pearson's correlation coefficient (r) was used to evaluate the relationship between renal size parameters (kidney length, cortical thickness, and renal volume) and eGFR.

Comparison of renal dimensions across different CKD stages was performed using one-way analysis of variance (ANOVA). Post hoc Tukey's test was applied where appropriate to identify intergroup differences.

Multiple linear regression analysis was performed to identify independent predictors of eGFR.

Variables including age, duration of diabetes mellitus, mean renal length, mean cortical thickness, and mean renal volume were entered into the regression model.

Regression coefficients (β), standard errors (SE), t-values, and corresponding p-values were calculated.

All statistical tests were two-tailed. A p-value <0.05 was considered statistically significant.

Results

A total of 110 patients with diabetic nephropathy were enrolled in the study.

Table 1: Demographic and Clinical Characteristics of Patients with Diabetic Nephropathy (n = 110)

Characteristics	Variables	Value
Mean age (years)	-	58.42 ± 9.76
Gender, n (%)	Male	68 (61.8)
	Female	42 (38.2)
Duration of Diabetes (years)	-	12.84 ± 5.62
Serum Creatinine (mg/dL)	-	2.14 ± 1.08
eGFR (mL/min/1.73 m²)	-	52.18 ± 24.37
HbA1c (%)	-	8.26 ± 1.34

Table 1 present the mean age of the participants was 58.42 ± 9.76 years. Males constituted the majority of the study population, accounting for 68 (61.8%) patients, while females comprised 42 (38.2%) patients. The mean duration of diabetes mellitus was 12.84 ± 5.62 years. The mean serum creatinine level was 2.14 ± 1.08 mg/dL, whereas the mean estimated glomerular filtration rate (eGFR) was 52.18 ± 24.37 mL/min/1.73 m². The mean HbA1c level was 8.26 ± 1.34%, indicating suboptimal glycemic control among the study participants.

Table 2: Ultrasonographic Renal Dimensions Among Patients with Diabetic Nephropathy (n = 110)

Renal Parameters	Mean ± SD
Right Kidney Length (cm)	10.21 ± 1.12
Left Kidney Length (cm)	10.38 ± 1.16
Right Kidney Width (cm)	4.86 ± 0.62
Left Kidney Width (cm)	4.93 ± 0.59
Right Cortical Thickness (mm)	8.24 ± 1.71
Left Cortical Thickness (mm)	8.36 ± 1.68
Mean Renal Volume (cm³)	116.48 ± 26.32

Table 2 demonstrate the mean right and left kidney lengths were 10.21 ± 1.12 cm and 10.38 ± 1.16 cm, respectively. The mean right kidney width was 4.86 ± 0.62 cm, while the mean left kidney width was 4.93 ± 0.59 cm. The mean cortical thickness measured 8.24 ± 1.71 mm in the right kidney and 8.36 ± 1.68 mm in the left kidney. The mean renal volume was 116.48 ± 26.32 cm³, reflecting the overall renal size among patients with diabetic nephropathy.

Table 3: Distribution of Patients According to CKD Stages Based on eGFR (n = 110)

CKD Stage	eGFR Range (mL/min/1.73 m²)	Frequency (n)	Percentage (%)
Stage 1	≥90	8	7.3
Stage 2	60–89	28	25.5
Stage 3a	45–59	22	20.0
Stage 3b	30–44	24	21.8
Stage 4	15–29	18	16.4
Stage 5	<15	10	9.1
Total	—	110	100.0

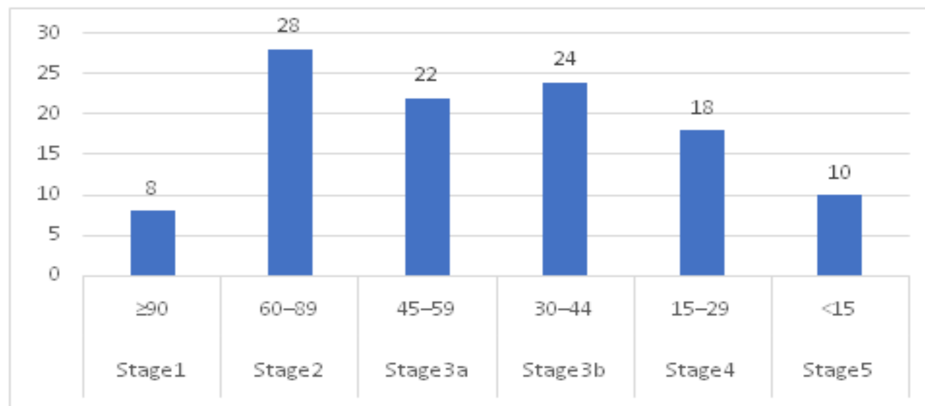

Figure 1: Distribution of Patients According to CKD Stages Based on eGFR (mL/min/1.73 m²)

Table 3 and Figure I, show the largest proportion of patients belonged to CKD Stage 2, accounting for 28 (25.5%) patients, followed by Stage 3b with 24 (21.8%) patients and Stage 3a with 22 (20.0%) patients. Eighteen (16.4%) patients were classified as Stage 4, while 10 (9.1%) patients had Stage 5 disease. Only 8 (7.3%) patients were categorized as Stage 1 CKD. Overall, more than two-thirds of the study population were in CKD Stages 2 to 4, indicating a substantial burden of moderate-to-severe renal impairment among patients with diabetic nephropathy.

Table 4: Correlation Between Renal Size Parameters and Estimated Glomerular Filtration Rate (eGFR)

Renal Parameter	Pearson Correlation Coefficient (r)	p-value
Right Kidney Length	0.512	<0.001*
Left Kidney Length	0.538	<0.001*
Right Cortical Thickness	0.701	<0.001*
Left Cortical Thickness	0.724	<0.001*
Mean Renal Volume	0.615	<0.001*

*Pearson correlation analysis; statistically significant at $p < 0.05$.

Table 4 presents the correlation between renal size parameters and eGFR. Pearson correlation analysis demonstrated statistically significant positive correlations between all ultrasonographic renal measurements and eGFR ($p < 0.001$ for all comparisons). Left cortical thickness exhibited the strongest positive correlation with eGFR ($r = 0.724$), followed by right cortical thickness ($r = 0.701$). Mean renal volume also showed a strong positive correlation ($r = 0.615$), whereas left kidney length ($r = 0.538$) and right kidney length ($r = 0.512$) demonstrated moderate positive correlations. These findings suggest that larger renal dimensions, particularly cortical thickness, are associated with better renal function in patients with diabetic nephropathy.

Table 5: Comparison of Renal Dimensions Across Different CKD Stages (n = 110)

CKD Stage	Mean Kidney Length (cm) Mean ± SD	Mean Cortical Thickness (mm) Mean ± SD	Mean Renal Volume (cm³) Mean ± SD
Stage 1 (n=8)	11.48 ± 0.72	10.62 ± 0.83	142.16 ± 18.74
Stage 2 (n=28)	10.96 ± 0.84	9.54 ± 1.12	131.74 ± 19.56
Stage 3a (n=22)	10.42 ± 0.91	8.76 ± 1.14	120.52 ± 21.32
Stage 3b (n=24)	9.98 ± 0.86	7.96 ± 1.21	111.34 ± 22.46
Stage 4 (n=18)	9.42 ± 0.94	6.98 ± 1.16	98.42 ± 18.84
Stage 5 (n=10)	8.84 ± 0.88	6.12 ± 1.08	86.68 ± 16.42
p-value	<0.001*	<0.001*	<0.001*

*One-way ANOVA; statistically significant at $p < 0.05$.

Table 5 show that a progressive decline in renal dimensions was observed with worsening CKD stage. Mean kidney length decreased from 11.48 ± 0.72 cm in Stage 1 to 8.84 ± 0.88 cm in Stage 5. Similarly, mean cortical thickness declined from 10.62 ± 0.83 mm in Stage 1 to 6.12 ± 1.08 mm in Stage 5, while mean renal volume decreased from 142.16 ± 18.74 cm³ to 86.68 ± 16.42 cm³ across the same stages. One-way ANOVA demonstrated statistically significant differences in kidney length, cortical thickness, and renal volume across CKD stages ($p < 0.001$ for all comparisons), indicating that renal structural parameters progressively deteriorate with declining kidney function.

Table 6: Multiple Linear Regression Analysis for Predictors of eGFR Among Patients with Diabetic Nephropathy

Predictor Variable	Standardized β Coefficient	Standard Error	t-value	p-value
Age (years)	-0.218	0.081	-2.69	0.012*
Duration of Diabetes (years)	-0.184	0.076	-2.42	0.024*
Mean Renal Length (cm)	0.294	0.088	3.34	0.002*
Mean Cortical Thickness (mm)	0.472	0.073	6.47	<0.001*
Mean Renal Volume (cm³)	0.238	0.082	2.90	0.006*

*Statistically significant at $p < 0.05$.

Table 6 show that cortical thickness emerged as the strongest independent predictor of eGFR (β = 0.472, $p < 0.001$), followed by mean renal length (β = 0.294, p = 0.002) and mean renal volume (β = 0.238, p = 0.006). In contrast, increasing age (β = −0.218, p = 0.012) and longer duration of diabetes (β = −0.184, p = 0.024) were independently associated with lower eGFR values. These findings indicate that renal morphological parameters, particularly cortical thickness, are significant determinants of renal function independent of age and duration of diabetes. Overall, the regression model demonstrated good explanatory power for predicting eGFR among patients with diabetic nephropathy.

Discussion

In the present study, the mean age of patients was 58.42 ± 9.76 years, with a predominance of male participants (61.8%). The mean duration of diabetes was 12.84 ± 5.62 years, while the mean serum creatinine and eGFR were 2.14 ± 1.08 mg/dL and 52.18 ± 24.37 mL/min/1.73 m², respectively. The mean HbA1c level of 8.26 ± 1.34% indicated suboptimal glycemic control among most participants. The observed age distribution is consistent with the natural history of diabetic nephropathy, which generally develops after several years of diabetes. Alicic et al. (2017) reported that diabetic kidney disease is most frequently encountered in middle-aged and elderly patients with long-standing diabetes and is associated with progressive decline in renal function [9]. Similarly, de Boer et al. (2022) observed that increasing age and longer diabetes duration significantly increase the risk of chronic kidney disease progression among patients with type 2 diabetes [10].

The predominance of male patients in our study is comparable to findings reported by Afkarian et al. (2016), who demonstrated a higher prevalence of diabetic kidney disease among men, possibly due to differences in hormonal influences, cardiovascular risk profiles, and lifestyle-related factors [11]. Furthermore, the elevated HbA1c levels observed in the present study support the established role of poor glycemic control in accelerating glomerular injury and nephron loss. Heerspink et al. (2020) reported that sustained hyperglycemia is strongly associated with albuminuria progression and decline in eGFR among diabetic individuals [12].

The mean eGFR observed in the present study indicates moderate impairment of renal function. This finding agrees with observations reported by Rossing et al. (2022), who noted that many patients with diabetic nephropathy present during the stage of moderate renal dysfunction rather than during the early asymptomatic phase [13].

The present study demonstrated mean right and left kidney lengths of 10.21 ± 1.12 cm and 10.38 ± 1.16 cm, respectively, with a mean renal volume of 116.48 ± 26.32 cm³. Mean cortical thickness was 8.24 ± 1.71 mm in the right kidney and 8.36 ± 1.68 mm in the left kidney.These findings indicate measurable structural alterations in the kidneys of patients with diabetic nephropathy. Although diabetic kidneys may initially undergo hypertrophy because of glomerular hyperfiltration, progressive nephron loss and interstitial fibrosis eventually lead to reduction in renal dimensions. Beland et al. (2020) reported that cortical thinning and reduced renal volume are among the most reliable ultrasonographic indicators of chronic renal damage [14].

Our findings are comparable to those reported by Singh et al. (2022), who observed significant reductions in renal cortical thickness and renal volume among patients with chronic kidney disease compared with healthy controls [15]. Similarly, Yuvabalakumaran et al. (2024) demonstrated that renal length, cortical thickness, and renal volume were significantly associated with renal function and progressively declined with worsening kidney disease [16]. The slightly greater dimensions observed in the left kidney compared with the right kidney are consistent with normal anatomical variations reported in previous imaging studies.

The cortical thickness values observed in our study suggest ongoing nephron loss and tubulointerstitial damage. Recent evidence by Limpisook et al. (2024) emphasized that renal cortical thickness remains one of the most reproducible sonographic markers for evaluating renal parenchymal integrity and chronic kidney disease severity [17].

The present study demonstrated that the largest proportion of patients belonged to CKD Stage 2 (25.5%), followed by Stage 3b (21.8%) and Stage 3a (20.0%). More than two-thirds of the participants were distributed across CKD Stages 2–4, indicating a substantial burden of moderate-to-advanced renal dysfunction. This findings are consistent with global epidemiological trends showing that diabetic nephropathy is frequently diagnosed after substantial decline in renal function has already occurred. Kovesdy (2022) reported that CKD Stages 2–4 account for the majority of diagnosed diabetic kidney disease cases worldwide, whereas Stage 1 disease remains relatively underdiagnosed because of its asymptomatic nature [18].

Similarly, Tuttle et al. (2022) observed that patients with diabetic nephropathy commonly present with moderate reductions in eGFR, reflecting delayed referral and limited early screening practices [19]. The relatively low proportion of Stage 1 patients in the present study supports this observation.

The substantial proportion of patients in Stages 4 and 5 further highlights the progressive nature of diabetic nephropathy. Fu et al. (2023) demonstrated that individuals with advanced diabetic kidney disease have markedly increased risks of cardiovascular events, hospitalization, and mortality compared with those in earlier CKD stages [20].

A major finding of the present study was the significant positive correlation between all renal size parameters and eGFR. Cortical thickness showed the strongest correlation, particularly left cortical thickness ($r = 0.724$), followed by right cortical thickness ($r = 0.701$). Renal volume also demonstrated a strong positive correlation ($r = 0.615$), whereas kidney length exhibited moderate positive correlations. These findings suggest that preservation of renal cortical architecture is closely linked to maintenance of renal function. Similar observations were reported by Moghazi et al. (2021), who found that cortical thickness correlated more strongly with renal function than kidney length or overall renal size [21]. Likewise, Yuvabalakumaran et al. (2024) reported significant positive correlations between eGFR and renal volume, cortical thickness, and kidney length, emphasizing the usefulness of sonographic measurements in evaluating renal function [16].

Studies by Beland et al. (2020) and Schmidt et al. (2023) further demonstrated that cortical thickness reflects the amount of functioning nephron mass and therefore exhibits stronger associations with eGFR than gross kidney dimensions [14, 22]. The strong correlation identified in the present study supports the concept that cortical thickness may serve as a surrogate marker of residual renal function in diabetic nephropathy.

The present study demonstrated a progressive reduction in kidney length, cortical thickness, and renal volume with advancing CKD stage. Mean kidney length decreased from 11.48 cm in Stage 1 to 8.84 cm in Stage 5, while cortical thickness decreased from 10.62 mm to 6.12 mm. Renal volume similarly declined from 142.16 cm^3 to 86.68 cm^3.These findings reflect the structural consequences of progressive nephron loss, glomerulosclerosis, and tubulointerstitial fibrosis. O'Neill et al. (2021) reported that reduction in cortical thickness parallels histological deterioration and increasing CKD severity [23]. Similar trends were documented by Singh et al. (2022), who observed significant reductions in renal dimensions with declining eGFR across CKD stages [15]. Furthermore, Yuvabalakumaran et al. (2024) reported that patients with advanced CKD exhibited substantially lower renal volumes and cortical thicknesses than those in early disease stages [16]. The statistically significant differences observed across CKD stages in the present study therefore reinforce the utility of ultrasonographic measurements as indicators of disease progression.

Multiple linear regression analysis revealed that cortical thickness was the strongest independent predictor of eGFR ($\beta = 0.472$, $p < 0.001$), followed by renal length and renal volume. Increasing age and longer duration of diabetes were independently associated with lower eGFR values. These findings indicate that structural renal parameters provide independent information regarding renal function beyond traditional clinical variables. Similar findings were reported by Yasuda et al. (2018), who demonstrated that cortical thickness was the strongest ultrasonographic predictor of future renal decline and progression to dialysis [24]. Their longitudinal analysis showed that cortical thickness outperformed kidney length and renal volume in predicting renal outcomes. The negative effects of age and diabetes duration observed in our study are biologically plausible because aging and chronic hyperglycemia contribute to nephron loss, vascular injury, and renal fibrosis. Rossing et al. (2022) reported that both factors independently accelerate decline in eGFR among patients with diabetic kidney disease [13].

Limitations of the Study

- The present study was limited by its cross-sectional and single-centre design, which restricts causal inference and generalizability.
- Renal measurements were obtained using ultrasonography, an operator-dependent modality subject to measurement variability. eGFR was estimated using serum creatinine-

based equations rather than directly measured GFR.

- Additionally, potential confounding factors such as proteinuria, medication use, and other comorbidities were not fully evaluated.
- The absence of longitudinal follow-up precluded assessment of temporal changes in renal morphology and function.

Conclusion

The present study demonstrated a significant positive association between ultrasonographic renal size parameters and estimated glomerular filtration rate in patients with diabetic nephropathy. Renal cortical thickness showed the strongest correlation with eGFR and emerged as the most significant independent predictor of renal function after adjustment for age, duration of diabetes, renal length, and renal volume.

Furthermore, kidney length, cortical thickness, and renal volume progressively decreased with advancing CKD stage, indicating a close relationship between renal structural changes and declining kidney function. These findings suggest that ultrasonographic renal measurements, particularly cortical thickness, may serve as useful non-invasive markers for assessing renal functional status and disease severity in diabetic nephropathy.

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