Original Article

Ultrasonographic Renal Parameters as Predictors of Chronic Kidney Disease Progression

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Abstract

Background: Chronic kidney disease (CKD) is a progressive condition associated with significant morbidity, mortality, and healthcare burden worldwide. Early identification of patients at risk of disease progression remains essential for timely intervention. Ultrasonography offers a non-invasive and widely accessible method for evaluating structural renal changes that may reflect underlying functional impairment. The objective is to evaluate the utility of ultrasonographic renal parameters as predictors of chronic kidney disease progression and to determine their relationship with renal functional status. **Material and Methods:** This prospective observational study included 230 patients diagnosed with CKD stages 1–5. Demographic, clinical, laboratory, and ultrasonographic data were collected. Ultrasonographic parameters assessed included renal length, renal width, cortical thickness, parenchymal thickness, renal volume, and cortical echogenicity. Estimated glomerular filtration rate (eGFR) was calculated using the CKD-EPI equation. **Results:** The mean age of participants was 56.8 ± 13.4 years, and 60.0% were male. Stage 3 CKD was the most common disease category (40.9%), followed by Stage 4 CKD (25.2%). Renal cortical thickness demonstrated the strongest positive correlation with eGFR ($r = 0.71$, $p < 0.001$), followed by parenchymal thickness ($r = 0.64$, $p < 0.001$), renal volume ($r = 0.58$, $p < 0.001$), and renal length ($r = 0.52$, $p < 0.001$). **Conclusion:** Ultrasonographic renal parameters, particularly cortical thickness, cortical echogenicity, and renal volume, are significant predictors of chronic kidney disease progression. Renal cortical thickness exhibited the strongest association with renal function and demonstrated excellent diagnostic performance for predicting disease progression.

Keywords: Chronic kidney disease; Ultrasonography; Renal cortical thickness; Renal echogenicity; Renal volume; Estimated glomerular filtration rate; Disease progression.

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Introduction

Chronic kidney disease (CKD) is a major global public health challenge characterized by a progressive and irreversible decline in renal structure and function. According to international estimates, CKD affects approximately 10–15% of the adult population worldwide and is associated with increased morbidity, mortality, cardiovascular complications, and healthcare expenditure.[1] The disease is defined by the presence of kidney damage or a reduction in glomerular filtration rate (GFR) below 60 mL/min/1.73 m² for at least three months, irrespective of the underlying etiology.[2] The rising prevalence of diabetes mellitus, hypertension, obesity, and aging populations has substantially contributed to the growing burden of CKD globally.[3]

Proper evaluation of the progression of the CKD is crucial for early therapeutic intervention and avoiding end-stage renal disease (ESRD). Biochemical parameters like serum Cr, urea nitrogen and estimated GFR (eGFR) have been traditionally used to assess renal function. These laboratory markers give important information about the function of the kidneys, but do not necessarily indicate the severity of the renal damage, especially in the initial stages of renal disease.[4] Thus, imaging techniques which show the morphological changes that occur within the kidneys have become increasingly significant when evaluating and monitoring CKD.

Ultrasonography is the most commonly used imaging method for renal assessment as it is non-invasive, inexpensive, radiation free, readily available, and easily repeatable.[5] An ultrasound of the kidneys can give useful information about the morphology of the kidneys and also be used to evaluate several structural parameters which may have a relationship with renal function. The parameters include renal length, renal volume, cortical thickness, parenchymal thickness, and echo characteristics of the cortex, corticomedullary differentiation, and intrarenal vascular indices.[6] These sonographic properties shift frequently with the changes in the pathological processes on the progress of CKD, such as nephron loss, glomerulosclerosis, tubular atrophy and interstitial fibrosis.[7]

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Renal length has been traditionally considered as a marker of chronic renal damage among ultrasonographic parameters. Loss of nephrons and fibrosis usually accompany the decrease in renal size, especially in advanced CKD.[8] The length of the kidneys, however, does not necessarily correlate with renal function as some renal diseases and age and sex influence kidney size. To gain this, the researchers sought other sonographic features that could more closely correlate with renal functional status.[9]

Renal cortical thickness has become one of the more promising parameters since most of the functioning glomeruli and proximal tubules are located in the renal cortex. These are progressive, so if they are destroyed, the cortex thins, sometimes in a manner that closely resembles the fall in renal function. A few studies have found that there are significant associations between eGFR and cortical thickness, indicating that cortical thickness may be a good sensitive marker used to reflect accurately the severity and progression of CKD.[10–12] Beland et al,[10] reported that cortical thickness was more strongly correlated with renal function than renal length, suggesting the ability of cortical thickness to be a useful clinical parameter for evaluating CKD.

Another renal sonographic feature that is of primary importance to be assessed in patients with CKD is renal cortical echogenicity. These factors are believed to lead to increased cortical echogenicity: glomerulosclerosis, tubular atrophy, inflammatory infiltrates and interstitial fibrosis. Gradually as the renal parenchymal damage gets more pronounced, the renal cortex becomes more echogenic than the liver or spleen.[13] Previous study has shown that the higher the grade of cortical echogenicity, the worse the renal function and the more advanced the stage of renal chronic kidney disease (CKD).[14] Moreover, when a patient develops chronic renal parenchymal disease, loss of corticomedullary differentiation is often seen and may be a sign of widespread structural damage.[5]

It is also now recognised that renal volume and parenchymal thickness are important new variables to consider as predictors of renal function decline. Renal volume indicates the total mass of the nephrons, and is reported to be positively associated with eGFR in multiple cohorts of patients.[15] Similarly, thinning of the parenchyma can be a marker of progressing renal scarring and renal function impairment.[16] Multiple ultrasonographic parameters may therefore give a more complete picture of the progression of the disease than would any one parameter alone.

Since there is a growing focus on early detection and monitoring of the progression of CKD, there has been a growing interest in the identification of reliable, non-invasive imaging biomarkers beyond biochemical assessment. Ultrasonographic renal parameters are valuable tools for the assessment of structural changes in the kidneys and also for predicting the prognosis of the disease and are a practical and cost-effective method. The correlation of these sonographic features with renal function may help in earlier identification of patients at risk, drive clinical management and enhance long-term outcomes. Thus, the use of ultrasonographic renal parameters as markers for the progression of CKD is a recent fertile field of current nephrology research.

Materials and Methods

Study Design and Setting: This prospective observational study was conducted in the Department of Nephrology in collaboration with the Department of Radiodiagnosis at a tertiary care teaching hospital. The study was carried out over a period of 24 months following approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrollment. The study adhered to the principles outlined in the Declaration of Helsinki and its subsequent amendments.

Study Population: A total of 230 patients diagnosed with chronic kidney disease (CKD) were consecutively recruited during the study period. CKD was defined according to the Kidney Disease: Improving Global Outcomes (KDIGO) guidelines as evidence of kidney damage or an estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m² persisting for at least three months.

Inclusion Criteria

1. Patients aged ≥18 years.
2. Confirmed diagnosis of CKD stages 1–5 according to KDIGO criteria.
3. Availability of baseline renal ultrasonographic evaluation and laboratory investigations.
4. Willingness to participate and provide informed consent.

Exclusion Criteria

1. Acute kidney injury or acute-on-chronic kidney injury.
2. Congenital renal anomalies, including polycystic kidney disease and horseshoe kidney.
3. Obstructive uropathy, hydronephrosis, or renal malignancy.
4. Previous renal transplantation.
5. Solitary kidney.
6. Pregnant women.
7. Inadequate ultrasonographic visualization of kidneys.

Sample Size Calculation: The sample size was calculated using the formula for estimating correlations between ultrasonographic renal parameters and renal function indices. Assuming a moderate correlation coefficient (r = 0.20–0.25), a confidence level of 95%, statistical power of 80%, and allowing for potential attrition, a minimum sample size of 220 participants was required. To enhance statistical reliability, 230 patients were included in the final analysis.

Clinical and Laboratory Assessment: Demographic characteristics including age, sex, body mass index (BMI), duration of CKD, comorbidities, and medication history were recorded. Blood pressure measurements were obtained using a standardized protocol.

Venous blood samples were collected for estimation of serum creatinine, blood urea nitrogen, hemoglobin, fasting blood glucose, serum albumin, and electrolyte levels. Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation. Urinary protein excretion was assessed using spot urine protein-to-creatinine ratio or 24-hour urinary protein measurements where applicable.

Ultrasonographic Evaluation: All participants underwent renal ultrasonography using a high-resolution ultrasound system equipped with a 3.5–5 MHz convex transducer. Examinations

were performed by experienced radiologists who were blinded to laboratory findings.

The following ultrasonographic renal parameters were measured bilaterally:

- Renal length (cm): Maximum longitudinal pole-to-pole distance.
- Renal width (cm): Maximum transverse diameter.
- Renal cortical thickness (mm): Measured from the renal capsule to the base of the medullary pyramid.
- Renal parenchymal thickness (mm): Distance from the renal sinus to the outer renal capsule.
- Renal volume (cm^3): Calculated using the ellipsoid formula:

Volume = Length × Width × Thickness × 0.523

- Cortical echogenicity: Graded according to comparison with adjacent liver or spleen parenchyma:
  - Grade 0: Normal echogenicity.
  - Grade I: Mild increase.
  - Grade II: Moderate increase.
  - Grade III: Marked increase.
  - Grade IV: Severe increase with loss of corticomedullary differentiation.
- Corticomedullary differentiation: Classified as preserved or impaired.

The mean values of both kidneys were used for statistical analysis.

Outcome Measures

The primary outcome was CKD progression, defined as:

1. A decline in eGFR of ≥25% from baseline accompanied by worsening CKD stage, or
2. Initiation of renal replacement therapy (hemodialysis, peritoneal dialysis, or kidney transplantation), or
3. Development of end-stage renal disease (eGFR <15 mL/min/1.73 m^2).

Secondary outcomes included the association between individual ultrasonographic parameters and baseline renal function.

Statistical Analysis: Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR) depending on data distribution. Categorical variables were presented as frequencies and percentages.

Normality of data distribution was assessed using the Shapiro–Wilk test. Comparisons between groups were performed using the independent samples t-test or Mann–Whitney U test for continuous variables and the Chi-square test or Fisher's exact test for categorical variables.

Pearson or Spearman correlation coefficients were calculated to evaluate associations between ultrasonographic renal parameters and eGFR. Multivariable logistic regression analysis was performed to identify independent ultrasonographic predictors of CKD progression after adjustment for potential confounders including age, sex, diabetes mellitus, hypertension, and baseline eGFR.

Receiver operating characteristic (ROC) curve analysis was conducted to determine the predictive performance and optimal cut-off values of significant ultrasonographic parameters. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). A two-tailed p-value <0.05 was considered statistically significant.

Results

A total of 230 patients with chronic kidney disease (CKD) were included in the study. The mean age of the participants was 56.8 ± 13.4 years (range: 21–85 years), and 138 (60.0%) were males. Diabetes mellitus and hypertension were present in 128 (55.7%) and 162 (70.4%) patients, respectively. The mean estimated glomerular filtration rate (eGFR) was 39.5 ± 19.2 mL/min/1.73 m^2.

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population (n = 230)

Variable	Value
Age (years), Mean ± SD	56.8 ± 13.4
Male, n (%)	138 (60.0)
Female, n (%)	92 (40.0)
Body Mass Index (kg/m^2), Mean ± SD	25.9 ± 4.3
Diabetes Mellitus, n (%)	128 (55.7)
Hypertension, n (%)	162 (70.4)
Serum Creatinine (mg/dL), Mean ± SD	2.61 ± 1.32
Blood Urea (mg/dL), Mean ± SD	58.7 ± 24.5
eGFR (mL/min/1.73m^2), Mean ± SD	39.5 ± 19.2
Hemoglobin (g/dL), Mean ± SD	10.8 ± 1.9

[Table 1] presents the baseline demographic and clinical characteristics of the 230 study participants diagnosed with chronic kidney disease. The mean age of the study population was 56.8 ± 13.4 years, indicating that CKD was predominantly observed among middle-aged and elderly individuals. Male participants constituted 60.0% of the cohort. The prevalence of major CKD risk factors was high, with diabetes mellitus present in 55.7% and hypertension in 70.4% of patients. The mean serum creatinine level was 2.61 ± 1.32 mg/dL, while the mean eGFR was 39.5 ± 19.2 mL/min/1.73 m^2, reflecting moderate to severe impairment of renal function. These findings indicate a population with substantial renal dysfunction and a high burden of cardiovascular and metabolic comorbidities.

Table 2: Distribution of Patients According to CKD Stage

CKD Stage	eGFR (mL/min/1.73m²)	n (%)
Stage 1	≥90	12 (5.2)
Stage 2	60–89	38 (16.5)
Stage 3	30–59	94 (40.9)
Stage 4	15–29	58 (25.2)
Stage 5	<15	28 (12.2)

[Table 2] illustrates the distribution of patients according to CKD stage based on eGFR classification. Stage 3 CKD was the most prevalent category, accounting for 40.9% of the study population, followed by Stage 4 CKD (25.2%). Stages 1 and 2 collectively represented only 21.7% of patients, whereas 12.2% had advanced Stage 5 disease. The predominance of Stage 3 and Stage 4 CKD suggests that most participants presented with established renal impairment rather than early-stage disease. This distribution provided an appropriate spectrum of CKD severity for evaluating the relationship between ultrasonographic renal parameters and disease progression.

Table 3: Ultrasonographic Renal Parameters in the Study Population

Parameter	Mean ± SD
Renal Length (cm)	9.34 ± 1.12
Renal Width (cm)	4.67 ± 0.71
Renal Cortical Thickness (mm)	5.9 ± 1.4
Parenchymal Thickness (mm)	12.8 ± 2.3
Renal Volume (cm³)	96.7 ± 24.6
Cortical Echogenicity Grade	
Echogenicity Grade	n (%)
Grade I	46 (20.0)
Grade II	88 (38.3)
Grade III	70 (30.4)
Grade IV	26 (11.3)

[Table 3] summarizes the ultrasonographic renal measurements obtained from the study participants. The mean renal length was 9.34 ± 1.12 cm, while the mean renal cortical thickness and parenchymal thickness were 5.9 ± 1.4 mm and 12.8 ± 2.3 mm, respectively. The average renal volume was 96.7 ± 24.6 cm³. Assessment of cortical echogenicity revealed that Grade II echogenicity was the most common finding (38.3%), followed by Grade III (30.4%). Only a minority of patients demonstrated Grade IV echogenicity. These findings indicate the presence of progressive structural alterations within the renal parenchyma, including cortical thinning and increased echogenicity, which are characteristic features of chronic kidney disease.

Table 4: Correlation of Ultrasonographic Parameters with eGFR

Parameter	Correlation Coefficient (r)	p-value
Renal Length	0.52	<0.001
Renal Width	0.39	<0.001
Cortical Thickness	0.71	<0.001
Parenchymal Thickness	0.64	<0.001
Renal Volume	0.58	<0.001
Cortical Echogenicity	-0.69	<0.001

[Table 4] demonstrates the correlation between ultrasonographic renal parameters and renal function as measured by eGFR. Renal cortical thickness showed the strongest positive correlation with eGFR ($r = 0.71$, $p < 0.001$), indicating that thicker renal cortices were associated with better preserved kidney function. Parenchymal thickness ($r = 0.64$, $p < 0.001$), renal volume ($r = 0.58$, $p < 0.001$), and renal length ($r = 0.52$, $p < 0.001$) also exhibited significant positive correlations. Conversely, cortical echogenicity demonstrated a strong negative correlation with eGFR ($r = –0.69$, $p < 0.001$), suggesting that increasing echogenicity was associated with worsening renal function. These findings support the utility of ultrasonographic measurements as non-invasive indicators of renal functional status in CKD patients.

Table 5: Multivariate Logistic Regression Analysis for Predictors of CKD Progression

Variable	Adjusted OR	95% CI	p-value
Age	1.02	0.99–1.04	0.118
Diabetes Mellitus	1.41	0.86–2.31	0.172
Hypertension	1.29	0.74–2.24	0.349
Renal Length	0.92	0.73–1.15	0.465
Cortical Thickness	0.58	0.45–0.74	<0.001
Renal Volume	0.97	0.95–0.99	0.008
Grade III/IV Echogenicity	2.94	1.68–5.16	<0.001

[Table 5] presents the results of multivariate logistic regression analysis evaluating independent predictors of CKD progression. After adjustment for demographic and clinical confounding factors, renal cortical thickness emerged as the strongest independent protective factor against disease progression (adjusted OR = 0.58, 95% CI: 0.45–0.74; p < 0.001). Increased cortical echogenicity (Grade III/IV) was independently associated with a nearly threefold higher risk of CKD progression (adjusted OR = 2.94, 95% CI: 1.68–5.16; p < 0.001). Renal volume also demonstrated a significant inverse association with progression risk (adjusted OR = 0.97, 95% CI: 0.95–0.99; p = 0.008). In contrast, age, diabetes mellitus, hypertension, and renal length were not significant independent predictors in the adjusted model. These results suggest that renal cortical thickness, cortical echogenicity, and renal volume may serve as valuable ultrasonographic biomarkers for predicting CKD progression.

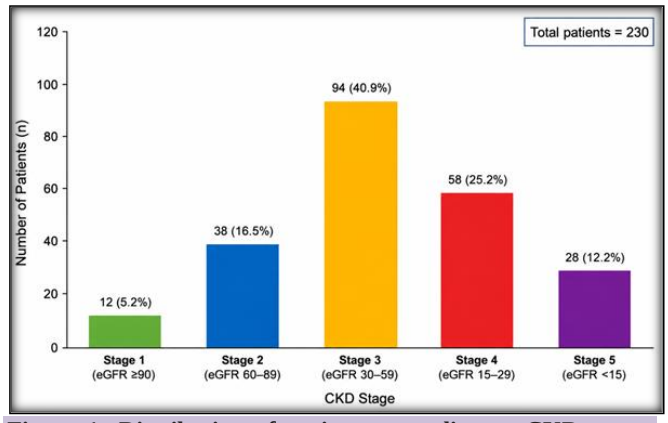

Figure 1: Distribution of patients according to CKD stages (Stages 1–5)

[Figure 1] The figure depicts the distribution of study participants across CKD stages. Stage 3 CKD constituted the largest proportion of cases, followed by Stages 4, 2, 5, and 1, demonstrating that most patients had moderate to advanced renal impairment at presentation.

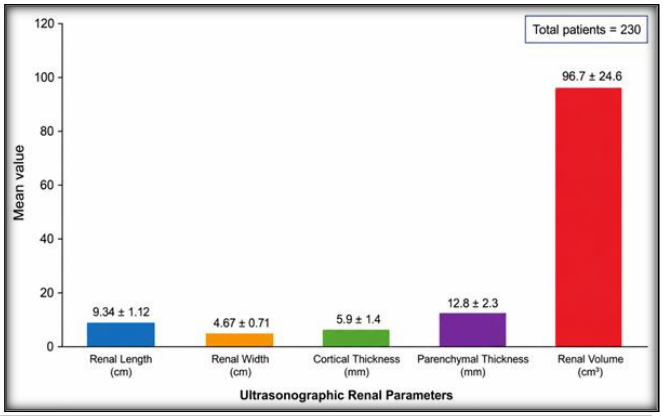

Figure 2: Mean ultrasonographic renal parameters among study participants

[Figure 2] The figure compares mean ultrasonographic renal measurements including renal length, width, cortical thickness, parenchymal thickness, and renal volume. The graphical representation highlights the progressive structural changes observed in CKD patients.

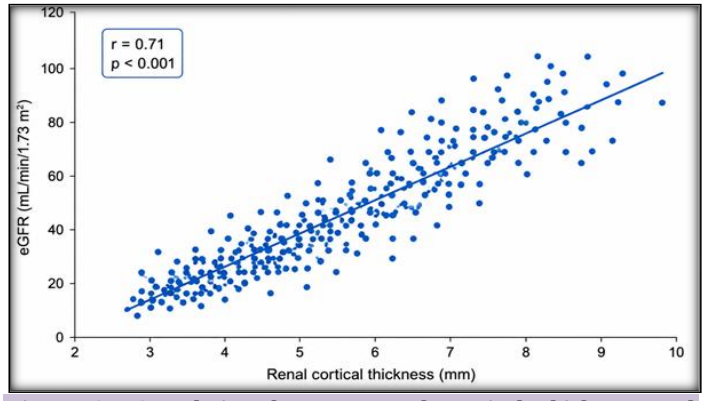

Figure 3: Correlation between renal cortical thickness and estimated glomerular filtration rate (eGFR)

[Figure 3] The scatter plot demonstrates a significant positive correlation between renal cortical thickness and eGFR. Patients with greater cortical thickness generally exhibited better renal function, supporting the role of cortical thickness as a marker of preserved nephron mass.

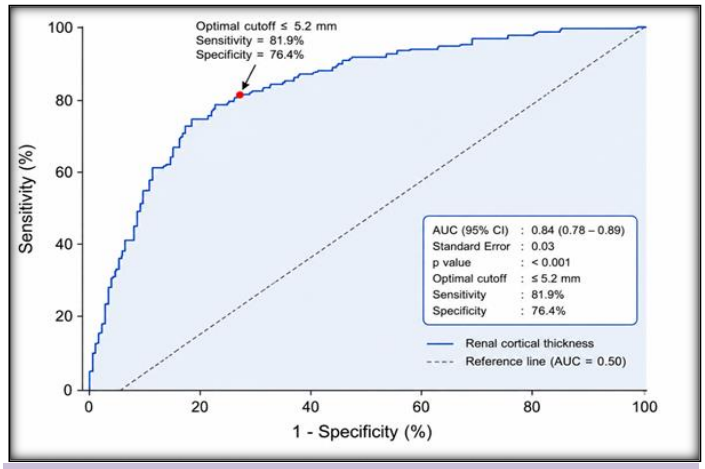

Figure 4: Receiver operating characteristic (ROC) curve demonstrating the predictive performance of renal cortical thickness for CKD progression (AUC = 0.84)

[Figure 4] The ROC curve illustrates the diagnostic performance of renal cortical thickness in predicting CKD progression. The area under the curve (AUC) of 0.84 indicates excellent predictive accuracy, with a cortical thickness threshold of ≤5.2 mm providing optimal sensitivity and specificity.

Discussion

This study validated the role of sonographic renal parameters as prognostic factors for chronic kidney disease (CKD) progression in 230 patients. The findings showed strong relationships between structural renal changes as evaluated by ultrasonography and renal functional status. Renal cortical thickness was the most powerful parameter to predict kidney

function and progression, followed by renal volume and cortical echogenicity, among those studied. We found that these markers are of great value in the non-invasive risk stratification and monitoring of CKD patients and this is in keeping with the evidence accumulating in the literature.

Demographic profile of the study population showed that there is the dominance of middle age and elderly population, Mean age is 56.8 years and a higher number of male population. The participants had high prevalence of hypertension and DM, which had a well recognized contribution toward the development and progression of CKD. The same demographic trends have been previously described in other epidemiological studies in which diabetic nephropathy and hypertensive nephrosclerosis were responsible for a significant number of cases of CKD.[17,18] Emphasis in the predominance of these comorbidities is the need for early identification of patients prone to progressive renal impairment.

The distribution of CKD stage showed that majority of the patients were in Stage 3 and Stage 4. This is similar to previous studies which have suggested that CKD is often only diagnosed when renal function has been significantly lowered.[19] This may be because many patients were either in the early stages of CKD (Stages 1 and 2) and asymptomatic, or routine screening programs were not routinely performed in many healthcare environments. Some of the strengths of the present study was the presence of a wide range of stages of CKD, which further supported the assessment of ultrasonographic parameters using different degree of renal dysfunction.

The ultrasonographic evaluation showed progressive renal structural changes with decreased renal length, thinning of renal cortex, thinning of parenchymal thickness and increased renal cortex echogenicity. These results are biologically plausible in light of the fact that chronic nephron loss is linked to glomerulosclerosis, tubular atrophy, interstitial fibrosis, and vascular remodeling which can all be detected on ultrasound examination.[20] In some previous studies, it has also been shown that renal size becomes smaller as the severity of the CKD increases, indicating irreversible renal damage.[21]

Out of all the sonographic parameters analysed, renal cortical thickness showed the highest positive correlation with eGFR ($r = 0.71$, $p < 0.001$). This result is consistent with the previous reports by Beland et al. and Yamashita et al. who found that cortical thickness is positively correlated with renal function rather than the standard renal parameters (i.e., renal length).[10,11] Cortical thinning reflects nephron loss and loss of renal reserve with the cortex holding the bulk of the active glomeruli and proximal tubules. Therefore, cortical thickness may be a more useful measure of renal functional impairment than kidney size. The present study demonstrated that there is a strong association between these variables; this warrants the use of cortical thickness as part of the routine renal ultrasound assessment.

There was also significant correlation between eGFR and parenchymal thickness and renal volume. These results are similar to reports that renal parenchymal mass preservation is linked to improved kidney function.[22,23] It has been implicated in progressive fibrosis and loss of functioning nephrons, confirming its role as a marker of chronic renal injury, and has been established that reduction of renal volume leads to this. Renal length was found to be significantly related to eGFR, but the correlation was weaker than that with cortical thickness and parenchymal thickness, implying that renal length may not be enough to assess the progression of CKD comprehensively.

One of the significant factors revealed in the present study was the cortical echogenicity and renal function and was seen to be truly inversely related. Higher echogenicity grades were associated with lower eGFR and increased risk of progression of CKD. The reported increase in the echo intensity of the cortex is thought to be the consequence of fibrosis, inflammatory infiltration and sclerosis of the renal parenchyma. In the similar studies performed by Moghazi et al. and Siddappa et al., they noted an increased echogenicity was associated with progressive histopathological damage and decreasing renal functions, respectively.[24] Hence, the grading of echogenicity could be useful in providing a qualitative hint of the degree of chronic renal injury.

Multivariate logistic regression analysis showed that thickness of the cortex, cortex echogenicity, and renal volume were independent predictors of CKD progression. Notably, cortical thickness proved to be the best predictor, even after adjustment for age, diabetes, hypertension and baseline renal function. These results indicate that structural imaging biomarkers can offer additional prognostic information to traditional clinical and laboratory markers. This information may help to identify patients earlier who are at high risk and need aggressive surveillance and therapeutic intervention.

Additionally, there was excellent predictive ability of cortical thickness for the progression of CKD as was shown by receiver operating characteristic (ROC) analysis with an area under the curve (AUC) of 0.84. A cutoff value of $\leq$5.2 mm had promising sensitivity and specificity, suggesting a good discriminatory property. No previous studies have been reported that have assessed sonographic markers of CKD progression in a similar manner. The present study data provide support for the use of cortical thickness as a clinical imaging biomarker suitable for use in clinical nephrology practice.

There are a number of strengths to the present study. Firstly, the sample size was relatively large, allowing for a higher statistical power and greater reliability of associations observed. Second, several ultrasonographic parameters (hemi-diameter, length of the mid-calf nephron, and the thickness of the outer medulla and cortex) were simultaneously measured, providing a comprehensive assessment of renal structural changes. Thirdly, all the CKD stages were included, allowing the assessment of sonographic findings in the entire spectrum of this disease.

However, some restrictions must be recognised. The study took place at one site only, thus reducing the generalizability to other populations. Renal biopsy was not routinely performed and hence there was no histopathological correlation. Also, there was no attempt to measure interobserver variability for the ultrasonographic measurements. Multicenter prospective studies with common imaging protocol and a longer follow-up are necessary to confirm these results and set up a universal cut off.

The results of the present study suggest that ultrasonographic renal parameters seem to be good indicators of CKD progression,

especially cortical thickness, cortical echogenicity, and renal volume. These non-invasive imaging biomarkers can be integrated into standard clinical evaluation, which could help with better risk stratification, earlier intervention and ultimately better long-term renal outcomes.

Conclusion

The present study demonstrates that ultrasonographic renal parameters are valuable noninvasive indicators of renal functional status and chronic kidney disease (CKD) progression. Among the evaluated sonographic measurements, renal cortical thickness showed the strongest correlation with estimated glomerular filtration rate (eGFR) and emerged as the most reliable independent predictor of disease progression. Increased cortical echogenicity and reduced renal volume were also significantly associated with worsening renal function and a higher risk of CKD progression.

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Conflicts of interest

There are no conflicts of interest.

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