Correlation Of Ultrasound-Based Renal Parameters With Renal Function In Patients Diagnosed With Chronic Kidney Disease In South Indian Population

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Abstract

Aims: *To correlate ultrasound based renal parameters like renal volume, length and mean renal cortical thickness with renal function in patients diagnosed with chronic kidney disease. To identify the renal parameter which is correlating the most with renal functions in patients with chronic kidney disease.*

Material and methods: *In the Department of Radiodiagnosis at Vinayaka Mission Medical College, Salem a prospective cross-sectional study was carried out on 76 patients with chronic kidney disease between September 2023 and August 2024.*

Results: *A statistically significant positive correlation was found between eGFR and mean renal volume, mean* *renal cortical thickness and mean renal length (p<0.001). The maximal correlation was between renal volume and eGFR (r = 0.91, r2 = 0.82; p-value <0.001).*

Conclusion: R*enal volume and cortical thickness should be taken into account with other parameters.*

Introduction

Chronic kidney disease (CKD) is one of the most significant chronic noncommunicable diseases in the world today. In addition to aging of the general population, the prevalence of diabetes, hypertension, and obesity has increased globally, contributing to the rise in chronic kidney disease (CKD). CKD describes the abnormal kidney structure or function, typically represented by a progressive loss of glomerular function. It can be identified by pathological abnormalities or markers of kidney damage, such as abnormalities in imaging, blood or urine composition, or GFR <60 mL/min/1.73 m^2 for more than three months, with or without kidney damage (1). Ultrasonography is used in clinical practice to evaluate patients with chronic kidney disease (CKD), as it helps to rule out potentially treatable reasons (e.g., collecting system dilatation) and to get renal measurements and other features as a prognostic factor. In most cases, chronic kidney disease (CKD) results in a common final-stage condition that is characterized by small kidneys, cortical and parenchymal thinning (indicating atrophy), and hyper echogenicity (indicating sclerosis and fibrosis; small, dense, echogenic kidneys); and hence the renal measurements are important (2). In this background, it is of immense value if we could predict the progression of nephropathy using function estimates calculated with the renal measurements obtained on imaging.

Typical US findings of CKD include increased renal cortical echogenicity (which is considered a marker/ diagnostic criterion for parenchymal nephropathy, arising from interstitial oedema or fibrosis), decreased renal size and loss of corticomedullary differentiation (3–5). Bipolar renal length is usually recorded on US examinations, but length does not directly correlate to the renal function. Renal size is correlated with body size. A small kidney might be considered normal, while a normal-sized kidney can be atrophic. Raised cortical echogenicity also do not always indicate fibrosis or sclerosis and correlate to renal function. Cortical thinning is a good indicator of end stage renal diseases. Compared to renal length, renal volume determined by USG provides a more precise assessment of a functional kidney (4,6). In a recent study, renal volume, especially the cortical volume determined by computed tomography had a substantial positive correlation with renal function. USG is a low-cost, non-invasive diagnostic technique that offers enough anatomical information to identify kidney disorders without requiring radiation or contrast material exposure. Therefore, the purpose of this study was to ascertain if renal function tests, such as estimated GFR (CG method), and sonographic renal parameters were related in patients with chronic kidney disease.

Material and method

Study population

In the Department of Radiodiagnosis at Vinayaka Mission Medical College, Salem a prospective cross-sectional study was carried out on patients with chronic kidney disease between September 2023 and August 2024 after obtaining informed written consent from the participants.

Patient selection

Inclusion criteria

1. All patients above 20 years of age;
2. All patients diagnosed with CKD.

Exclusion criteria

1. Individuals who have received kidney transplants, peritoneal dialysis, or hemodialysis.
2. Individuals with unilateral kidney disease, hydronephrosis, polycystic kidney disease, or isolated cysts larger than 4 cm.
3. Individuals suffering from severe illnesses such as end-stage cardiac, pulmonary, or hepatic disease, sepsis, renal damage, or primary or secondary renal cancer.

Methodology

Study was conducted using GE LOGIQ F8 Expert machine. A curvilinear probe operating between 3 and 5 MHz was used. To eliminate air between the transducer and the abdominal skin, USG coupling gel was administered to the abdomen. The longitudinal measurements of kidneys were taken in a portion that was visually considered to be the largest in long axis. The distance between the lowest edge of the lower pole and the highest edge of the upper pole was used to determine renal length. The width and thickness of a kidney was then measured in a section that was perpendicular to the longitudinal axis. The shortest distance between the base of the medullary pyramid and the renal capsule was used to estimate the renal cortical thickness in the sagittal plane at the level of the mid-kidney over a medullary pyramid. The average of the three measurements of cortical thickness taken at the upper, mid, and lower poles was recorded. Images were taken in the longitudinal plane, clearly showing both renal poles, and in the transverse plane, at the level of the hilum, in order to calculate the renal volume. The renal width (W) was measured as the largest transverse diameter on the transverse scan and the renal length (L) as the longest distance between the renal poles on the longitudinal scan using electronic callipers. The average of the greatest separation between the anterior and posterior walls of the kidney's midsection on the longitudinal and transverse scans (D1 and D2) was used to calculate the renal thickness or depth (D). The prolate ellipsoid formula ($L \times W \times (D1 + D2/2) \times 0.523$) was used to calculate the kidney volume. It was done for both the kidneys.

The eGFR was calculated using the Cockcroft-Gault (CG) equation, as follows:

eGFR is calculated as $(140 - \text{age}) \times (\text{weight in kg}) \times (0.85 \text{ if female}) / (72 \times Cr)$, where Cr is creatinine.

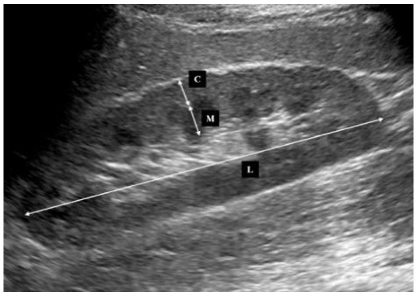

Image 1: Longitudinal section of kidney. L: length, C: cortical thickness

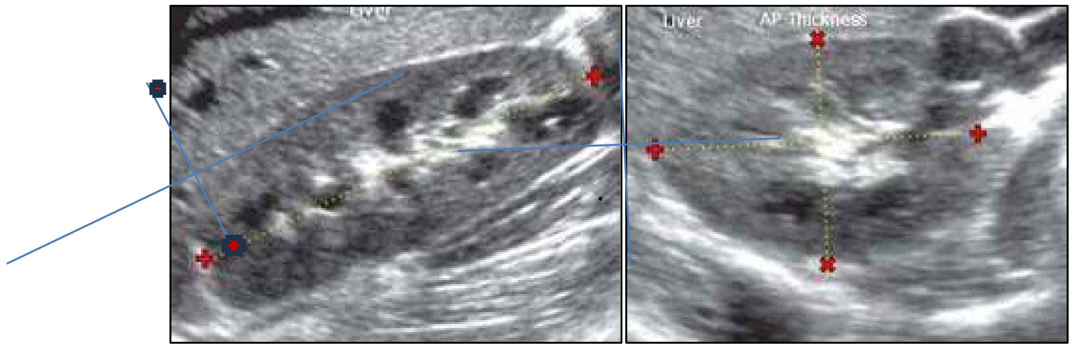

Image 2: a) Length and Depth b) Width and Depth

Statistical analysis

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The information derived was entered in a Microsoft Excel spreadsheet. Analyses were conducted using mean cortical length and thickness. The Matlab (MathWorks) platform was used for statistical analysis and visualization. Linear regression was used to examine the relationship between renal function and USG measurements. When the p-value was less than 0.05, it was considered significant.

Results

This study assessed 76 patients with recently diagnosed chronic kidney disease. The patients ranged in age from 20 to 70 years, with a mean age of 54.6 years. The majority of patients were between the ages of 41 and 70. The ratio of male to female patients was 1.53:1, with 46 (60.5%) being male and 30 (39.5%) being female. In 33 cases (43.5 %), the kidneys were tiny (less than 8 cm). The kidneys were of normal size in 43 patients (56.5%). In 34 cases (39.4%), the mean renal cortical thickness was less than 6.5 mm, and in 42 cases (55.2%), it was greater than 6.5 mm. The renal cortical thickness ranged from 1.8 to 9.8 mm, with a mean of 6.75 ± 2.97 mm. The measured renal length ranged from 5.92 to 11.27 cm, with a mean of 8.68 ± 1.43 cm. The renal volume ranged from 14.66 to 143.77 cm3, with an average of 77.35 ± 30.78 cm3. Mean renal length, mean renal cortical thickness, and mean renal volume all showed statistically significant positive correlations with eGFR. The mean renal volume and eGFR showed the strongest association.

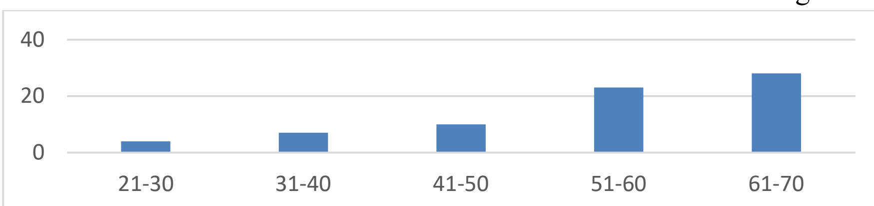

Chart 1 Age distribution of patients

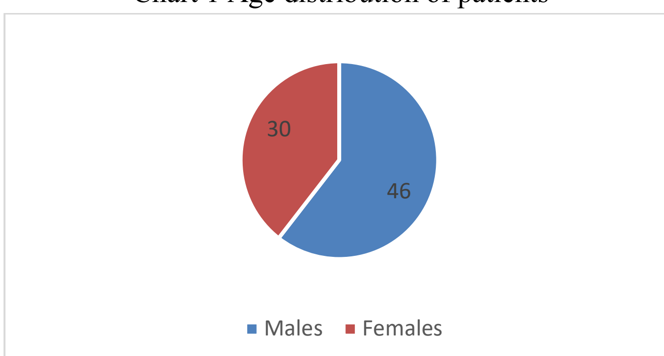

Chart 2: Sex distribution of patients

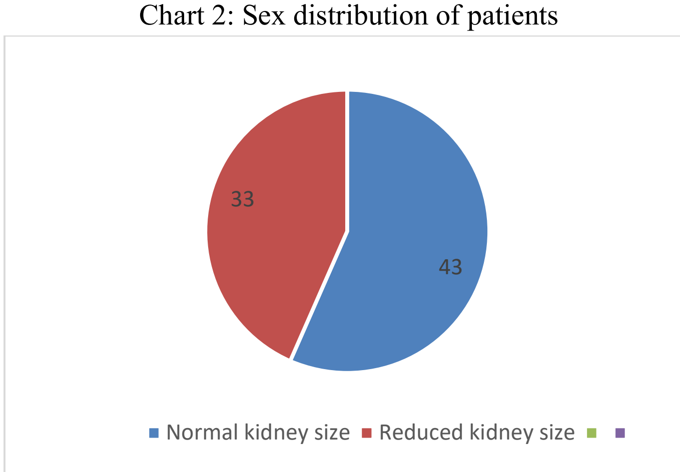

Chart 3: Renal size

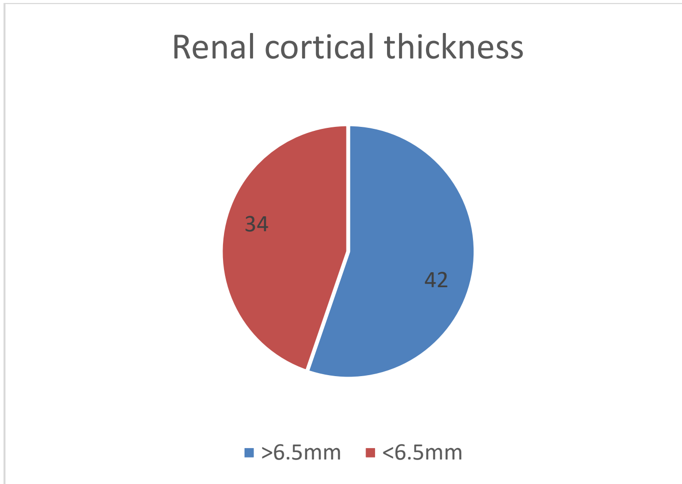

Chart 4: Renal cortical thickness

Renal Parameters	eGFR (ml/min)	
	Correlation coefficient (r)	p Values
Mean renal length (cm)	0.76	<0.001
Mean renal cortical thickness (mm)	0.85	<0.001
Mean renal volume (cm3)	0.91	<0.001

Table 1: Statistical correlation between renal parameters and eGFR

Discussion

In this study, there was a statistically significant positive association between the eGFR determined using the CG formula and the renal volume (determined using the ellipsoid formula) ($r = 0.91$, $r2 = 0.82$; p-value <0.001). The renal volume falls in tandem with the patient's declining eGFR. This might be the result of nephron loss brought on by declining renal function and the ensuing reduction in renal size, which is manifested as a drop in renal volume. The results of the research by Yamashita et al.(7), Jovanovic et al.(8), Johnson et al.(9), Sanusi et al. (10) and Adibi et al.(11) showed a strong correlation with this. However, Bakker et al.(12) contended that the application of the ellipsoid formula to the kidney, which is not ellipsoid, resulted in an inherent flaw in the USG-based estimation of kidney volume. Consequently, he recommended the use of magnetic resonance imaging (MRI). Regretfully, the researchers discovered that the voxel count approach, an MRI-based technique, also had a similar flaw and underestimated the actual kidney volume. They came to the conclusion that USG was ultimately a better modality of choice because MRI-based volumetry requires more processing time and is more expensive. Cheong et al.(13) then used the disc summation approach and the ellipsoid formula to analyze MRI data and contrast it with the water displacement method for kidney volume assessment. He discovered that the kidney volume was understated by up to 21–29% using the ellipsoid formula. This discrepancy in volume calculation was quite comparable to the % inaccuracy observed in kidney volume calculations based on USG using the ellipsoid formula. Thus, MRI-based volumetry is superior to renal volume as estimated by sonography. However, in a nation like India, where millions of people have chronic kidney disease (CKD), the ellipsoid formula using sonography is a suitable method for estimating renal volume because MRI-based volumetry is both expensive and time-consuming, per a study by Bakker et al(12).

Additionally, there was a statistically significant positive correlation (r = 0.85, r2 = 0.72; p-value <0.001) between eGFR and the mean renal cortical thickness. These results align with research conducted by Yamashita et al.(7), Korkmaz et al.(14), and Beland et al(3). The mean cortical thickness in our study was 6.65 ± 2.27 mm, with a range of 1.75 to 9.9 mm. The results shown by Yamashita et al. (7) (mean cortical thickness of 7.1 mm), Beland et al. (3) (mean cortical thickness of 5.9 mm), Korkmaz et al. (14) (5.76 ± 2.05 mm at the start of the study and 5.28 ± 1.99 mm at the end of the study), and El-Reshaid et al (15). (6 mm and more considered to be normal) were all in close agreement with this finding. The mean cortical thickness has become a new metric for CKD patient assessment in recent years. Because it has a strong link with eGFR, it has been found to be helpful for cases of early CKD. Another reason is that in early-stage CKD, renal pyramids are easier to see. However, it is challenging to identify the corticomedullary interface in endstage renal illness, because corticomedullary distinction is lost. This is among this parameter's disadvantages. After analyzing the Yamashita et al. (7) work and our research, it can be concluded that the reason for renal volume and renal cortical thickness exhibiting a strong positive link with eGFR is that the renal cortex is made up of the glomeruli and collecting tubules within the renal pyramids. Cortical thinning results from glomerular damage brought on by the advancement of renal illness. The renal volume decreases and corticomedullary differentiation is lost as a result of the gradual deterioration of the glomeruli and collecting tubules. As a result, renal cortical thickness decreases on USG in the early stages of renal disorders, and renal volume likewise decreases proportionately to renal impairment as the disease advances. Renal length is typically the only measure provided in USG reports and has long been used as a conventional metric for assessing chronic renal illness. However, this study found that renal cortical thickness and renal volume were superior quantitative measures over renal length.

The patients' surface area and body weight were not regulated during our trial. Consequently, the study's limitations are the patients' height, gender, and body mass index.

Conclusion

This study demonstrated the value of cortical thickness and renal volume measures in the regular assessment of patients with chronic kidney disease. The results suggest that in addition to the conventional measures, renal volume and cortical thickness should be taken into account.

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