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Correlation of sonographic parameters with renal function in patients with newly diagnosed chronic kidney disease

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Keywords

ultrasonography; chronic kidney disease; eGFR; GFR; Cockcroft-Gault formula

Abstract

Aims: To correlate sonographic renal parameters (mean renal cortical thickness, length and volume) with renal functions in patients with newly diagnosed chronic kidney disease. To predict the best renal parameter correlating with renal functions in patients with newly diagnosed chronic kidney disease. **Material and methods:** A hospital-based prospective cross-sectional study was conducted in the Department of Radiodiagnosis, Indira Gandhi Medical College and Hospital, Shimla, in 78 adults with newly diagnosed chronic kidney disease visiting the hospital from December 2019 to November 2020. **Results:** A statistically significant positive correlation was found between eGFR and mean renal length, mean renal cortical thickness, and mean renal volume ($p < 0.001$).The strongest correlation was shown between mean renal volume and eGFR ($r = 0.90$, $r^2 = 0.82$; p-value <0.001). **Conclusions:** Renal volume and cortical thickness should be considered along with traditional renal parameters.

Introduction

Chronic kidney disease (CKD) has become one of the most important, chronic, noncommunicable diseases in the world. CKD is defined as the presence of kidney damage ≥3 months, either by structural or functional abnormalities of the kidney with or without decreasing GFR, manifested by either pathological abnormalities or markers of kidney damage including the composition of blood or urine or abnormalities in imaging tests or GFR <60 mL/min/1.73 m^2 for >3 months with or without kidney damage[(1)]. Bipolar renal lengths are routinely reported in renal USG, as traditional teaching is that renal length correlates with renal function in CKD, but kidney length has low specificity in predicting renal impairment[(2)]. Renal size varies with body size; a small kidney can be normal and a normal-sized kidney can be atrophic. On the other hand, increased echogenicity does not always indicate fibrosis or sclerosis because it can also be produced by cellular infiltrates. Although cortical thinning is a good indicator of advanced renal disease, the converse is not true. For instance, even in advanced diabetic nephropathy, cortical thickness is usually normal or increased[(3)]. Renal volume calculated on USG is a more exact measurement of a functioning kidney than renal length[(4,5)]. A recent study showed that renal volume, specifically cortical volume, measured by computed tomography had a strong positive relationship with renal function[(6)]. USG is a non-invasive and inexpensive investigation modality providing sufficient anatomical details to diagnose renal diseases without any exposure to radiation or contrast agents. Hence, this study was conducted to determine whether there was a relationship between sonographic renal parameters and renal function tests including estimated GFR (CG method) in patients of CKD.

Material and method

Study population

A hospital-based prospective cross-sectional study was conducted in the Department of Radiodiagnosis, Indira Gandhi Medical College and Hospital, Shimla, in adults with CKD visiting the hospital from December 2019 to November 2020.

Ethical statement and approval

All the patients referred from various departments during the study period and eligible patients fulfilling the inclusion criteria and consenting to participate were enrolled in the study after obtaining written informed consent. The research procedure was in accordance with the approved standards of the ethics committee at Indira Gandhi Medical College and Hospital, Shimla.

Patient selection

Inclusion criteria

1. All patients above 18 years of age;

2. All newly diagnosed patients with CKD.

Exclusion criteria

1. Patients who have undergone haemodialysis, or peritoneal dialysis and renal transplant.

2. Patients with hydronephrosis, PCKD or solitary cysts >4 cm, unilateral kidney.

3. Patients with serious conditions like primary or secondary renal malignancy, sepsis, renal injury or end-stage cardiac, pulmonary or hepatic disease.

Methodology

The study was done on GE LOGIQ P6 ultrasound system, with a curvilinear probe of 3–5 MHz, using grey scale B-mode imaging scale. USG coupling gel was applied to the abdomen to remove air between the abdominal skin and the transducer.

The longitudinal dimensions of the kidneys were measured in a section visually estimated to represent the largest longitudinal size of the kidney. Renal length was measured between the uppermost edge of the upper pole and the lowest edge of the lower pole.

The width and thickness were measured in a section perpendicular to the longitudinal axis of the kidney as assessed from the longitudinal image.

The renal cortical thickness was measured in the sagittal plane at the level of the mid-kidney over a medullary pyramid, perpendicular to the capsule as the shortest distance from the base of the medullary pyramid to the renal capsule. The cortical thickness was measured at the upper, mid and lower poles, and the average of three values was documented[(6)].

To determine the renal volume, images were acquired in the longitudinal plane with both renal poles clearly demonstrated, and in the transverse plane at the level of the hilum. Using electronic callipers, the renal length (L) was taken as the longest distance between the renal poles on the longitudinal scan and the renal width (W) as the maximum transverse diameter on the transverse scan. The renal thickness or depth (D) was taken as the average of the maximum distance between the anterior and posterior walls of the mid-portion of the kidney on the longitudinal and transverse scans (D1 and D2). The kidney volume was obtained using the prolate ellipsoid formula ($L \times W \times D1 + D2/2 \times 0.523$)[(7)].

All measurements were done for both kidneys.

The Cockcroft-Gault (CG) equation was used for eGFR calculation, as follows[(4)]:

$eGFR = (140 - age) \times (weight\ in\ kg) \times (0.85\ if\ female) / (72 \times Cr)$ where Cr is creatinine.

To illustrate the methodology, a 66-year-old male patient, weighing 75 kg, newly diagnosed with CKD, had serum creatinine of 1.87 mg/dl. On calculating eGFR by CG formula, it came to be 41 ml/min. On USG, it had mean renal length: 9.71 cm, mean renal volume: 143.96 cm^3 and mean cortical thickness: 9.45 mm (Fig. 1, Fig. 2, Fig. 3, Fig. 4).

Statistical analysis

The data were entered and stored in a spreadsheet (Excel, Microsoft). Mean cortical thickness and length were used in analyses. Statistical analysis and visualisation were performed using the Matlab platform (MathWorks). The relationship between ultrasound measurements and renal function was tested using linear regression. Significance was considered at a p-value <0.05.

Results

A total of 78 patients with newly diagnosed CKD were evaluated in this study. The age of the patients was 21–81 years, with a mean age of 56.88 years. Maximum patients were in the age group of 51–70 years. There were 46 (58.97%) male patients and 32 (41.03%) were females, with a male to female ratio of 1.38:1. The kidneys were small in size (less than 8 cm) in 28 (35.9%) cases. In 50 (64.1%) cases, the kidneys were of normal size. The mean renal cortical thickness was less than 6 mm in 31 cases (39.74%) and more than 6 mm in 47 cases (60.26%). The mean renal cortical thickness was 6.65 ± 2.27 mm (range 1.75–9.9 mm). The mean renal length measured was 8.58 ± 1.32 cm (range 5.85–11.165 cm). The mean renal volume was 73.35 ± 40.78 cm^3 (range 13.46–163.67). There was a statistically significant positive correlation between eGFR and mean renal length, mean renal cortical thickness, and mean renal volume. The strongest correlation was found between the mean renal volume and eGFR (Tab. 1, Fig. 5, Fig. 6, Fig. 7).

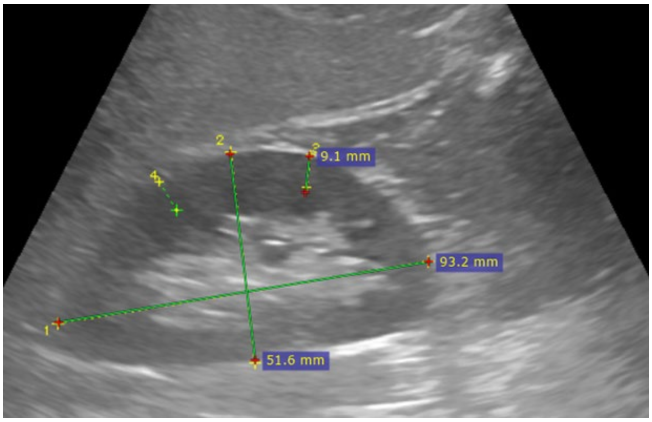

Fig. 1. *Right renal length (9.32 cm) and depth (5.16 cm). Right renal cortical thickness (9.1 mm)*

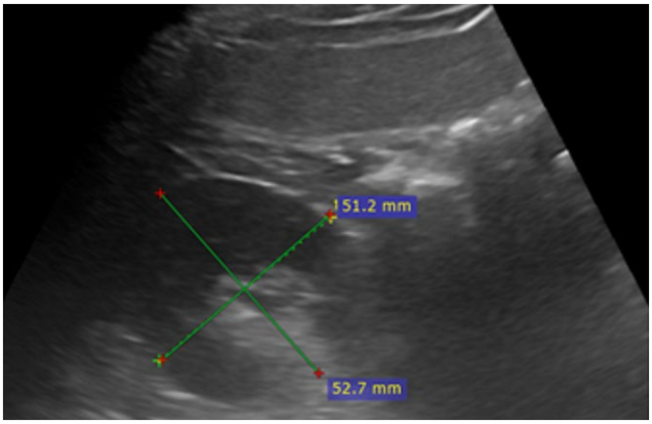

Fig. 2. *Right renal width (5.27 cm) and depth (5.12 cm)*

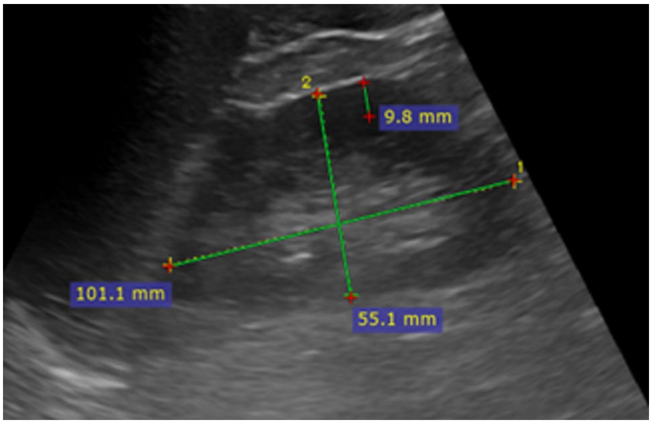

Fig. 3. *Left renal length (10.1 cm), depth (5.51 cm) and mean cortical thickness (9.8 mm)*

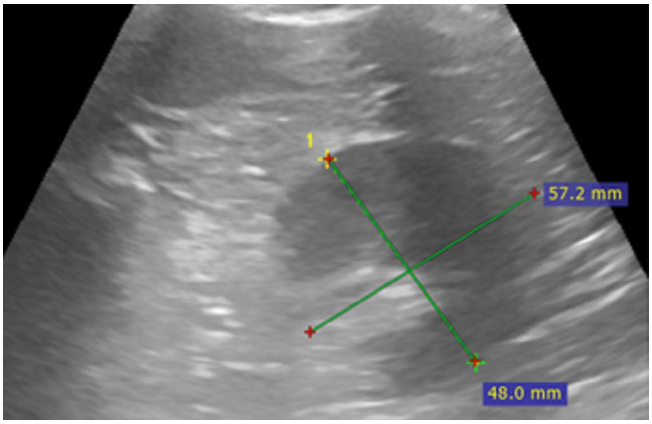

Fig. 4. *Left renal width (5.72 cm) and renal depth (4.8 cm)*

Discussion

In this study, the renal volume (calculated by using the ellipsoid formula) showed a statistically significant positive correlation with the eGFR calculated by the CG formula (r = 0.90, r^2 = 0.82; *p*-value <0.001). As the eGFR of the patient decreases, the renal volume also declines. This could be because of the loss of nephrons with the deterioration of renal function and the resultant decrease in the renal size which are reflected in the form of a decrease in renal volume. This correlated well with the findings of the studies conducted by Yamashita *et al.*[(8)] Jovanovic *et al.*[(9)], Johnson *et al.*[(10)] , Sanusi *et al.*[(11)] and Adibi *et al.*[(12)]. However, it was argued by Bakker *et al.*[(13)] that USG-based determination of kidney volume had an inherent defect due to the ellipsoid formula being applied to the kidney, which is not actually ellipsoid. Therefore, he suggested using Magnetic Resonance Imaging (MRI). Unfortunately, the researchers found that a MRI-based technique (voxel count method) also had a similar defect, underestimating the true kidney volume. Consequently, they concluded that MRI-based volumetry needs more processing time and because of its higher cost, USG was ultimately a superior modality of choice. Subsequently, Cheong *et al.*[(14)] applied the ellipsoid formula and disc summation method to MRI data and compared it with the water displacement method for kidney volume measurement. He found that the ellipsoid formula underestimated the kidney volume by as much as 21–29%. This difference in volume determination was quite similar to the percentage error seen in USG-based kidney volume determinations with the ellipsoid formula. Therefore, MRI-based volumetry is better than sonographically determined renal volume. But in a country like India, where there are millions of patients suffering from CKD, and in accordance with the study done by Bakker *et al.*[(13)] the estimation of renal volume is acceptable by the ellipsoid formula on sonography as MRI-based volumetry is both costly and time-consuming.

Tab. 1. *Statistical correlation between renal parameters and eGFR*

Renal parameters	eGFR (ml/min)	
	Correlation coefficient (r)	*p*-Values
Mean renal length (cm)	0.76	<0.001
Mean renal cortical thickness (mm)	0.86	<0.001
Mean renal volume (cm^3)	0.90	<0.001

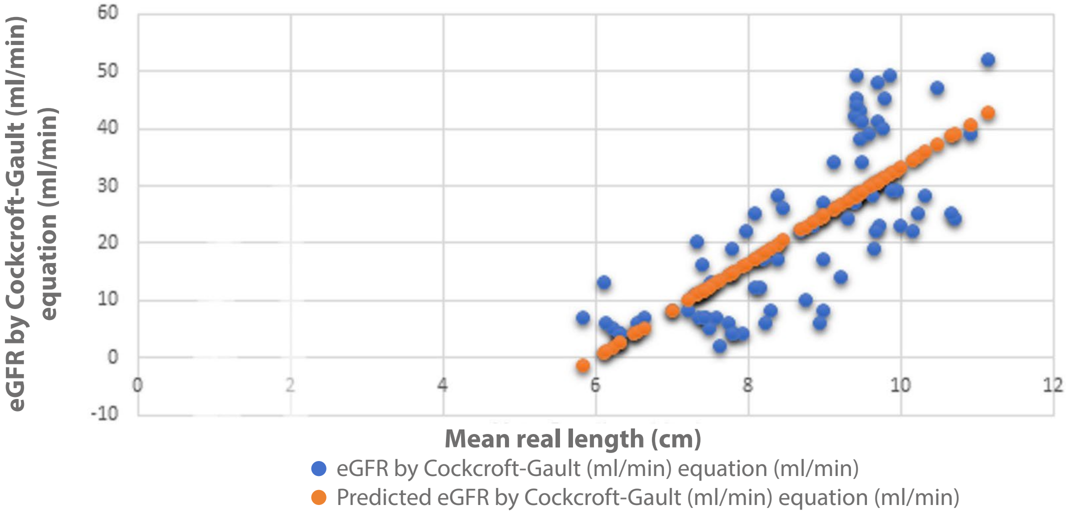

Fig. 5. *Correlation between mean renal length and eGFR*

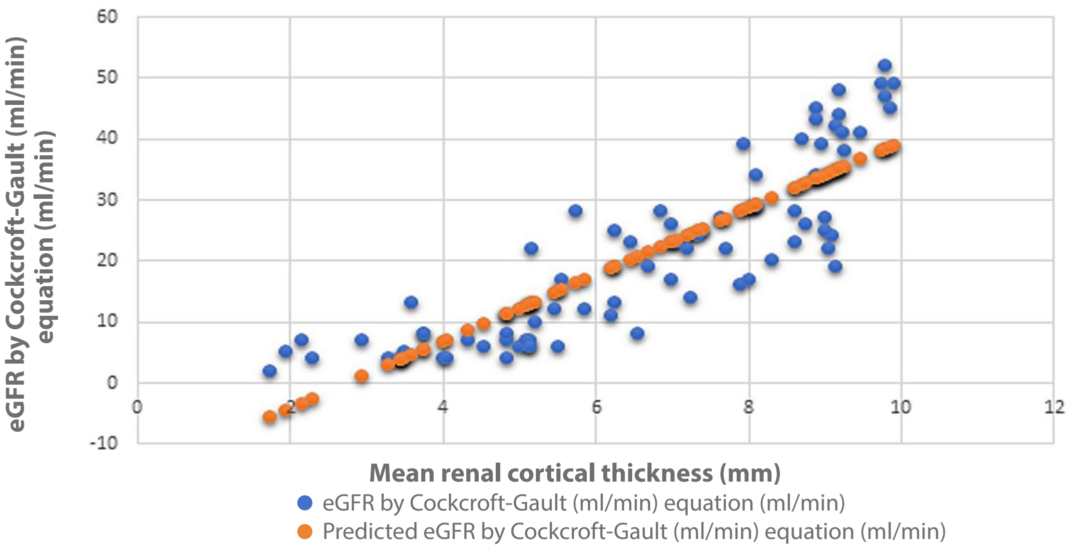

Fig. 6. *Correlation between mean renal cortical thickness and eGFR*

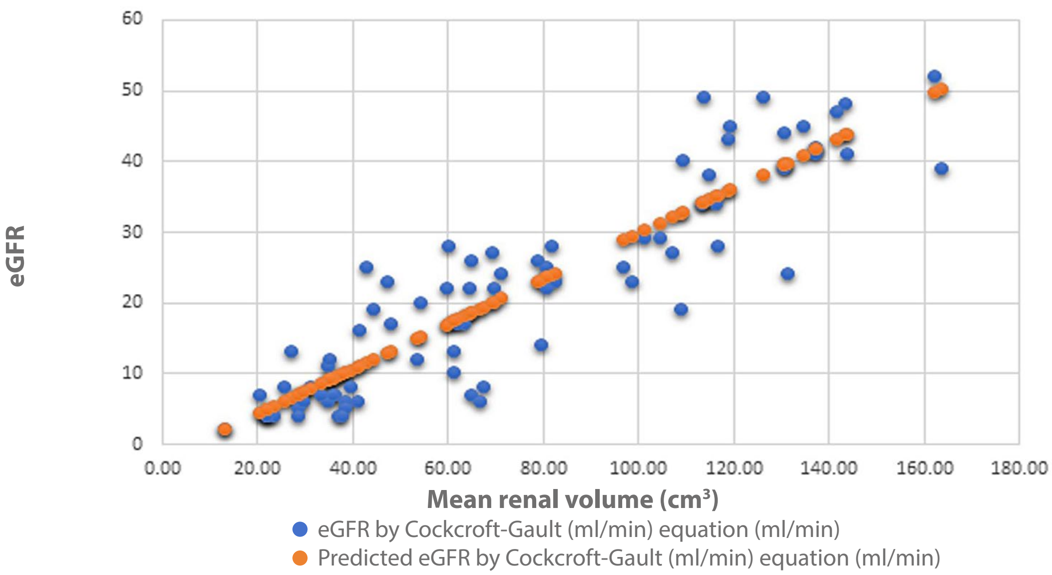

Fig. 7. *Correlation between mean renal volume and eGFR*

There was also a statistically significant positive correlation between the mean renal cortical thickness and eGFR ($r = 0.86$, $r^2 = 0.74$; p-value <0.001). These findings are consistent with the studies by Beland *et al*.[15], Korkmaz *et al*.[16], and Yamashita *et al*.[8] The mean cortical thickness in our study was found to be 6.65 ± 2.27 mm (range 1.75–9.9 mm). This finding was closely consistent with those reported by Yamashita *et al*.[8] (mean cortical thickness of 7.1 mm), Beland *et al*.[15] (mean cortical thickness of 5.9 mm), Korkmaz *et al*.[16] (5.76 ± 2.05 mm at the beginning of the study and 5.28 ± 1.99 mm at the end of the study) and El-Reshaid *et al*.[7] (6 mm and more considered to be normal). In recent years, the mean cortical thickness has emerged as a new parameter for the evaluation of CKD patients. It has been found to be beneficial for cases of early CKD due to its strong correlation with eGFR. Another factor is that renal pyramids are better visible in cases of early CKD. On the other hand, in end-stage renal disease, where there is loss of corticomedullary differentiation, it is difficult to determine the corticomedullary interface. This is one of the drawbacks of this parameter.

On reviewing the paper by Yamashita *et al*.[8] and our study, it can be concluded that the reason for the renal volume and renal cortical thickness showing a strong positive correlation with eGFR is that the renal cortex comprises the glomeruli and collecting tubules within the renal pyramids. With the progression of renal disease, there is damage of the glomeruli, leading to cortical thinning. With time, both the glomeruli and collecting tubules are affected, which leads to shrinkage of the renal volume and loss of corticomedullary differentiation. Consequently, in the early stages of renal diseases, on USG there is a decrease in the renal cortical thickness, and as the disease progresses, the renal volume will also decrease in proportion to renal impairment.

The renal length has always been used as a traditional parameter for the evaluation of chronic renal disease and, most of the time, the only parameter included in USG reports. But in this study, it was observed that the renal volume and renal cortical thickness were better quantitative parameters than the renal length.

In our study, the body weight and surface area of the patients were not controlled. Therefore, the gender, height and body mass index of the patients are the limitation factors of this study.

Conclusion

This study showed the relevance of renal volume and cortical thickness measurements in the routine evaluation of CKD patients. Based on the findings, renal volume and cortical thickness should be considered along with the traditional parameters.

Conflict of interest

None to disclose.

Author contributions

Original concept of study: AG, AJ, DR. Writing of manuscript: AG, AJ, SK. Analysis and interpretation of data: AG, AJ, SK. Final acceptation of manuscript: AG, AJ, DR. Collection, recording and/or compilation of data: AG, DR. Critical review of manuscript: AJ, SK, DR.

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