

ORIGINAL RESEARCH ARTICLE

ULTRASONOGRAPHY IN PATIENTS WITH CHRONIC KIDNEY DISEASE

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Received: 16 Feb, 2021

Accepted: 2 Jun, 2021

Published: 19 Jun, 2021

**Key words:** Chronic kidney disease; USG.

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**Citation**

Chhetri PK, Basnet SB. Ultrasonography in patients with chronic kidney disease. Journal of Chitwan Medical College. 2021;11(36):110-14.



**ABSTRACT**

**Background:** Chronic kidney disease can be defined as kidney damage for > 3 months as evidenced by structural or functional abnormalities. Ultrasonography is the initial imaging modality employed in kidney disease. This study was undertaken to compare various sonographic parameters of the kidney with serum creatinine level and to establish the reliability of ultrasonography for estimating severity of kidney damage.

**Methods:** This was a hospital based cross-sectional study on 60 patients with known chronic kidney disease who were advised for ultrasonography in the Department of Radiodiagnosis, COMS-TH during one-year period from Feb 2017 to Jan 2018. The serum creatinine level of each patients was compared subjectively to the renal cortical echogenicity. Other parameters like cortico-medullary differentiation and morphological parameters including kidney length, parenchyma thickness, and cortical thickness were also measured. Data analysis was done using SPSS 20.0 software program. The statistical correlations between sonographic parameters and serum creatinine were calculated using one-way analysis of variance (ANOVA) followed by Scheffe's test.

**Results:** Renal cortical echogenicity in patients with chronic renal disease showed a significant positive correlation with serum creatinine ( $F = 120.93$ ;  $p < 0.001$ ). Other parameters like renal length ( $r = -0.933$ ;  $p < 0.001$ ), parenchymal thickness ( $r = -0.945$ ;  $p < 0.001$ ) and cortical thickness ( $r = -0.980$ ;  $p < 0.001$ ) also showed significant but negative linear correlation with serum creatinine.

**Conclusions:** Ultrasonography parameters like cortical echogenicity, renal length, parenchymal and cortical thickness can be used along with serum creatinine for estimating severity of renal damage in chronic kidney disease.

**INTRODUCTION**

Chronic kidney disease (CKD) is a major public health problem and its prevalence is on the increase.<sup>1</sup> CKD is usually a silent disease in the early stages with a long latent period.<sup>2</sup> Failure to recognize CKD early is a missed opportunity and lead to development of end stage renal disease (ESRD) or other cardiovascular events complicating CKD.<sup>3,4</sup>

The definition of chronic kidney disease was proposed for the first time by the National Kidney Foundation - Kidney Disease Outcomes Quality Initiative (NKF-KDOQI) in 2002 and was endorsed by the Kidney Disease: Improving Global Outcomes (KDIGO) in 2004. According to the guidelines, CKD is defined as kidney damage for > 3 months, as defined by structural or functional abnormalities, with or without decreased glomerular filtration rate (GFR). Such kidney damage can be diagnosed by pathological abnormalities, markers of kidney damage or imaging abnormalities.<sup>5</sup>

The clinical utility of serum creatinine as a measure of renal function centers on its relation to the GFR.<sup>6</sup> CKD is classified into various stages by the level of GFR, with higher stages of CKD representing lower GFR levels.<sup>7</sup>

The availability, lack of ionizing radiation and portability with the option of repeatability makes USG the initial investigating modality in patients with renal diseases.<sup>8</sup> Echogenic kidneys indicate the presence of parenchymal renal disease; the kidneys may be of a normal size or enlarged. Small kidneys suggest advanced stage of chronic kidney disease.<sup>9</sup>

This study aimed to correlate various renal USG parameters with serum creatinine level in patients with CKD.

**METHODS**

This hospital-based cross-sectional study was carried out in the Department of Radiodiagnosis, College of Medical Science-Teaching Hospital, Bharatpur during one-year period from Feb 2017 to Feb 2018 after approval by Ethical Committee of College of Medical Sciences-Teaching Hospital, Bharatpur (Ref No. 2017-065). Sixty patients diagnosed with CKD were included in the study. Patients on renal replacement therapy (hemodialysis, peritoneal dialysis, and renal transplantation) as well as those with fatty liver and other liver diseases were excluded. Patients with acute renal failure on the setting of CKD and those with severe cachexia were also excluded.

Serum creatinine level of each patient was collected prior to USG. Renal length, parenchymal thickness, cortical thickness, cortical echogenicity, and cortico-medullary differentiation were evaluated in all the patients. In every case, the mean values of the right and left renal length, parenchymal thickness, and cortical thickness were calculated.

USG (Toshiba Aplio 500) of the kidneys and liver was performed using curved array transducer of 3.5 MHz. The kidney was scanned in both longitudinal and transverse planes, with the patient supine or in the lateral decubitus position in quiet respiration. If necessary patients were advised to hold breath in deep inspiration esp for measurement of longitudinal renal length which was taken as the greatest pole-to-pole distance in the mid-sagittal plane. The distance between the renal sinus fat and the capsule was taken as the measurement of renal parenchymal thickness. Renal parenchymal thickness was obtained at the upper, middle, and lower poles of both kidneys. The average was used as there was variation in distance between the echogenic sinus fat and the renal capsule in renal poles.

The renal cortical thickness was measured at the level of the mid- kidney in the sagittal plane. This measurement was taken as the shortest distance from the base of the medullary pyramid to the renal capsule over a medullary pyramid and perpendicular to the capsule. If the renal pyramid was not distinct in mid- kidney, cortical thickness was taken at one point where the cortico-medullary differentiation was most obvious. In cases with loss of cortico-medullary differentiation, cortical thickness was not recorded.

Renal cortical echogenicity was compared subjectively with the echogenicity of the liver. Normal renal cortex is typically less echogenic than adjacent liver and spleen. Sonographic grading was done based on subjective evaluation of renal cortical echogenicity and status of cortico-medullary differentiation, where:

Grade 0: Normal echogenicity less than that of the liver, with maintained corticomedullary definition

Grade 1: Echogenicity same as that of the liver, with maintained corticomedullary differentiation

Grade 2: Echogenicity greater than that of the liver, with maintained corticomedullary differentiation

Grade 3: Echogenicity greater than that of the liver, with poorly maintained corticomedullary differentiation

Grade 4: Echogenicity greater than that of the liver, with a loss of corticomedullary differentiation

Data analysis was done using SPSS (Statistical Package for the Social Sciences) 20.0 software program. The statistical correlations between renal sonographic grading and other renal parameters with serum creatinine were calculated using one-way analysis of variance (ANOVA) followed by Scheffe's test. The relationship between serum creatinine and sonographic parameters were also assessed by Pearson's correlation coefficient and p values less than 0.05 was considered statistically significant.

## RESULTS

Sixty consecutive patients with CKD who presented to the Department of Radiology for USG were included in this study. Of the 60 patients, 28 were male and 32 were female. The age ranged from 31 to 70 years. As shown in Table 1, the mean serum creatinine was 2.16 mg/dl for grade 1, 3.47 mg/dl for grade 2, 5.72 mg/dl for grade 3, and 8.67 mg/dl for grade 4. Significant difference was found in ANOVA when the independent variable was renal sonographic grades (1 to 4) and dependent numerical variables was serum creatinine (F= 120.93; p<0.001)

**Table 1: Comparison of serum creatinine with renal sonographic grades**

Sonographic grades	No of patients	Mean Serum creatinine (mg/dl)	SD	Min	Max	F value	p-value
Grade 1	15	2.16	0.24	1.80	2.80	120.93	<0.001
Grade 2	21	3.47	0.78	1.90	4.70		
Grade 3	14	5.72	0.80	3.70	6.90		
Grade 4	10	8.67	1.67	6.00	11.50		
Total	60	4.54	2.42	1.80	11.50		

SD: Standard deviation, F value: ANOVA test value, Min: Minimum, Max: Maximum,

**Table 2: Comparison of mean renal length (mm) with renal sonographic grades**

Sonographic grades	No of patients	Mean parenchymal thickness (mm)	SD	Min	Max	F value	p-value
Grade 1	15	18.48	0.23	18.20	19.00	374.17	<0.001
Grade 2	21	16.69	1.03	14.90	18.30		
Grade 3	14	13.09	0.58	12.40	14.80		
Grade 4	10	9.88	0.39	9.20	10.40		
Total	60	15.16	3.14	9.20	19.00		

As shown in Table 2, the mean renal length was 97.87 mm for grade 1, 91.51 mm for grade 2, 83.91 mm for grade 3, and 74.42 mm for grade 4. A significant difference was found in ANOVA when the independent variable was renal sonographic grades (1 to 4) and dependent numerical variables were renal length (F= 209.75; P<0.001)

As shown in Table 3, the mean parenchymal thickness was 18.48 mm for grade 1, 16.69 mm for grade 2, 13.09 mm for grade 3 and 9.88 mm for grade 4. A significant difference was found in ANOVA when the independent variable was renal sonographic grades (1 to 4) and dependent numerical variables were renal parenchymal thickness (F= 374.17; P<0.001)

**Table 3: Comparison of mean parenchymal thickness (mm) with renal sonographic grades**

Sonographic grades	No of patients	Mean parenchymal thickness (mm)	SD	Min	Max	F value	p-value
Grade 1	15	18.48	0.23	18.20	19.00	374.17	<0.001
Grade 2	21	16.69	1.03	14.90	18.30		
Grade 3	14	13.09	0.58	12.40	14.80		
Grade 4	10	9.88	0.39	9.20	10.40		
Total	60	15.16	3.14	9.20	19.00		

**Table 4: Comparison of mean cortical thickness (mm) with renal sonographic grades**

Sonographic grades *	No of patients	Mean cortical thickness (mm)	SD	Min	Max	F value	p-value
Grade 1	15	8.45	0.16	8.20	8.70	187.48	<0.001
Grade 2	21	7.63	0.45	7.10	8.40		
Grade 3	14	6.06	0.27	5.70	6.50		
Grade 4	-	-	-	-	-		
Total	50	7.43	0.99	5.70	8.70		

As shown in Table 4, the mean cortical thickness was 8.45 mm for grade 1, 7.63 mm for grade 2 and 6.06 mm for grade 3. A significant difference was found in ANOVA when the independent variable was renal sonographic grades (1 to 4) and the dependent numerical variable was renal cortical thickness (F= 187.48; p<0.001). By definition, Grade 4 involves loss of corticomedullary definition and thus cortical thickness cannot be measured; hence, Table 4 excludes cortical thickness with renal sonographic grades 4.

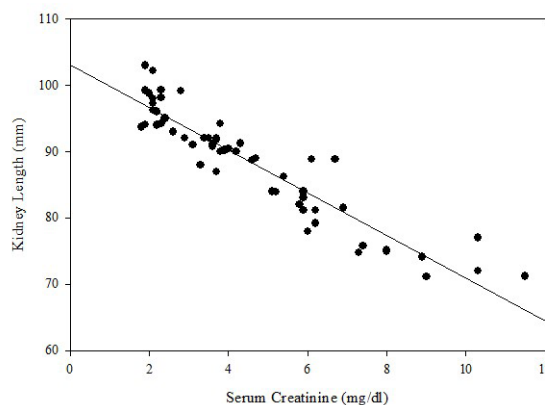
Table 5 showed statistically significant negative linear correlation between serum creatinine and kidney length, parenchymal and cortical thickness.

**Table 5: Statistical correlation between serum creatinine and mean renal length, parenchymal and cortical thickness**

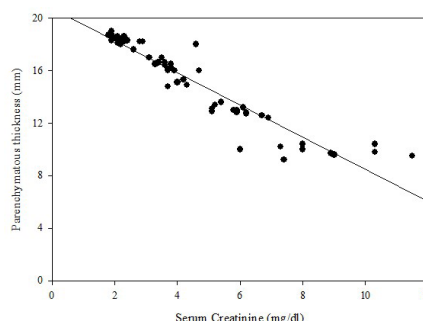
Renal Parameters	Number of patients	Pearson's Correlation (r)	p value
Kidney length	60	-0.933**	<0.001
Parenchymal thickness	60	-0.945**	<0.001
Cortical thickness	50	-0.980**	<0.001

\*\* . Correlation is significant at the 0.01 level (2-tailed)

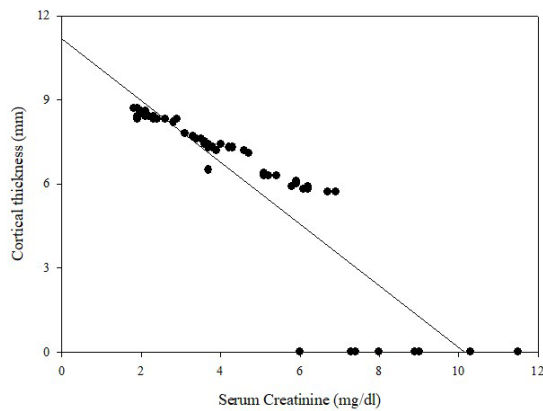
A negative correlation between serum creatinine and kidney length is shown in Fig 1, parenchymal thickness in Fig 2 and cortical thickness in Fig 3.



**Figure 1: Negative correlation between renal length and serum creatinine**



**Figure 2: Negative correlation between renal parenchymal thickness and serum creatinine**



**Figure 3: Negative correlation between renal cortical thickness and serum creatinine**

### DISCUSSION

In this study of 60 patients with CKD, significant positive correlation was observed between serum creatinine and renal sonographic grades ( $p < 0.001$ ). The mean serum creatinine was 2.16 mg/dl for Grade 1, 3.47 mg/dl for Grade 2, 5.72 mg/dl for Grade 3, and 8.67 mg/dl for Grade 4. Increased sonographic grading was thus associated with increased serum creatinine level.

In a similar study, Siddappa et al. observed a significant positive relationship between serum creatinine and renal sonographic grades ( $p = 0.004$ ). The reported mean serum creatinine was 2.80 mg/dl for Grade 1, 3.69 mg/dl for Grade 2, 3.86 mg/dl for Grade 3, and 7.90 mg/dl for Grade 4.<sup>10</sup> Similarly, Singh et al. also showed a statistically significant positive correlation ( $p < 0.001$ ) between renal sonographic grades and serum creatinine level. The mean serum creatinine was 2.87 mg/dl for Grade 1, 3.27 mg/dl for Grade 2, 4.3 mg/dl for Grade 3, and 5.8 mg/dl for Grade 4.<sup>11</sup> Thus both these studies by Siddappa et al. and Singh et al. had similar results to our study which concluded that increased renal sonographic grading was associated with increased serum creatinine level.

With progressive renal failure, the renal cortical echogenicity increases. This may be indicative of worsening renal function. Gradually, the whole parenchyma becomes echogenic blending in with the echogenicity of the renal sinus, giving the kidney an entirely echogenic appearance.<sup>7, 9</sup> A study by Moghazi et al. showed that renal cortical echogenicity showed strong correlation with histologic parameters of glomerular sclerosis, tubular atrophy, interstitial fibrosis, and interstitial inflammation but only tubular atrophy and interstitial inflammation remained significant in multivariate analysis. It shows that renal cortical echogenicity is determined primarily by tubular atrophy and interstitial inflammation, and is the sonographic parameter that correlates best with pathologic findings.<sup>12</sup>

A statistically significant negative correlation was observed between mean renal length and serum creatinine ( $r = -0.933$ ;  $p < 0.001$ ) in this study. A negative value of Pearson's correlation

coefficient means that increased serum creatinine was associated with decreased renal length. Similarly, Siddappa et al. also observed a statistically significant negative linear correlation between renal length and serum creatinine ( $r = -0.224$ ;  $p = 0.085$ ) which also meant that increased serum creatinine was associated with decreased renal length.<sup>10</sup>

Lucisano et al. in their study of adult patients with CKD compared USG parameters with GFR estimated by the chronic kidney disease epidemiology collaboration equation (CKD-EPI). The renal length showed the highest correlation ( $r = 0.510$ ;  $p < 0.001$ ) with the GFR. The Positive value of Pearson's correlation coefficient means that decreased GFR (decreased renal function) was associated with decreased renal length.<sup>13</sup>

Renal length has traditionally been considered a surrogate marker of renal function. According to Fiorini and Barozzi, renal length under 8 cm is definitely reduced and should be attributed to CKD, whereas a length between 8 and 9 cm should always be correlated to the patient's phenotype, particularly the height.<sup>14</sup> However, a study by Noortgate et al. reported that kidney length and volume correlated with estimated glomerular filtration rate (eGFR) in the elderly, but that kidney length had lower specificity in predicting renal impairment.<sup>15</sup>

In this study, a statistically significant negative correlation was observed between mean renal parenchymal thickness and serum creatinine ( $r = -0.945$ ;  $p < 0.001$ ) which means that increased serum creatinine (decreased renal function) was associated with decreased renal parenchymal thickness. Similarly, Siddappa et al. also noted a statistically significant negative linear correlation between mean parenchymal thickness and serum creatinine ( $r = -0.259$ ;  $p = 0.046$ ) which also meant that increased serum creatinine was associated with decreased renal length.<sup>10</sup> Lucisano et al. in their study compared renal parenchymal thickness with GFR. They showed that renal parenchymal thickness showed a positive correlation ( $r = 0.537$ ;  $p < .001$ ) with GFR in patients with CKD which means that decreased GFR was associated with decreased renal parenchymal thickness.<sup>13</sup> Thus both these two studies had similar conclusion to our results that decreased renal function was associated with decreased renal parenchymal thickness. Moghazi et al. showed that parenchymal thickness correlated with renal tubular atrophy on histopathology.<sup>12</sup>

In this study, a significant negative correlation was observed between mean renal cortical thickness and serum creatinine ( $r = -0.980$ ;  $p < 0.001$ ) which means that increased serum creatinine was associated with decreased renal cortical thickness. Similarly, Beland et al. suggested that cortical thickness would be a good indicator for renal function impairment as they demonstrated a statistically significant linear relationship and a strong correlation ( $r^2 = 0.66$ ) between cortical thickness and renal function.<sup>16</sup> Yamashita et al. compared renal sonographic parameters with eGFR in patients with CKD. They found moderate correlation between GFR and measurements of renal cortical thickness ( $r = 0.478$ ;  $p < 0.001$ ) which means that decreased GFR and thus decreased renal function was associated with decreased renal cortical thickness.<sup>17</sup>

It is known that glomeruli are found in the renal cortex and column of Bertin and progressive renal function impairment affects the glomeruli which results in tapering of the renal cortex and of columns of Bertin. Even with these changes, however, the bipolar length and parenchymal thickness may still be within normal limits, hence the relevance of cortical thickness as a possible predictor of CKD.<sup>18</sup>

Takata et al. found stepwise associations in renal length, cortical thickness and parenchymal thickness with decreased renal function and cortical thickness to be the strongest associated parameter.<sup>19</sup> Likewise Beland et al. showed that cortical thickness on USG appears to be more closely related to GFR than renal length in patients with CKD.<sup>16</sup> Similarly Widjaja et al. reported that cortical thickness was better predictor of renal function than renal length in patients with renal artery stenosis.<sup>20</sup> This could be explained by the fact that renal length varies with the height of the individual and tends to decrease after the age of 50, when the kidneys become wider.<sup>21</sup> Also CKD predominantly consists of hypertensive and diabetic patients resulting in a combination of ischemic nephropathy

that theoretically causes renal cortex thinning and diabetic nephropathy which is associated with hypertrophy (nephromegaly).<sup>17</sup>

## CONCLUSION

USG parameters based on cortical echogenicity and cortico-medullary differentiation showed positive correlation with serum creatinine. Other USG parameters such as renal length, parenchymal thickness and cortical thickness showed a negative linear correlation with serum creatinine. Hence, renal USG can be used along with serum creatinine for estimating extent of renal damage in CKD. These renal parameters are also important in the assessment and follow up of patients because these renal changes are the results of long term changes in kidney morphology and function. This study further confirms the significance of USG in patients with CKD.

**CONFLICT OF INTEREST:** None

**FINANCIAL DISCLOSURE:** None

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