Correlation of B-mode and Doppler Ultrasound Parameters of Kidney with Serum Creatinine Level in Chronic Kidney Disease Patients

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ABSTRACT

Background: Chronic kidney disease (CKD) is an emerging health issue around the world. The prevalence of CKD is 22.48% among the Bangladeshi population, which is higher than the global scenario. Early detection and making adequate therapeutic decisions are essential for the medical care of CKD. B-mode and Doppler renal ultrasound parameters could be of great utility in CKD, providing valuable information about the morphological changes occurring in kidneys in the course of the disease. Such information could usefully complement the laboratory investigations commonly performed in the follow-up of patients with CKD to achieve a more complete assessment.

Objective: The purpose of this study was to determine which B-mode ultrasound parameter is better correlated with serum creatinine level and the correlation of Doppler parameters (resistive index of intra-renal arteries) with serum creatinine level in CKD patients.

Patients and Methods: This cross-sectional study was conducted in the Ultrasound and Color Doppler division of NINMAS between August 2020 and November 2021. Fifty study subjects diagnosed with CKD according to the KDIGO (Kidney Disease Improving Global Outcomes) guideline, having raised serum creatinine levels >1.4 mg/dl, were enrolled in this study. USG was performed by a Phillips Affinity 70G machine with a curvilinear transducer having a central frequency of 3.5–5 MHz. Cortical echogenicity, kidney size (bipolar length, width, and volume), cortical thickness, and cortico-medullary differentiation (CMD) were assessed by B-mode ultrasonography, and the perfusion of the kidney and RI of the segmental, interlobar, and arcuate branches of the renal artery was assessed by color Doppler. Then all these parameters were correlated with the serum creatinine level of the patients.

Results: Mean serum creatinine was significant among echogenicity grades (p=0.003). A statistically significant strong positive correlation was observed between serum creatinine and cortical echogenicity grading (r= +0.794, p = 0.001); a strong positive correlation was observed between serum creatinine and RI of the segmental and interlobar arteries (r = +0.767, p<0.001) and (r= +0.744, p<0.001), respectively. Moderate negative correlation was observed between serum creatinine and bipolar length (r = -0.678, p<0.001) and serum creatinine and cortical thickness (r= -0.664, p =<0.00and Moderate positive correlation was observed between serum creatinine and cortico-medullary differentiation (r = +0.445, p = 0.00100and).

Conclusion: The best ultrasound parameter that correlates with serum creatinine is renal cortical echogenicity and its grading, the resistive index of segmental and interlobar arteries, in comparison to bipolar length, cortical thickness, cortico-medullary differentiation, and the RI of the arcuate artery in patients with CKD.

Keywords: Chronic kidney disease, B-mode ultrasonography, Doppler ultrasound

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INTRODUCTION

An increased creatinine level over a period of few months to years is termed as chronic kidney disease (CKD). It is based on the extent of kidney damage, calculated through decreased glomerular filtration rate (GFR) (i.e. < 60 ml/min per 1.7 m2) for more than three months (1,2). CKD is one of the common causes of renal failure and leads to end stage renal disease (ESRD). It involves a progressive loss over the course of months in the structure and functions of the kidneys, with or without a decreased glomerular filtration rate (GFR). Chronic kidney disease can be diagnosed by its pathological abnormalities, changes in the levels of kidney function markers (GFR, serum creatinine, blood urea and BUN) in the blood or urine, or by imaging investigations (3).

Ultrasonography is a noninvasive and inexpensive imaging modality, provides sufficient anatomical details necessary to diagnose renal diseases without exposing the patient to radiation or contrast and hence has replaced standard radiography in our country and abroad (4,5,6).

Doppler study of renal vessels is also a noninvasive method widely used in clinical practice for CKD patients. It can detect not only renal macro-abnormalities but also changes in the renal vasculature and blood flow. The resistive index (RI) is commonly used as an index of intrarenal arterial resistance. Resistive index of intrarenal vessels increase in various kidney diseases and previous studies have shown the associations of resistive index with renal function and patient prognosis (7). All these factors promote early detection and prediction of deranged renal function tests necessary for making a therapeutic decision.

In patients with chronic kidney disease, B mode and Doppler sonographic dimensional parameters could be of great utility, providing valuable information about the morpho-structural changes occurring in the kidney in the course of chronic kidney disease. Such information could usefully complement the laboratory investigations commonly performed in the follow-up of the patients with chronic kidney disease to achieve a more complete assessment of the disease by the combination of functional and morpho-structural information. However, this possibility is not fully realized yet, probably because the reliability of renal sonography is questioned by the observation that sonographic parameters are often operator dependent, renal dimensions also depend on anthropometric variables (8,9) and that these limitations are not adequately considered in clinical practice. Ultrasound identifies kidney size, cortical thickness, and echogenicity of renal cortex apart from its importance in detailing a dilated collecting system (10). These details assist in identifying the extent of renal parenchymal damage and the possibility of its reversibility (11) and the decision to perform a renal biopsy (12). According to a study, abnormal sonographic findings were seen in 67% of cases of chronic kidney disease (13).

Hence, B-mode ultrasound and Doppler study of intra-renal vessels is a good modality to ascertain renal insufficiency and progression of chronic kidney disease. The aim of our study is to correlate renal cortical echogenicity, kidney size, cortical thickness, corticomedullary differentiation and resistive index of intrarenal vessels (segmental and arcuate branches of renal artery) with serum creatinine level to investigate which of these parameters are more significant in identifying the extent and progression of chronic kidney disease as well as the use of ultrasound imaging in the grading of chronic kidney disease (14).

PATIENTS AND METHODS

This cross-sectional study was conducted in Ultrasound and Color Doppler division of NINMAS. The study period was August 2020 to November 2021. Fifty study subjects diagnosed with CKD according to KDIGO (Kidney Disease Improving Global Outcomes) guideline, having raised serum creatinine level >1.4 mg/dl were enrolled in this study. The patient's serum creatinine level was measured on the same day that ultrasonography was done. Ethical clearance was taken from the Medical Research Ethics Committee (MREC), prior to the commencement of the study. Informed written consent was obtained from every study subjects, detail history was recorded and confidentiality was maintained. USG was done by Phillips Affinity 70G machine with curvilinear transducer having central frequency 3.5-5MHz. Cortical echogenicity, kidney size (bipolar length, width and volume), cortical thickness, cortico-medullary differentiation (CMD) were assessed by B mode ultrasonography and perfusion of kidney and RI of segmental, interlobar and arcuate branches of renal artery was assessed by Color Doppler study. Then all these parameters were correlated with serum creatinine level of the patients.

Statistical analysis:

All data were recorded systematically in a pre-prepared data collection form. Quantitative data was expressed as mean and standard deviation, and qualitative data was expressed as frequency distribution and percentage. Statistical analyses were performed using Windows-based computer software with Statistical Packages for Social Sciences (SPSS-26) (SPSS Inc., Chicago, IL, USA). An ANOVA test was done among groups. The correlation between variables was seen by Pearson's correlation test (for quantitative parameters) and the Spearman rho correlation test (for qualitative parameters). A P value of <0.05 was considered statistically significant.

RESULT

A total of 50 patients diagnosed with chronic kidney disease were enrolled in this cross-sectional study. Among them, 28 (56%) were male and 22 (44%) were female. The male-to-female ratio was 1.3:1. Two patients (4%) were in the less than 29-year-old age group, nine patients (18%) were in the 30-39-year-old age group, twelve patients (24%) were in the 40-49-year-old age group, sixteen patients (32%) were in the 50-59-year-old age group, ten patients (20%) were in the 60-69-year-old age group, and there was only one patient (2%) in the more than 70-year-old age group.

Table 1 shows the distribution of the study population by CKD stage as per GFR, calculated by the CKD-EPI equation. It was observed that among the study population, fifteen (30%) patients were in CKD stage 3, twenty-three (46%) patients were in CKD stage 4, and twelve (24%) patients were in CKD stage 5.

Table 1: Total study population (n=50) with chronic kidney disease and their stages according to glomerular filtration rate, calculated by CKD-EPI equation

CKD stage by CKD-EPI	No of patients	Percentage (%)
Stage 3	15	30.0
Stage 4	23	46.0
Stage 5	12	24.0

Table 1: Total study population (n=50) with chronic kidney disease and their stages according to glomerular filtration rate, calculated by CKD-EPI equation

Distribution of serum creatinine level among echogenicity grading of the study population is shown in Table 2. Maximum patients (19) were in echogenicity grade 3. Two patients were in echogenicity grade 1 and their mean creatinine was 1.5. Seventeen patients were in echogenicity grade 2 and their mean creatinine was 2.4. Nineteen patients were in echogenicity grade 3 and their mean creatinine was 3.4. Twelve patients were in echogenicity grade 4 and their mean creatinine was 4.2. Mean serum creatinine was significant among echogenicity grades (p = 0.003).

Table 2: Grading of renal cortical echogenicity in comparison to serum creatinine (n=50)

Echogenicity Grading	N	Mean S. Cr	SD	95% CI		F-value	*p*-value
				Lower	Upper		
Grade 1	2	1.50	0.14	0.23	2.77	5.31	0.003[s]
Grade 2	17	2.46	1.01	1.94	2.98		
Grade 3	19	3.42	1.66	2.62	4.23		
Grade 4	12	4.19	1.14	3.47	4.92		
Total	50	3.20	1.49	2.78	3.63		

CI= Confidence interval
p-value reached from ANOVA test, s= significant

Pearson correlation was done to compare the levels of serum creatinine with kidney size (length, width and renal volume) (Table 3). Statistically significant moderate negative correlation was observed between bipolar length of the kidney and serum creatinine level (r= -0.678, p=<0.001). Negligible negative correlation was observed between width of the kidney and serum creatinine level, p value was not significant (r= -0.140, p=0.334). Negligible negative correlation was also observed between volume of the kidney and serum creatinine level, p value was also not significant (r= -0.145, p=0.315).

Table 3: Renal length, width and volume were measured to compare kidney size with serum creatinine (n=50)

	Pearson Correlation	
	r-value	*p*-value
Kidney size (length) (cm)	-0.678**	<0.001
Kidney size (width) (cm)	-0.140	0.334
Renal volume (ml)	-0.145	0.315

**significant

Table 4 shows correlation of serum creatinine with cortical thickness of the kidney using Pearson correlation. Moderate negative correlation was observed between cortical thickness of the kidney and serum creatinine level (r= -0.664 and p <0.001), p value was significant. Cortical thickness cannot be measured when CMD is lost. In 14 patients of this study population, CMD was lost. So, for this table study population was 50-14= 36).

Table 4: Correlation of serum creatinine with cortical thickness of kidney

	Pearson Correlation	
(n=36)	r-value	*p*-value
Cortical thickness (cm)	-0.664**	<0.001

**significant

Correlation of serum creatinine with cortical echogenicity, CMD and perfusion of the kidney was shown in Table 5 using Spearman's rho correlation. Statistically significant strong positive correlation was observed between serum creatinine and cortical echogenicity grading. Spearman's rho correlation coefficient was +0.794, p=0.001.

Statistically significant moderate positive correlation was observed between serum creatinine and CMD. Here, Spearman's rho correlation coefficient was +0.445, p=0.001.

Negligible negative correlation was observed between serum creatinine and perfusion of kidney. Here, Spearman's rho correlation coefficient was -0.167, and p value was not significant (p=0.248).

Table 5: Correlation of serum creatinine with cortical echogenicity, corticomedullary differentiation and renal perfusion (n=50)

	Spearman's rho Correlation	
	r-value	*p*-value
Cortical echogenicity grading	+0.794**	0.001
Corticomedullary differentiation	+0.445**	0.001
Renal perfusion	-0.167	0.248

**significant

Table 6 shows correlation of serum creatinine with resistive index of segmental, interlobar and arcuate branches of renal artery using Pearson correlation. Statistically significant strong positive correlation was found between serum creatinine and resistive index of segmental artery, r=+0.767, p<0.001. Strong positive correlation was also found between serum creatinine and resistive index of interlobar artery, r= +0.744, p<0.001 which was statistically significant. Statistically significant moderate positive correlation was found between serum creatinine and resistive index of arcuate artery, r= +0.445 p=0.001.

Table 6 : Correlation of serum creatinine with resistive index (n=50)

	Pearson Correlation	
	r-value	*p*-value
Resistive Index (segmental artery)	+0.767**	<0.001
Resistive Index (interlobar artery)	+0.744**	<0.001
Resistive Index (arcuate artery)	+0.445**	0.001

**significant

DISCUSSION

Chronic kidney disease (CKD) is a growing public health problem and one of the most common causes of mortality and morbidity around the world. The incidence of CKD is higher among the Bangladeshi population than in the global scenario. Ultrasound is also a popular and common modality for routine checkup investigations as well as investigations for other causes than CKD. The incidental abnormal renal ultrasound findings may alert the clinician to further investigation and lead to an early diagnosis.

In this cross-sectional study, it was observed that CKD was most common (32%) in the 50–59-year-old age group. This study included a total of 50 patients diagnosed with CKD; among them, 56% were male and 44% were female. The male-to-female ratio is 1.3:1. A study conducted by Sidappa et al. with 60 CKD patients similarly showed a higher prevalence of CKD among males (70%) than in females (30%) (15).

This study showed that, among the study population, 30% of patients were in CKD stage 3 (GFR 30–60 ml/min), 46% were in CKD stage 4 (GFR 15–30 ml/min), and 24% were in CKD stage 5 (GFR <15 ml/min). Here, GFR was estimated by the CKD-EPI equation. A study by Chen, Knicely, and Grams reported that the estimation of GFR by the CKD-EPI 2009 creatinine equation is more accurate and preferred over the MDRD equation in the United States and in much of the world (16).

This study showed statistically significant strong positive correlation between serum creatinine and cortical echogenicity and its grading (r= +0.794, p = 0.001), which was quite similar to the study done by Ahmed et al., where statistically significant strong positive correlation was also observed between serum creatinine and cortical echogenicity and its grading (r= +0.915, p where a005) (14). Research by Päivänsalo, Huttunen, and Suramo also showed that a highly echogenic cortex was the most common abnormality among CKD patients (17).

Statistically significant moderate negative correlation was observed between bipolar length of the kidney and serum creatinine level (r= -0.678, p =<0.001) in this study. A study by Ahmed et al. also showed significant moderate negative correlation between bipolar length of the kidney and serum creatinine level (r= -0.505, p =<0.0005) (14). According to a study by Fiorini and Barozzi, renal length under 8 cm is definitely reduced and should be attributed to chronic renal failure. Renal length decreases with decreasing renal function; renal length has traditionally been considered a surrogate marker of renal function. Hence, for the progression of the disease process, estimation of renal length should be preferred to renal volume (18). A negligible negative correlation was observed between the width and volume of the kidney and serum creatinine level in this study; the p value was not significant (r = -0.140, p = 0.334) or15r = respectively. Similarly, a study by Lucisano et al. revealed that renal width is the worst parameter (r=0.371, p = 0.2), and kidney length (r = 0.460, p<0.001) is better correlated with serum creatinine (19) over width and volume of kidney.

Sonographically, cortical thickness cannot be measured when CMD is lost. In 14 patients in this study population, CMD was lost. So, a correlation was found between serum creatinine and cortical thickness in 36 study subjects (n = 50, 14 = 36). A significant moderate negative correlation was observed between cortical thickness of the kidney and serum creatinine level (r = -0.664 and p <0.001) in this study, which is similar to a study conducted by Ahmed et al, that also reported statistically significant negative correlation between cortical thickness and serum creatinine (r= - 0.845; .nd p = 0.0005) (14).

A statistically significant moderate positive correlation was observed between serum creatinine and CMD in this study (r = +0.445, p = 0.001), which was quite similar to a study done by Ibinaiye et al. and Singh et al. and also showed similar values (p<0.001) (20).

This study showed a statistically significant strong positive correlation between serum creatinine and the resistive index of the segmental artery (r = +0.767, p<0.001). A statistically significant, strong positive correlation was also observed between serum creatinine and the resistive index of the interlobar artery (r = +0.744, p<0.001). Significant moderate positive correlation was observed between serum creatinine and resistive index of arcuate artery (r= +0.445 p = 0.001). Similarly, the correlation between serum creatinine and RI of the segmental artery was evaluated in a study conducted by Bigé et al., and their Pearson's correlation coefficient was 0.99 (21). An Iranian cross-sectional study by Ghafouri M et al. also showed a statistically significant positive correlation between serum creatinine level and RI (r = 0.68, p<0.001) of the interlobar artery (22). Many of our study population were hypertensive and were on medication prescribed by their physician. A study by Bigé et al. revealed that RI was not different between patients who received antihypertensive treatment and those who did not (p =0.87) (21).

In a cross-sectional study done by Shirin et al., it was similarly reported that RI measured by Doppler ultrasonography is a useful diagnostic modality for the detection of renal dysfunction. RI is well correlated with serum creatinine (r = 0.581, p<0.01) and can be used as an additional diagnostic tool (23). In a study by Hanamura, it was also mentioned that RI in CKD patients was considered a marker of renal function and an indicator of a risk factor for adverse renal prognosis (24).

In this study, a negligible negative correlation was observed between serum creatinine and perfusion of the kidney. Spearman's rho correlation coefficient was -0.167, p = 0.248. This signifies that renal perfusion is not a good parameter for evaluating renal functional status.

The Pearson correlation coefficient was +0.794 between serum creatinine and echogenicity grades, +0.767 and +0.744 between serum creatinine and RI of segmental and interlobar arteries, respectively, -0.678 between serum creatinine and kidney length, -0.664 between serum creatinine and cortical thickness, and +0.445 between serum creatinine and CMD in this study. From this study, according to the r-value, it can also be said that changes in cortical echogenicity can be found in 64% of CKD patients, and changes in the resistive index of intrarenal arteries can be observed in more than 50% of CKD patients. So, cortical echogenicity and its grading and RI of segmental and interlobar arteries show the best correlation with serum creatinine levels and can be considered a fair predictor of renal function.

CONCLUSION

The best B-mode ultrasound parameter that correlates with serum creatinine is renal cortical echogenicity, and it's grading in comparison to bipolar length, cortical thickness, and cortico-medullary differentiation. The best Doppler ultrasound parameter that correlates with serum creatinine is the RI of the segmental and interlobar arteries in comparison to the RI of the arcuate artery and renal perfusion. As incidental sonographic findings, these parameters (renal cortical echogenicity, RI of segmental and interlobar arteries) may be a good predictor of renal impairment that may alert the clinician for further detail investigation, leading to an early diagnosis.

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