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Correlation of Duplex Ultrasonographic Parameters with Glomerular Filtration Rate in Chronic Kidney Disease

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ABSTRACT

Background: Chronic kidney disease encompasses a spectrum of different pathophysiological processes associated with abnormal renal function and a progressive decline in glomerular filtration rate. Duplex ultrasonography is widely available and important imaging investigation required in the work-up of chronic kidney disease. The objective of the study was to assess correlation of renal duplex ultrasonographic parameters with decreased glomerular filtration rate in patients with chronic kidney disease.

Methods: This was a crosssectional hospital-based study. A total of sixty-two patients with chronic kidney disease referred for ultrasonography were included in the study. Patients were evaluated by duplex ultrasonography. Correlation of renal length, parenchymal thickness, cortical thickness, cortical echogenicity, peak systolic velocity, end diastolic velocity pulsatility index and resistive index with glomerular filtration rate was evaluated by using Pearson's correlation coefficient.

Results: Chronic kidney disease was seen more prevalent in 41-50 years of age group. The major risk factors associated with Chronic kidney disease was Hypertension and Diabetes Mellitus. A significant positive correlation of renal length, parenchymal thickness, cortical thickness (p value < 0.01) and end diastolic velocity (p value < 0.05) with eGFR and significant negative correlation of cortical echogenicity, resistive index and pulsatility index (p value < 0.01) with eGFR was derived.

Conclusions: Duplex sonographic findings of renal length, parenchymal thickness, cortical thickness, cortical echogenicity, end diastolic velocity, pulsatility index and resistive index are found to be useful parameters in evaluation of chronic kidney disease.

Keywords: Chronic kidney disease; duplex ultrasonography; glomerular filtration rate.

INTRODUCTION

Chronic Kidney Disease (CKD) is defined as abnormalities of kidney structure or function, present for >3 months, with implications for health. Criteria for CKD includes either decreased glomerular filtration rate (eGFR) or markers of kidney damage (albuminuria, urine sediment abnormalities, electrolyte and other abnormalities, abnormalities detected on histopathology or imaging, history of kidney transplantation).[1] The prevalence of CKD has increased worldwide because of the growing number of cases of diabetes, hypertension etc.[2] With appropriate pharmacological measures and lifestyle changes, progression to end stage renal disease can be prevented and number of dialysis can be decreased if diagnosis of CKD could be made at an early stage.[3]

Ultrasound helps to determine an irreversible disease, assess prognosis and avoid unnecessary diagnostic or therapeutic intervention.[4] This study aims to assess the correlation of duplex sonographic parameters (gray scale parameters: renal length, parenchymal and cortical thickness, cortical echogenicity ; and doppler parameters: peak systolic velocity(PSV), end diastolic velocity(EDV), resistive index (RI) and pulsatility index (PI) in evaluation of chronic kidney disease.

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METHODS

This is a cross sectional study done in Department of Radiodiagnosis and Imaging, B. P. Koirala Institute of Health Sciences, over a period of one year (September 1, 2015- August 31, 2016). Approval of institutional review board, BPKIHS was taken before commencing the study. Patients' consent, detailed clinical information and treatment history was collected as per structured pro forma.

Diagnosed CKD patients or having clinical suspicion of CKD with abnormal serum creatinine undergoing ultrasonographic examination of abdomen at BPKIHS were included in the study.

Patients on kidney replacement therapy ; with ADPKD (difficult to evaluate CMD, cortical and renal parenchymal thickness), with fatty liver or other diffuse liver disease diagnosed during ultrasonography (because of difficulty in grading the echogenicity of the kidney); with acute kidney injury; with features of obstructive uropathy on ultrasonography and with superimposed renal infection were excluded from the study.

Using standard B mode grayscale, ultrasonography was done on Siemens Acuson X300 machine. Ultrasonography of the kidney and liver was performed. Length of the kidney was measured pole to pole. The parenchymal thickness was measured in transverse plane in upper, mid and lower poles as the distance between outer renal margin and outer margin of renal sinus. Cortical thickness was measured in the sagittal plane over a medullary pyramid, perpendicular to the capsule in upper, mid and lower poles. Renal length, parenchymal thickness, cortical thickness, cortical echogenicity, and corticomedullary differentiation were evaluated. In each case, the values of the right and left renal length were recorded. The mean value of parenchymal thickness and cortical thickness for each kidney was calculated. Cortical echogenicity of the kidney was compared with liver and ultrasonographic grading of cortical echogenicity was derived as suggested.[5] Cortical echogenicity less than that of liver with maintained corticomedullary definition was considered normal or Grade 0. Cortical echogenicity same as that of liver with maintained corticomedullary definition was considered Grade 1. Cortical echogenicity greater than that of the liver with maintained corticomedullary definition was considered Grade 2.Cortical echogenicity greater than that of the liver with poorly maintained corticomedullary definition was considered Grade 3. Cortical echogenicity greater than that of the liver with loss of corticomedullary definition was considered Grade 4.

For Doppler study, kidneys were approached either from back or lateral lumbar approach and intrarenal segmental/interlobar arteries were identified with the aid of color flow box and spectral trace were obtained keeping the Doppler sample volume at the minimum. Doppler parameters were calculated from spectral trace using the software provided by the manufacturer (Fig.3). Appropriate Doppler angle, pulse repetition frequency (PRF) setting and sample volume was optimized. Peak systolic velocity (PSV), End diastolic velocity (EDV), Pulsatility index (PI) and Resistive index (RI) were evaluated in upper, mid and lower poles' region and average values were recorded. While obtaining the spectral tracings, the patient was asked to hold the breath completely.

Serum creatinine level estimated by BPKIHS laboratory (by Jeffe's reaction method) was used for the estimation of GFR .GFR was calculated by Cockcroft-Gault equation.[6] Staging of CKD was done on the basis of eGFR (>90 ml/min , 60-89 ml/min , 30-59 ml/min,15-29 ml/min and < 15 ml/min corresponding to stage 1, 2, 3, 4 and 5 respectively).

The data collected was tabulated in Microsoft Excel and analysis was carried out using Statistical Package for Social Sciences (SPSS) version 20.0.The relationship between sonographic parameters and eGFR was analysed by Pearson's correlation coefficient. P-values less than 0.05 was considered statistically significant.

RESULTS

A total of 62 patients were included in the study. The age of the patients ranged from 19 to 79 years with mean age of the patient 46.68±13.66 years. The maximum number of patients (i.e. 24.2% of total) with CKD was seen in 41-50 years of age group. Among the total patients, 35 were males and 27 were females. Distribution of patients according to stage of CKD is as shown in fig 1.

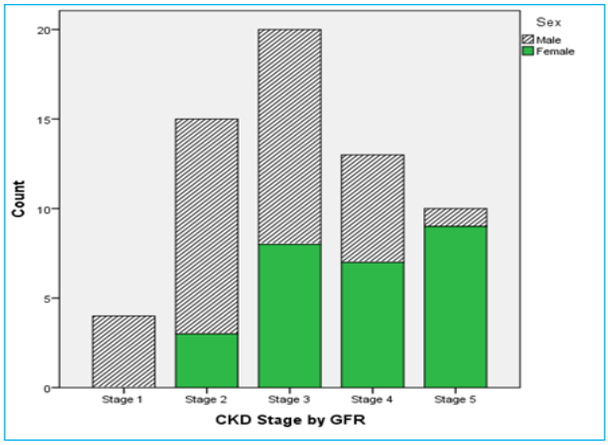

Figure 1. Distribution of patients according to stage of CKD.

The major risk factors associated with CKD was found to be Hypertension followed by Diabetes Mellitus among the patients under study. In 11.29%, there were no identifiable risk factors were found (Table 1).

Table 1. Risk factors associated with CKD.

Risk factors	Frequency (n=62)	Percentage (%)
Hypertension	36	58.06
Diabetes Mellitus (DM)	3	4.84
Hypertension and DM	14	22.58
Chronic Glomerulonephritis	2	3.23
Unknown	7	11.29

The mean renal length, mean parenchymal thickness and mean cortical thickness according to different stage of CKD are shown in Table 2 which shows decrease in value of these parameters with increasing stage of CKD. Similarly, the mean values of Doppler parameters: PSV, EDV, PI and RI according to stage of CKD are depicted in Table 2. PI and RI showed increase in values with increase in stage of CKD. However, PSV and EDV showed inconsistent values.

Renal length, parenchymal thickness, cortical thickness, EDV, PI and RI showed significant correlation with eGFR (Table 3).

Table 2. Renal parameters analysed according to stage of CKD.

GRAY SCALE:

CKD stage	Mean renal Length (cm)		Mean Parenchymal thickness (cm)		Mean Cortical thickness (cm)	
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.
Stage 1	11.38±0.21	11.73± 0.41	3.40±0.16	3.36±0.17	1.74 ± 0.15	1.78±0.19
Stage 2	10.41±0.76	10.57± 0.66	2.93±0.32	2.95±0.34	1.32± 0.19	1.31± 0.19
Stage 3	9.59± 0.79	9.94±0.79	2.61±0.32	2.68± 0.34	1.22± 0.24	1.31± 0.19
Stage 4	8.65±0.67	8.72± 0.79	2.41± 0.34	2.49± 0.39	1.14± 0.22	1.15± 0.20
Stage 5	7.49± 0.39	7.49± 0.54	1.95± 0.36	1.99± 0.42	0.88± 0.24	0.92± 0.34

DOPPLER:

CKD stage	PSV (cm/s^2)		EDV (cm/s^2)		PI		RI	
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.
Stage 1	24.36±4.72	26.84±8.17	9.71±2.43	10.09±3.08	1.09±0.11	1.13±0.09	0.60±0.04	0.62± 0.03
Stage 2	29.51±8.19	31.49±13.19	11.45±3.41	12.54±5.44	1.09±0.16	1.06±0.10	0.61±0.04	0.60± 0.03
Stage 3	30.89±10.30	33.55±11.78	11.21±3.37	12.19±3.97	1.16±0.15	1.16±0.18	0.63±0.04	0.63± 0.05
Stage 4	24.37±6.57	27.21±11.31	7.18±1.97	7.65± 2.98	1.43±0.43	1.49±0.49	0.69±0.06	0.70±0.06
Stage 5	31.13±10.47	32.42±10.51	7.55±2.39	8.60± 2.24	1.64±0.16	1.47±0.12	0.75±0.04	0.72±0.04

Table 3. Correlation of duplex sonographic parameters with GFR.

Parameters	Rt. Kidney		Lt. Kidney	
	r-value	p-value	r-value	p-value
Renal length	0.832*	<0.001	0.832*	<0.001
Renal parenchymal thickness	0.735*	<0.001	0.695*	<0.001
Renal cortical thickness	0.593*	<0.001	0.560*	<0.001
Cortical echogenicity			-0.723*	<0.001
PSV	-0.042	0.748	-0.030	0.817
EDV	0.371*	0.003	0.304**	0.016
PI	-0.560*	<0.001	-0.515*	<0.001
RI	-0.663*	<0.001	-0.651*	<0.001

Grading of renal cortical echogenicity as described above was compared with stage of CKD estimated by eGFR. The distribution of patients of different stage of CKD based on renal cortical echogenicity is depicted on fig.2 which showed with increasing stage of CKD, patients with higher grade of CKD based on echogenicity are included. Grading of renal cortical echogenity showed strong negative correlation with eGFR (Table 3).

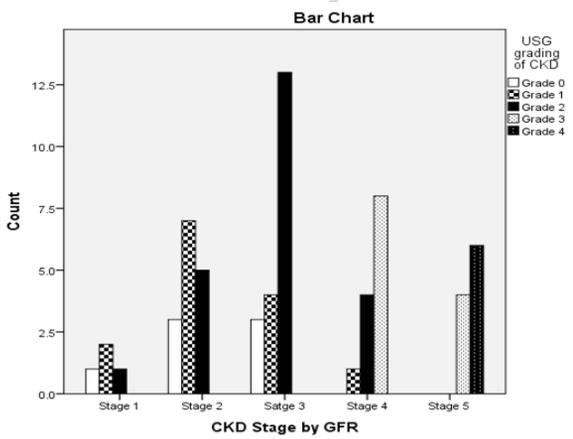

Figure 2. Bar diagram showing distribution of the patients of different stage of CKD based on renal cortical echogenicity.

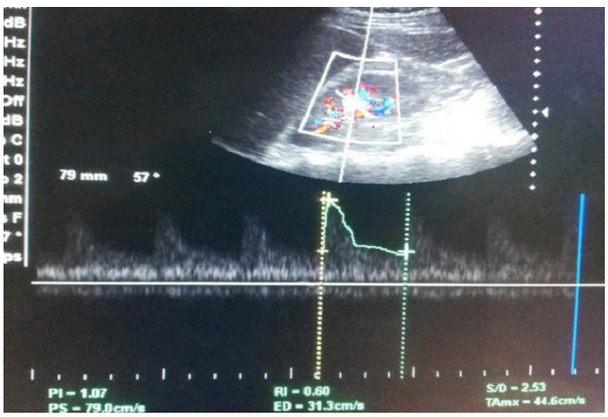

Figure 3. Doppler sonography showing spectral waveform with values of PSV, EDV, PI and RI in CKD stage 3 patient.

DISCUSSION

Various ultrasound parameters also changes with decreased renal function. Renal length has traditionally been considered as a surrogate marker of renal function as renal length is found to decrease with the decreasing renal function. Different studies support this finding. Our study also reproduced the same finding as previous studies revealing a statistically significant positive correlation between renal length and eGFR.[6-9] Our study also showed decrease in both parenchymal and cortical thickness with decrease in GFR as seen in previous studies.[5,7] Similarly, cortical thinning with decrease in GFR as demonstrated in earlier studies was also reproduced in our study.[8-11]

In chronic kidney disease, progressive loss of nephrons and glomerulosclerosis may be attributed to the changes noted in renal length, parenchymal thickness and cortical thickness.

The cortical echogenicity is altered in many medico-renal diseases. Increased echogenicity of the kidney parenchyma results from the increased presence of material that can reflect sound waves back, thus increasing its brightness on the ultrasonography image. Because fibrous tissue increases echogenicity, CKD is typically associated with increased echogenicity. In our study we graded the renal cortical echogenicity as per Siddappa et al. (2013)and there was a significant correlation between renal cortical echogenicity and eGFR. Various previous studies have also shown correlation of cortical echogenicity with severity of CKD.[5,12,13]

Peak systolic velocity is one of the least studied parameters for evaluation of CKD. PSV is a semiquantitative indicator of renal blood flow on spectral Doppler imaging and markedly depends on the distensibility of small arteries in the kidney. Thus it is associated with renal vascular compliance and resistance which is also affected in the CKD. In the present study no correlation was established between PSV and eGFR. A retrospective study in 992 patients with CKD by Chen et al. also correlated Doppler parameters with GFR and histopathological pattern which also showed no correlation with eGFR , analogous to our study.[14]

Flow resistance is increased as the severity of chronic kidney disease increases. This is characterized by the decreased forward flow throughout the diastole. So we assumed that the end-diastolic velocity can also be used as a parameter to assess the chronicity of the kidney disease. In our study, a weak positive correlation was seen between EDV and estimated GFR. But studied correlation of EDV with eGFR in 992 patients with CKD and showed no correlation of EDV with eGFR.[14] The difference may be attributed to the smaller sample size in our study.

Pulsatility index and Resistive index are measurements of renal arterial resistance. Both are angle independent measurements. With increase in severity of the chronic kidney disease, the vascular resistance is also increased

which is reflected by the increased RI and PI value. In our study, there was a negative correlation between PI and RI with estimated GFR. Our study reproduced the similar finding as seen in several previous studies.[14-20]

The results of the present study demonstrated that the renal function status can be indirectly estimated by means of renal ultrasonographic parameters. Gray scale parameters: renal length, parenchymal thickness and cortical thickness tends to decrease with decrease in renal function and cortical echogenicity increases with decrease in renal function. Doppler parameters: RI and PI tends to increase with decrease in renal function status. EDV only showed a weak correlation and PSV didn't show any correlation.

The present study presents some limitations This study was a cross sectional hospital based study with limited sample size. Because it was a cross-sectional study, a follow-up of the measurements was not performed, so the progressive changes could not be observed. However, by considering the distribution of patients according to five stages of chronic kidney injury, the authors expect to partially neutralize this limitation. The cut off value of USG parameters to differentiate CKD from healthy population was not possible. This requirement prompts a further case control study. Further, the newer modalities like shear wave elastography derived estimates of renal stiffness being higher in patients with CKD than in healthy controls and Contrast Enhanced Ultrasound detecting perfusion in chronic kidney disease to assess the diagnostic capabilities in early stage of the disease process are also other parameters that would estimate the renal status in CKD and hence increase the diagnostic accuracy.[21,22]

CONCLUSIONS

This study showed that renal length, parenchymal thickness, cortical thickness, cortical echogenicity, EDV, PI and RI also changes with change in renal status and thus can be usefulsonographic parameters in the evaluation of chronic kidney disease.However a large scale study is needed to further fortify our diagnosis.

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