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Ultrasonographic chronic kidney disease score and eGFR in the assessment of chronic kidney disease

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Abstract
Objective: A prospective study developed to determine the relationship between the ultrasonographic parameters (kidney length, parenchymal thickness and parenchymal echogenicity obtained from both kidneys) and glomerular filtration rate in patients with Chronic Kidney Disease.
Materials and methods: A cross sectional study in 50 patients referred to the department of Radiodiagnosis, Sree Mookambika Institute of Medical Science, Kulasekharam, for ultrasound abdomen with abnormal renal function tests during the period of 12 months (June 2019- June 2020) and who fulfilled the inclusion and exclusion criteria were selected. Both kidneys were evaluated by Siemens ACUSON X300 scanner using a 5.0MHZ wide frequency band, phased assay probe. The US parameters renal length, mean parenchymal thickness and parenchymal echogenicity were evaluated for both right and left kidneys. All three parameters were scored for each kidney and sum of the average scores were used to calculate ultrasonographic CKD score. The eGFR was calculated by using MDRD equation. The correlation between the eGFR and the kidney length, parenchymal thickness, parenchymal echogenicity and ultrasonographic CKD score were made out separately.
Results: The mean serum creatinine was 3.9±2.2 and estimated glomerular filtration rate is 22.8±15.1. No patients with eGFR > 90 ml i.e. stage I of kidney disease was studied. The mean renal length in stage V (8.0±1.4), stage IV (8.4±1.0), stage III (9.5±1.3) and stage II (9.8±0.6). The parenchymal thickness in stage V (10.2±3.2), stage IV (10.4±1.8), stage III (13.2±2.6) and stage II (14.2±2.1). The median parenchymal echogenicity in stage V (2.5), stage IV & III (2) and stage II (1). The sonographic CKD score from 4 to 13, stage V (7.9±2.4), stage IV (8.1±1.6), stage III (6.1±1.5) and stage II (5.0±0.7).
Conclusion: The ultrasonographic CKD score calculated from the USG parameters such as renal length, parenchymal thickness and parenchymal echogenicity is useful for differentiation of CKD stage 3-5 compared to CKD stage 1-2. We concluded that the ultrasonographic CKD score provide more objective data in the assessment of CKD.

Keywords: Ultrasound, chronic kidney disease, modified diet in renal diet

Introduction
Abnormality of renal function or morphology persistent for more than 3 months duration is defined as Chronic Kidney Disease (CKD). Current study stated that the CKD is the 6th deadliest disease in the world causing 2.4 million deaths per year. The international society of nephrology (ISN) and the international federation of kidney foundation (IFKF) stated that the diabetes, hypertension and obesity are the major risk factors of CKD. The ultrasound examination is considered to be the one of the ideal methods for renal imaging. The renal cortex, renal medulla and renal collecting system have different acoustic properties, so the pathological changes are easily discernible in ultrasound and can be correlate with histological findings. Kidney size is found to be correlated with renal function. Therefore the renal sonographic parameters such as pole-to-pole kidney length, width and parenchymal thickness are considered to be in association with kidney function, thus helps in the better assessment of Chronic Kidney Disease status [1]. Serial sonographic evaluation of renal length, cortical thickness and parenchymal echogenicity is helpful in identifying the progression of renal disease [2]. Renal volume is found to be the accurate measurement in patients with end stage renal disease and longitudinal diameter of kidney length is enough to be measured in normal patients [3]. Calculation of kidney volume by computerized tomography (CT) has also been found to be correlated with renal function tests [4, 5]. However, the major disadvantages of computed tomography (CT) to calculate renal volume are higher cost and radiation exposure. Primary preferred imaging procedure in the assessment of kidney diseases is ultrasonography, because it is inexpensive, noninvasive and

easy to access [6]. The Glomerular filtration rate is estimated by the Chronic Kidney Disease MDRD formula (Modification of Diet in Renal Disease study) [7]. MDRD formula estimates the glomerular filtration rate which is adjusted for body surface area and gives accurate value than the Cockcroft-Gault formula.

Materials and Methods

A cross sectional study in 50 patients referred to the department of Radiodiagnosis, Sree Mookambika Institute of Medical Science, Kulasekharam, for ultrasound abdomen with abnormal renal function tests during the period of 12 months (June 2019- June 2020). Exclusion criteria includes Autosomal dominant polycystic kidney disease, solitary kidney, acute kidney injury, renal tumours, renal asymmetry with difference of >2cm between each kidneys and patients on renal replacement therapy. Both kidneys were evaluated by Siemens ACUSON X300 scanner using a 5.0MHZ wide frequency band, phased assay probe. The ultrasound parameters renal length, mean parenchymal thickness and parenchymal echogenicity were evaluated for both right and left kidneys. Kidney length was determined by measuring the maximum longitudinal dimension. Parenchymal thickness was measured from ectosinus echoes, which was sonographically determined to consist of a highly echogenic core called the renal sinus in centre of kidney, to the outer renal cortical margin at each site in three levels (upper, lower and mid-levels) of each kidney, and a mean value was estimated for each kidney. Parenchymal echogenicity was compared and graded with the echogenicity of liver or spleen. All three parameters were scored for each kidney and sum of the average scores were used to calculate ultrasonographic CKD score. Estimated glomerular filtration (eGFR) is calculated by MDRD formula using serum creatinine, age and race of the patient. The correlation between the eGFR and the kidney length, parenchymal thickness, parenchymal echogenicity and ultrasound CKD score were made by statistical analysis.

Statistical analysis

The data was expressed in number, percentage, mean and standard deviation. Statistical Package for Social Science (SPSS 20.0) version used for analysis. Unpaired test applied to find the statistical significant. Pearson correlation test applied to find the correlation between the variables. P value less than 0.05 ($p<0.05$) considered statistically significant at 95% confidence interval.

In our study, 50 patients were studied and the incidence of CKD is more commonly found in males (62%) with predominant age group of around 41-60 yrs (64%) followed by 61-80yrs (20%). The most common cause of CKD was found to be coexisting diabetes and hypertension (44%). 8 cases were found to have hypertension (16%) and 6 patients with diabetes (12%). 2 patients diagnosed with chronic glomerulonephritis and 2 patients are a known case of systemic lupus erythematous. The underlying cause for the renal disease was unknown in 10 cases (20%).

Table 1: Age distribution of cases with Chronic Kidney Disease

Age (Years)	Number	Percentage
≤ 20 yrs	1	2.00
21-40 yrs	5	10.00
41-60 yrs	32	64.00
61-80 yrs	10	20.00
> 80 yrs	2	4.00

Table 2: Clinical etiology of Chronic Kidney Disease

Etiology of CKD	Number	Percentage
Unknown etiology	10	20.00
Diabetes mellitus	6	12.00
Hypertension	8	16.00
DM & hypertension	22	44.00
Other known causes	4	8.00

Table 3: Mean serum urea, creatinine and calculated eGFR values

Observations	Mean±SD
Serum urea (mg/dl)	102.02±50.48
Serum creatinine (mg/dl)	3.94±2.25
eGFR (ml/min)	22.8±15.1

Table 4: Distribution of patients based on renal length

Renal length (mm)	Point	Right		Left	
		Number	Percentage	Number	Percentage
<80	5	18	36.00	14	28.00
80-89	4	13	26.00	10	20.00
90-99	3	10	20.00	12	24.00
100-109	2	7	14.00	7	14.00
110-119	1	2	4.00	6	12.00
>120	0	0	0.00	1	2.00

Table 5: Distribution of patients based on renal parenchymal thickness

Parenchymal thickness (mm)	Point	Right		Left	
		Number	Percentage	Number	Percentage
<8	4	5	10.00	8	16.00
9-10	3	18	36.00	17	34.00
11-12	2	16	32.00	14	28.00
13-14	1	4	8.00	8	16.00
>15	0	7	14.00	3	6.00

Table 6: Distribution of patients based on renal parenchymal echogenicity

Parenchymal echogenicity	Point	Right		Left	
		Number	Percentage (%)	Number	Percentage (%)
Grade-IV	4	5	10.00	5	10.00
Grade-III	3	7	14.00	6	12.00
Grade-II	2	34	68.00	35	70.00
Grade-I	1	4	8.00	4	8.00
Grade-0	0	0	0.00	0	0.00

Table 7: Demographic characteristics and laboratory measurements of patients according to CKD stages

Observation	Total (n=50)	CKD5 (n=19)	CKD4 (n=16)	CKD3 (n=13)	CKD2 (n=2)
Age (years)	53.9±14.8	59.4±13.3	53.1±13.1	50.4±14.9	30.5±21.9
Gender(F/M)	19/31	8/11	8/8	2/11	1/1
Height (cm)	159.2±12.2	157.2±11.6	159.1±11.8	165.4±10.6	138.5±2.1
Weight (kg)	58.8±14.3	54.3±11.7	59.3±15.6	67.6±12.1	40.5±7.7
BMI (kg/m^2)	23.0±3.3	21.0±2.8	24.4±3.0	23.2±3.7	22.0±3.1
Diabetes mellitus	28	11	9	8	-

Hypertension	30	13	9	8	-
Other known causes	4	-	3	1	-
Unknown etiology	10	4	3	1	2
Urea (mg/dl)	102.02±50.4	142.3±59.9	83.9±18.8	69.7±14.3	70.0±26.8
Creatinine	3.9±2.2	6.4±1.6	2.9±0.5	1.95±0.2	1.3±0.4
e-GFR	22.8±15.1	9.0±2.2	21.3±3.7	38.6±8.4	62.5±0.7
Renal length(mm)	8.6±1.4	8.0±1.4	8.4±1.09	9.5±1.3	9.8±0.6
Parenchymal thickness(mm)	11.2±3.01	10.2±3.2	10.4±1.8	13.2±2.6	14.1±2.1
Parenchymal echogenicity (median)	2.0	2.5	2.0	2.0	1.0
Sonographic CKD score	7.9±2.4	9.4±2.4	8.1±1.6	6.1±1.5	5.0±0.7

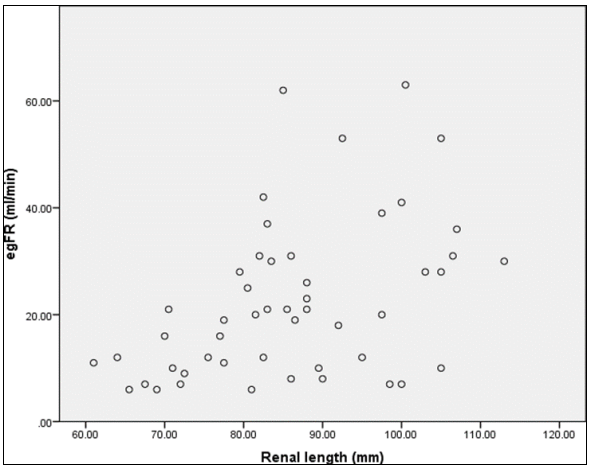

Fig 1: Correlation of e-GFR and renal length

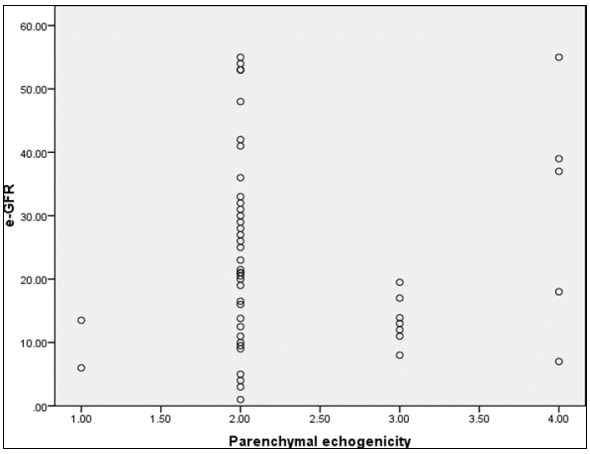

Fig 3: Correlation of e-GFR and renal parenchymal echogenicity

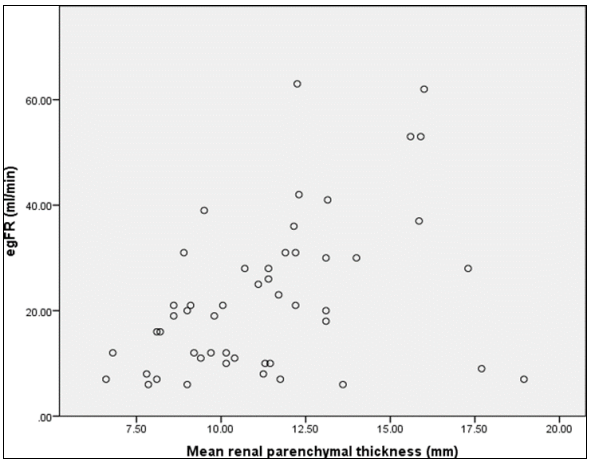

Fig 2: Correlation of e-GFR and renal parenchymal thickness

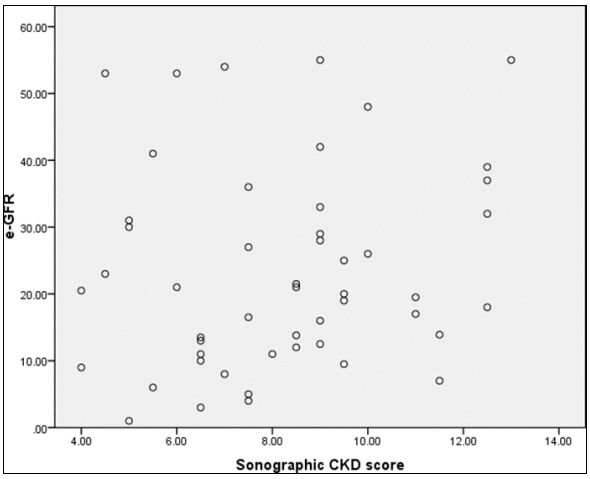

Fig 4: Correlation of e-GFR and sonographic CKD score

Table 8: Correlation between e-GFR and ultrasonographic parameters

Observation	Renal length		Parenchymal thickness		Parenchymal echogenicity		CKD score
	Right	Left	Right	Left	Right	Left	
e-GFR	3.76	3.32	2.20	2.38	-2.26	-2.24	-7.94
p value	0.002	0.005	0.0001	0.004	0.0001	0.002	0.0003

The above table shows that eGFR was positively correlated with renal length parenchymal thickness and negatively correlated with parenchymal echogenicity and ultrasonographic CKD score.

Table 9: Analysis of receiver operating characteristics curve (GFR<60mL/min)

Parameters	Renal length (mm)	Parenchymal thickness (mm)	Parenchymal echogenicity	Sonographic CKD score
Cutoff value	94.17	12.78	0.78	4.93
AUC (95% Confidence interval)	0.78(0.42-0.81)	0.67(0.62-0.76)	0.74(0.67-0.89)	0.82(0.72-0.94)
Sensitivity (%)	58	54	75	76
Specificity (%)	84	81	67	63
Positive predictive value (%)	92.5	91.21	86.92	91.18
Negative predictive value (%)	64.5	61.28	54.34	51.67
Test validity	75.6	71.24	72.13	71.98
p value	0.001	0.001	0.001	0.001

The above table shows receiver operating curve analysis for eGFR lower than 60mL/min showed that the ultrasonographic CKD score higher than 4.93 was the best parameter with the sensitivity of 76% and positive predictivity of 91% (AUC 0.82 95% CI, 0.72-0.0.94; p <0.001)

Discussion

In our study, eGFR was positively correlated with renal length parenchymal thickness and negatively correlated with parenchymal echogenicity and ultrasonographic CKD score. Levey AS *et al.*, 1999, stated that calculating estimated glomerular filtration rate using MDRD formula is more accurate than the creatinine clearance calculated by Cockcroft-Gault formula [8]. Lucisano G *et al., 2015*, concluded that the ultrasonographic parameters such as pole-to-pole renal length and parenchymal thickness are correlated with the glomerular filtration rate that makes renal ultrasound a reliable tool for the assessment of Chronic Kidney Disease [1]. Platt JF *et al., 1988*, observed that the renal cortical echogenicity is more often equal to the liver echogenicity in patients who had no evidence of renal diseases and concluded that the renal echogenicity equal to the echogenicity of liver is not a good indicator of renal disease [9]. Shivashankara VU *et al.*, 2016, stated that the renal sonographic parameters and eGFR using MDRD formula has good correlation and the renal status in the CKD patients can be more accurately reported [7].

Yaprak M *et al.*, 2016, stated that the kidney length and parenchymal thickness is correlated with the clinical eGFR value, whereas the parenchymal echogenicity is not always correlated with eGFR and therefore parenchymal echogenicity alone is not a good parameter for the evaluation of kidney disease. The ultrasonographic CKD score which has been calculated from the mean kidney length, parenchymal thickness and parenchymal echogenicity grading is useful in identifying stage 3-5 compared to stage 1 & 2 of CKD [10]. Ahmed S, Bughio S *et al.*, 2019, Conducted a study in comparision of ultrasonographic findings in CKD patients with serum creatinine value, they found a strong positive correlation between the renal cortical echogenecity and the serum creatinine (r=0.915, P=0.0005). They also stated that the mean parenchymal thickness showed positive correlation with the serum creatinine and renal length is negatively correlated with the serum creatinine [11]. Fiorini F *et al.*, 2007, the purpose of the study is to identify the importance of ultrasound in the study of medical nephropathy. They stated that ultrasound is considered to be the initial choice of investigation in the diagnosis of medical nephropathy to differentiate from acute and chronic kidney disease and also to exclude other causes like urological pathologies. Ultrasound is a real time imaging to renal length and it necessary to report the renal cortical thickness in patients with CKD who are not on dialysis [12].

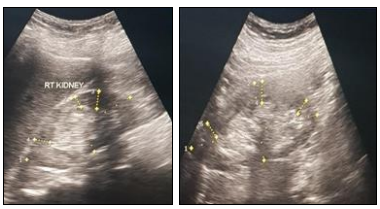

Fig 5: CASE, sonographic CKD score calculation

Right kidney length measures 11.7 cm (1 point), mean parenchymal thickness is 12.4 (2 points) and the renal parenchymal echogenicity is greater than the liver/ spleen with maintained CMD, grade II renal parenchymal changes (2 points).Left kidney length measures 8.9 cm (4 points), mean parenchymal thickness is 11.1 (2 points) and grade II echogenicity (2 points). Ultrasonographic CKD score = 1+ 2+ 2+ 4+ 2+ 2 =13/2 = 6.5

Conclusion

The ultrasonographic CKD score calculated from the USG parameters such as renal length, parenchymal thickness and parenchymal echogenicity is useful for differentiation of CKD stage 3-5 compared to CKD stage 1-2. We concluded that the ultrasonographic CKD score provide more objective data in the assessment of CKD.

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