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Role of Ultrasound in Diagnosing Chronic Kidney Disease (CKD)

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Abstract **Original Research Article**

***Background*:** Ultrasonography is a noninvasive and cost-effective diagnostic tool that provides detailed anatomical information crucial for diagnosing renal diseases. It avoids radiation and contrast exposure, making it preferable over traditional radiography both domestically and internationally. These advantages facilitate early detection and enable accurate prediction of abnormal renal function tests, aiding in timely therapeutic decision-making. ***Objective*:** Our objective was to explore the utility of ultrasound in diagnosing chronic kidney disease (CKD). ***Methods*:** This study, conducted between 2021 and 2022, employed a retrospective cross-sectional design within the ultrasound department of a Tertiary Hospital. The study involved 200 CKD patients with a glomerular filtration rate (GFR) of < 60 ml/min. Serum creatinine estimation was performed alongside blood tests on the same day as ultrasonography, which assessed echogenicity, parenchymal thickness, cortical thickness, and longitudinal length. All gathered data were recorded in the pro forma. ***Results*:** The patient cohort had an average age of 54.62±13.3 years. Mean serum creatinine showed significant variance across echogenicity grades (p=0.0005). Comparable trends were observed for mean parenchymal thickness (p=0.0005), mean longitudinal length (p=0.0005), and mean corticomedullary distinction (p=0.0005). A statistically significant highly positive correlation emerged between serum creatinine and cortical echogenicity grading (r=0.915, p = 0.0005). ***Conclusion*:** Renal cortical echogenicity, particularly its grading, exhibited the most substantial correlation with serum creatinine among various sonographic parameters like longitudinal length, parenchymal thickness, and cortical thickness in CKD patients. As renal cortical echogenicity's irreversible nature contrasts with serum creatinine levels, it stands as a viable parameter for renal function assessment.

Keywords: Chronic kidney diseases (CKD), ultrasound, serum creatine.

INTRODUCTION

The condition of having an abnormal creatinine level persisting over several months to years is referred to as chronic kidney disease (CKD). CKD is categorized by the degree of kidney damage, assessed by a reduced glomerular filtration rate (GFR) (< 60 ml/min per 1.7 m²) sustained for more than three months [1, 2].

Ultrasonography provides a noninvasive and cost-effective approach for diagnosing renal diseases. It offers detailed anatomical insights without subjecting patients to radiation or contrast agents, rendering it a preferred alternative to conventional radiography both domestically and internationally [3-5]. These attributes facilitate early identification and anticipation of abnormal renal function, vital for informed therapeutic choices.

Sonography serves to measure renal parameters including length, thickness, and echogenicity of the renal parenchyma. It also aids in characterizing a dilated collecting system [6]. Such details contribute to gauging the extent of renal parenchymal impairment, gauging the potential for reversibility [7, 8], and determining the necessity for renal biopsy [9]. Notably, a study

discovered abnormal sonographic findings in 67% of CKD cases [10].

Echogenicity intensifies due to the presence of collagen in interstitial fibrosis and glomerulosclerosis [11], a phenomenon not widely acknowledged. This elevation in echogenicity could potentially signify heightened interstitial inflammation. While human observation can infer echogenicity, its reliability is questionable [12, 13]. Nevertheless, a small adult cohort demonstrated the ability to quantifiably and reliably assess renal parenchymal echogenicity within a normal range [14]. Furthermore, significant correlations were established between renal length or cortical echogenicity and glomerular sclerosis or tubular atrophy [15].

Renal characteristics encompass various measurements, including renal length, volume, and cortical thickness. Evaluating renal function also hinges on these metrics, underpinning crucial clinical decisions. Hence, serial sonographic assessments serve to track the progression of renal disease or its stability [16]. While renal parenchymal volume proves accurate in end-stage renal disease patients, measuring renal longitudinal length suffices for individuals with normal renal function [17].

Given its capacity to gauge renal insufficiency and disease progression, ultrasound emerges as a valuable tool. Our study's objective is to correlate renal echogenicity with serum creatinine levels and to unravel the significance of renal echogenicity in detecting CKD progression. Additionally, we delve into the role of sonographic imaging in grading CKD.

OBJECTIVE

To asses role of ultrasound in the diagnosis of chronic kidney disease.

METHOD

This study, conducted between 2021 and 2022, employed a retrospective cross-sectional design within the ultrasound department of a Tertiary Hospital. The study encompassed patients referred for kidney ultrasounds, with simultaneous creatinine checks on the ultrasound day, yielding a sample of 200 patients.

The study embraced new patients seeking chronic kidney disease (CKD) evaluations, individuals with established CKD meeting operational criteria, those categorized in CKD stages 3/4/5 with a calculated GFR of < 60 ml/min via the Modification of Diet in Renal Disease (MDRD) equation, and participants aged 30 and above (both male and female). Excluded were patients with known acute kidney injury, kidney transplant recipients, individuals undergoing hemodialysis or peritoneal dialysis, those with fatty liver, chronic liver disease, and solitary kidney conditions.

Utilizing a standard B-Mode grayscale ultrasound with a sector curved-array transducer operating between 3.5-5 MHz, kidney and liver ultrasounds were administered. Low tissue harmonic and speckle reduction imaging techniques were applied to mitigate interobserver bias in assessing the parenchymal echogenicity of both organs. Manual adjustments were made for gain and time gain compensation. The measurement of longitudinal length occurred within a visually approximated section representing the largest longitudinal segment. Width and thickness measurements were taken perpendicularly to the longitudinal axis of the kidney, guided by the longitudinal image. While maintaining perpendicularity of the ultrasound probe to the skin was unnecessary, the transverse section's placement was proximal to the kidney's hilum, avoiding contact with the pelvis [2].

Statistical analysis was executed via the Statistical Package for the Social Sciences (SPSS version 20) from IBM Corp. (Armonk, NY). Age was summarized using mean and SD; gender and echogenicity grade were presented as mean parenchymal thickness, mean longitudinal size, frequency, and percentages. The connection between serum creatinine and sonographic parameters was scrutinized through correlation coefficient analysis. Significance was attributed to P-values under 0.05.

RESULTS

Table-1 shows descriptive statistics of the patients where Twenty percent of the patients were below and equal to 40 years of age, 42.5% were between 41 and 60 years, and 37.5% were above 60 years of age. The average age of the patients was 54.62 ± 13.3 years.

Table 1: Descriptive Statistics of the Characteristics of the Patients

Variables	Mean ± SD	95% Confidence Interval for Mean		Median (IQR)
		Lower Bound	Upper Bound	
Age (years)	54.62±13.30	52.77	56.47	56 (21)
Serum creatinine (mg/dl)	2.19±1.08	2.046	2.337	1.9 (1.3)
Parenchymal thickness	4.69±0.82	4.578	4.806	4.5 (0.9)
Longitudinal length	9.87±0.94	9.745	10.008	10 (0.8)
Cortical thickness	0.94±0.253	0.902	0.973	1.1 (0.3)

Table-2 shows Comparison of Serum Creatinine with Renal Cortical Echogenicity. Mean serum creatinine was significant among echogenicity grades [ANOVA F-Value= 367.726; p=0.0005].

Table 2: Comparison of Serum Creatinine with Renal Cortical Echogenicity

Serum Creatinine (mg/dl)							
Echogenicity Grades [Grading based on ultrasound features]	**No. of Patients**	**Mean**	**SD**	**95% Confidence Interval for Mean**		**F Value**	**P-Value**
				Lower Bound	**Upper Bound**		
Grade 0	60	1.252	0.050	1.239	1.265	367.726	0.0005
Grade 1	60	1.853	0.129	1.820	1.887		
Grade 2	44	2.568	0.651	2.370	2.766		
Grade 3	24	3.275	0.352	3.126	3.424		
Grade 4	12	5.033	0.528	4.698	5.369		
Total	**200**	**2.191**	**1.0431**	**2.046**	**2.337**		

Table-3 shows comparison of Parenchymal Thickness with Renal Cortical Echogenicity where Mean parenchymal thickness was also significant among echogenicity grades (ANOVA F-value= 31.628; p=0.0005).

Table 3: Comparison of Parenchymal Thickness with Renal Cortical

Parenchymal Thickness (cm)							
Echogenicity Grades [Grading based on ultrasound features]	**No. of Patients**	**Mean**	**SD**	**95% Confidence Interval for Mean**		**F Value**	**P-Value**
				Lower Bound	**Upper Bound**		
Grade 0	60	4.397	0.101	4.371	4.423	31.628	0.0005
Grade 1	60	4.582	0.905	4.348	4.816		
Grade 2	44	5.048	0.920	4.768	5.328		
Grade 3	24	4.433	0.481	4.230	4.637		
Grade 4	12	5.933	1.029	5.280	6.587		
Total	**200**	**4.692**	**0.820**	**4.578**	**4.806**		

Table-4 shows Comparison of Longitudinal Length with Renal Cortical Echogenicity. Mean longitudinal length was also significant among echogenicity grades (ANOVA F-value= 66.004; p=0.0005)

Table 4: Comparison of Longitudinal Length with Renal Cortical Echogenicity

Longitudinal Length (cm)							
Echogenicity Grades [Grading based on ultrasound features]	**No. of Patients**	**Mean**	**SD**	**95% Confidence Interval for Mean**		**F Value**	**P Value**
				Lower Bound	**Upper Bound**		
Grade 0	60	10.000	0.0000	10.000	10.000	66.004	0.0005
Grade 1	60	10.272	0.8114	10.062	10.481		
Grade 2	44	10.348	0.7457	10.121	10.574		
Grade 3	24	8.758	0.4898	8.551	8.965		
Grade 4	12	7.792	0.8107	7.277	8.307		
Total	**200**	**9.876**	**0.9450**	**9.745**	**10.008**		

Table-5 shows Comparison of Cortical Thickness with Renal Cortical Echogenicity. Mean cortical thickness was also significant among echogenicity grades (ANOVA F-value= 477.83; p=0.0005).

Table 5: Comparison of Cortical Thickness with Renal Cortical Echogenicity

Cortical Thickness (cm)							
Echogenicity Grades [Grading based on ultrasound features]	**No. of Patients**	**Mean**	**SD**	**95% Confidence Interval for Mean**		**F Value**	**P-Value**
				Lower Bound	**Upper Bound**		
Grade 0	60	1.100	0.0000	1.100	1.100	477.83	0.0005
Grade 1	60	1.093	0.0756	1.074	1.113		
Grade 2	44	0.900	0.1034	0.869	0.931		
Grade 3	24	0.462	0.1135	0.415	0.510		
Grade 4	12	0.433	0.0888	0.377	0.490		
Total	**200**	**0.938**	**0.2531**	**0.902**	**0.973**		

Table-6 shows Statistical Correlation between Serum Creatinine and Mean Parenchymal Thickness, Mean Longitudinal Size, Mean Cortical Thickness and Echogenicity grade. A statistically significant negative correlation was also observed between longitudinal size and serum creatinine (r= -0.505; P = 0.0005); a statistically significant negative correlation was observed between cortical thickness and serum creatinine (r= - 0.845; P = 0.0005) and a statistically significant positive correlation was observed between parenchymal thickness and serum creatinine (r=0.413; P = 0.0005). A statistically significant highly positive correlation was observed between serum creatinine and cortical echogenicity grading (r=0.915 P = 0.0005) as shown in Table 6. There was also a statistically significant positive correlation between mean parenchymal thickness and renal echogenicity (r=0.336; P 0.005). There was also a statistically significant negative correlation between longitudinal length, cortical thickness with renal echogenicity (r= -0.513; P= 0.005) and (r= - 0.869; P= 0.0005), respectively.

Table 6: Statistical Correlation between Serum Creatinine and Mean Parenchymal Thickness, Mean Longitudinal Size, Mean Cortical Thickness and Echogenicity grade

		Parenchymal Thickness	Longitudinal Length	Cortical Thickness	Echogenicity Grade
Serum creatinine (mg/dl)	Pearson correlation	0.413**	-0.505**	-0.845**	0.915**
	P-Value	0.0005	0.0005	0.0005	0.0005
Parenchymal thickness	Pearson correlation		0.092	-0.240**	0.336**
	P-Value		0.194	0.001	0.005
Longitudinal length	Pearson correlation			0.634**	-0.513**
	P-Value			0.0005	0.0005
Cortical thickness	Pearson correlation				-0.869**
	P-Value				0.0005

DISCUSSION

Chronic kidney disease, denoting the progressive deterioration of kidneys due to structural or functional anomalies, can worsen over time, leading to kidney failure. The decline in kidney function can manifest through pathological abnormalities or changes in imaging tests [18].

This investigation assesses kidney function in CKD and determines GFR using serum creatinine. Sonography serves as the preferred imaging technique due to its accessibility, affordability, and real-time renal information.

The presence of chronic kidney disease can influence ultrasonographic measurements like longitudinal length, echogenicity, and cortical thickness [19, 20]. The GFR and disease stage can be determined through endogenous serum creatinine levels [21].

O'Neill proposed a 12 cm upper limit for normal kidney length [20], whereas our study found a mean longitudinal length of 9.7 cm. Fiorini and Barozzi indicated renal length under 8 cm as indicative of chronic renal failure [22]. Decreasing renal length, tied to declining renal function, has conventionally acted as a surrogate marker for renal function progression. Consequently, renal length estimation is preferable to volume for gauging disease progression.

Serum creatinine levels varied across echogenicity grades: 1.25 mg/dl for Grade 0, 1.85 mg/dl for Grade 1, 2.5 mg/dl for Grade 2, 3.27 mg/dl for Grade 3, and 5.03 mg/dl for Grade 4. Echogenicity grades exhibited significant correlation with serum creatinine [ANOVA F-Value= 367.726; p=0.0005]. Our study, like Siddappa *et al.*'s, noted a significant correlation between serum creatinine and echogenicity grade (p=0.004) [23]. Ibinaiye *et al.*, and Singh A *et al.*, [24] reported similar findings (p=<0.001).

This study disclosed significant variation in mean parenchymal thickness among echogenicity grades (ANOVA F-value= 31.628; p=0.0005), echoing Siddappa *et al.*'s findings. A positive correlation between renal echogenicity grading and parenchymal thickness was observed (p = 0.009) [25], with increasing echogenicity corresponding to decreased parenchymal thickness.

Among echogenicity grades, mean cortical thickness displayed significance (ANOVA F-value= 477.83; p=0.0005). Our study measured mean cortical thickness at 9.3 mm (p=0.0005), akin to Singh A *et al.*'s result of 8.5 mm [24]. Cortical thickness decreased as echogenicity increased.

Notably, this study's limitation is the overrepresentation of Grade 1 and Grade 2 CKD patients compared to Grade 3 and 4. This skew results from the tertiary care hospital setting, excluding cases undergoing renal replacement therapies like dialysis and transplantation. Elevated serum creatinine intensifies renal cortical echogenicity, a change that is irreversible. Consequently, CKD's severity can be assessed through sonological grading of renal echogenicity.

CONCLUSION

The most effective sonographic parameter in alignment with serum creatinine is the echogenicity of the renal cortex and its corresponding grading, as contrasted with metrics like longitudinal length, parenchymal thickness, and cortical thickness among CKD patients. Given the irreversible nature of renal cortical echogenicity, unlike serum creatinine levels, it emerges as a viable candidate for assessing renal function.

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