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COMPARATIVE ULTRASOUND ASSESSMENT OF RENAL PARENCHYMAL THICKNESS AND RENAL FUNCTION TESTS IN CHRONIC KIDNEY DISEASE

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Abstract

Background: Chronic kidney disease (CKD) is a global public health problem with increasing incidence, poor prognosis, and significant economic burden. Early detection and monitoring are crucial in mitigating adverse outcomes. Ultrasonography is a non-invasive, cost-effective tool for evaluating renal function, particularly renal parenchymal thickness, in CKD patients.

Objective: To compare renal parenchymal thickness using ultrasound findings between CKD patients and healthy controls, and to evaluate differences in renal function tests (RFTs) between these two groups.

Methods: This case-control study involved 64 CKD patients and 64 healthy controls. Renal parenchymal thickness was measured via ultrasound, while serum creatinine levels and estimated glomerular filtration rate (eGFR) were assessed as part of the RFTs. Statistical analyses were performed to compare these parameters between the groups.

Results: CKD patients exhibited significantly lower mean parenchymal thickness (8.51 ± 3.03 mm) compared to controls (15.82 ± 1.78 mm, $p < 0.001$). Serum creatinine was significantly elevated in CKD patients (9.05 ± 5.14 mg/dL) compared to controls (1.05 ± 0.25 mg/dL, $p < 0.001$). Similarly, eGFR was markedly reduced in CKD patients (14.01 ± 15.04 mL/min/1.73m²) relative to controls (106.56 ± 7.92 mL/min/1.73m², $p < 0.001$).

Conclusions: Renal parenchymal thickness, serum creatinine, and eGFR are significant and independent predictors of CKD progression. Ultrasonography is a reliable, non-invasive diagnostic tool for assessing structural renal changes in CKD.

Keywords:
CKD, eGFR, serum creatinine, renal parenchymal thickness, ultrasonography.

Introduction

Chronic kidney disease (CKD) is a universal health challenge that has become increasingly prevalent due to the aging global population and the rising incidence of diabetes and hypertension (1). These two conditions are major risk factors for CKD and have contributed significantly to its widespread nature. The progression of CKD often occurs silently, with symptoms manifesting only at advanced stages when significant kidney damage has already occurred (2). This underscores the importance of timely diagnosis and intervention to slow the decline in kidney function and improve patient outcomes (1).

In recent years, ultrasonography has emerged as a valuable diagnostic tool in the evaluation of CKD. As a non-invasive, cost-effective, and readily available imaging modality, ultrasonography plays a pivotal role in assessing renal structure and function (3). Unlike other imaging techniques, ultrasonography does not expose patients to radiation, making it particularly suitable for repeated use in the monitoring of CKD progression (1, 4).

One of the key parameters evaluated using ultrasonography is renal parenchymal thickness (Figure 1), which serves as an indicator of nephron mass. Renal parenchymal thickness has been shown to correlate strongly with kidney function, making it a reliable marker for assessing the severity of CKD (5). Changes in parenchymal thickness often reflect structural alterations in the kidneys caused by disease progression (1). For example, thinning of the renal parenchyma is commonly observed in advanced stages of CKD and is associated with declining renal function. As such, the measurement of renal parenchymal thickness provides valuable insights into the structural integrity of the kidneys and can aid in staging the disease (6).

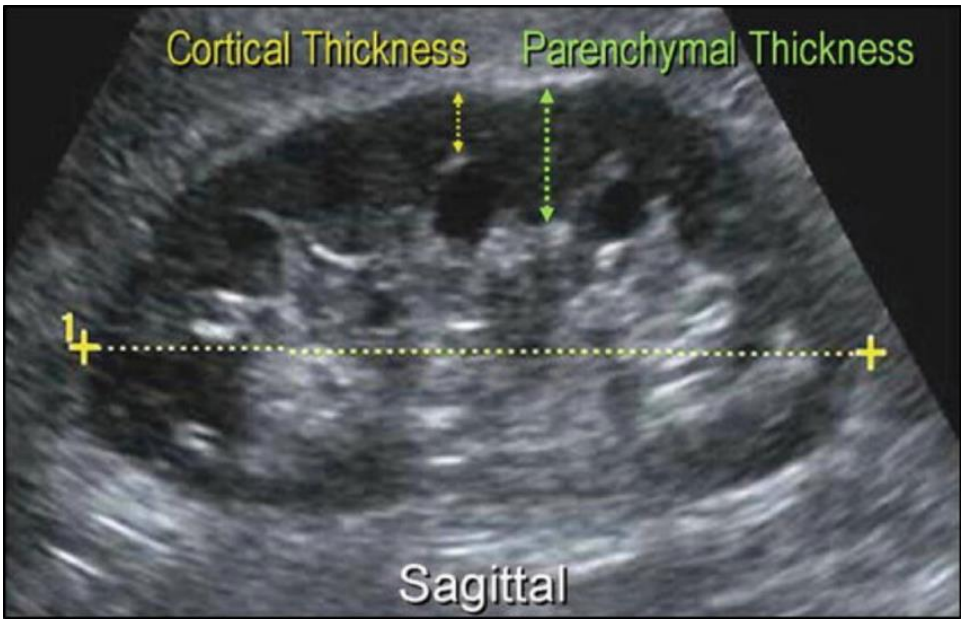

Figure 1: Measurement of renal cortical thickness, renal parenchymal thickness and kidney bipolar length by ultrasonography

In addition to ultrasonographic parameters, biochemical markers such as serum creatinine and estimated glomerular filtration rate (eGFR) are widely used in the diagnosis and staging of CKD (1). Serum creatinine is a byproduct of muscle metabolism that is excreted by the kidneys. Elevated levels of serum creatinine are indicative of impaired kidney function. eGFR. It provides an estimate of the rate at which

the kidneys filter waste products from the blood. Both serum creatinine and eGFR are integral to the classification of CKD into different stages, which guide clinical decision-making and treatment strategies.

This study aims to explore the relationship between renal parenchymal thickness and renal function tests (RFTs) in patients with CKD. By comparing these parameters between CKD patients and healthy controls, the study seeks to elucidate their diagnostic value and potential role in disease management. Understanding the correlation between structural and functional markers of kidney health can enhance the accuracy of CKD diagnosis and facilitate the implementation of targeted interventions to improve patient outcomes.

Methods

This study was designed as a case-control study and conducted at a tertiary care hospital located in Distract Swabi, Khyber Pakhtunkhwa, Pakistan, over a period of six months. Ethical approval for the research was obtained from the institutional review board to ensure adherence to ethical guidelines. Informed consent was secured from all participants after providing them with detailed information about the study's objectives and procedures.

The study included a total of 128 participants, comprising 64 confirmed CKD patients and 64 healthy controls. Participants were selected based on specific inclusion and exclusion criteria. Individuals aged between 15 and 75 years were eligible for inclusion. CKD patients were diagnosed based on established clinical criteria, including evidence of renal damage persisting for more than three months or reduced renal function as indicated by a decreased glomerular filtration rate (GFR). Healthy controls were selected from the same demographic region to ensure comparability. Exclusion criteria included congenital renal anomalies, acute infections, and non-CKD-related renal pathologies that could interfere with the measurement of renal parenchymal thickness.

Data collection involved both imaging and laboratory evaluations. Renal parenchymal thickness was measured using high-resolution ultrasonography, performed by experienced radiologists to ensure accuracy and consistency. The thickness was measured at predefined anatomical landmarks on both kidneys, and the average value was recorded for analysis. Additionally, serum creatinine levels were assessed using an automated biochemical analyzer. Estimated glomerular filtration rate (eGFR) was calculated using the CKD-EPI formula, which incorporates factors such as age, sex, and serum creatinine levels to provide an accurate estimate of kidney function. Data on demographic and clinical characteristics, including age, gender, weight, and comorbidities such as diabetes and hypertension, were also collected from medical records and patient interviews.

All collected data were entered into SPSS version 27.0 for statistical analysis. Descriptive statistics, including means, standard deviations, and ranges, were calculated for continuous variables such as renal parenchymal thickness, serum creatinine, and eGFR. Independent t-tests were conducted to compare these parameters between CKD patients and healthy controls. The level of statistical significance was set at $p < 0.05$. Additionally, graphical representations such as bar charts and scatter plots were generated to visualize the differences and correlations between the parameters under study. These analyses were aimed at determining the diagnostic value of renal parenchymal thickness and its association with biochemical markers in CKD.

Results

The descriptive statistics (Table 1) for age among CKD patients and healthy controls reveal important insights into the study population. Both groups included 64 participants, ensuring an equal sample size for comparative analysis. The age of CKD patients ranged from 16 to 72 years, with a mean age of 43.91 years (15.28 SD), while the healthy controls had a similar age range of 17 to 72 years, with a mean age of 45.70 years (15.97 SD).

Table 1: Descriptive Statistics for Age in CKD Patients and Controls

Group	N	Minimum Age (years)	Maximum Age (years)	Mean Age (years)	Std. Deviation (years)
CKD Patients	64	16.00	72.00	43.91	15.28
Healthy Controls	64	17.00	72.00	45.70	15.97

The gender distribution among healthy controls and CKD patients reveals notable patterns (Table 2). In the group of 64 healthy controls, 35 participants were male (54.7%), and 29 were female (45.3%), indicating a slightly higher proportion of males compared to females. The cumulative percentage shows that males comprised 54.7% of the group, while females accounted for the remaining 45.3%. Among the 64 CKD patients, 40 males (62.5%) and 24 females (37.5%). These findings indicate that males are more frequently represented in both groups, with a notably higher proportion among CKD patients compared to healthy controls. This difference in gender distribution may suggest a higher prevalence of CKD in males or a possible gender-related predisposition to the disease, warranting further investigation.

Table 2: Gender Distribution in Healthy Controls and CKD Patients

Gender	Frequency (Healthy Controls)	Percent (%) (Healthy Controls)	Frequency (CKD Patients)	Percent (%) (CKD Patients)
Male	35	54.7	40	62.5
Female	29	45.3	24	37.5
Total	**64**	**100.0**	**64**	**100.0**

Table 3 presents descriptive statistics comparing various renal parameters between CKD patients and healthy controls. CKD patients exhibited significantly lower renal parenchymal thickness (8.51 ± 3.03 mm) compared to controls (15.82 ± 1.78 mm), with a p-value of <0.001, indicating a substantial reduction in kidney tissue thickness. The range of parenchymal thickness in CKD patients varied from 3.61 mm to

16.72 mm, suggesting considerable variability in kidney damage. In terms of renal function, serum creatinine levels were much higher in CKD patients (9.05 ± 5.14 mg/dL) than in controls (1.05 ± 0.25 mg/dL), also with a p-value of <0.001. Elevated serum creatinine levels are indicative of impaired kidney function in CKD patients. Additionally, the estimated glomerular filtration rate (eGFR) was significantly reduced in CKD patients (14.01 ± 15.04 mL/min/1.73m²) compared to the controls (106.56 ± 7.92 mL/min/1.73m²), with a p-value of <0.001. This lower eGFR in CKD patients reflects the reduced kidney filtration capacity, which aligns with the progression of the disease. Overall, these findings highlight the significant renal dysfunction in CKD patients, characterized by reduced kidney size, impaired function, and decreased filtration capacity.

Table 3: Comparison of Renal Parameters between CKD Patients and Healthy Controls

Parameter	CKD Patients (Mean ± SD)	Controls (Mean ± SD)	p-value
Parenchymal Thickness (mm)	8.51 ± 3.03	15.82 ± 1.78	<0.001
Serum Creatinine (mg/dL)	9.05 ± 5.14	1.05 ± 0.25	<0.001
eGFR (mL/min/1.73m²)	14.01 ± 15.04	106.56 ± 7.92	<0.001

Discussion

This study highlights critical findings regarding the diagnostic value of renal parenchymal thickness, serum creatinine, and eGFR in assessing chronic kidney disease (CKD). One significant observation was the marked reduction in renal parenchymal thickness among CKD patients compared to healthy controls, which underscores the structural changes that accompany disease progression. The parenchymal thickness of CKD patients was found to be significantly lower, with a mean of 8.52 mm compared to 15.83 mm in healthy controls. This finding aligns with previous research indicating that thinning of the renal parenchyma is a reliable indicator of nephron loss and CKD severity.

Similarly, biochemical markers such as serum creatinine and eGFR showed significant differences between the two groups. CKD patients exhibited elevated serum creatinine levels (mean = 9.06 mg/dL) compared to healthy controls (mean = 1.06 mg/dL), reflecting impaired renal function. The reduced eGFR values in CKD patients (mean = 14.01 mL/min/1.73m²) further highlight the functional decline associated with CKD, consistent with established clinical diagnostic criteria.

In addition, this study aligns with previous findings from research conducted by **Gupta** et al. (7), **Webster** et al. (8), and **Yaprak** et al. (9), which highlighted similar associations between renal parenchymal thickness, serum creatinine, and eGFR with CKD severity. For instance, Gupta et al. (7), emphasized the predictive significance of reduced parenchymal thickness in CKD, while Yaprak et al. (9), demonstrated a strong relationship between eGFR and parenchymal thickness, consistent with the results of this study. Moreover, **Schwartz** et al. (10), and **Kashani** et al. (11), further validated the use of eGFR and serum creatinine as reliable indicators of CKD progression and staging, respectively. These findings collectively underline the robustness of these markers in diagnosing and monitoring CKD.

The diagnostic accuracy of serum creatinine and eGFR in staging CKD observed in this study mirrors the work of **Coresh** et al. (12), who underscored the utility of these markers in classifying disease stages. The correlation between reduced eGFR and CKD progression observed in this study reaffirms its role as a critical indicator of renal function deterioration. This consistency across studies strengthens the validity of using ultrasonographic parameters and biochemical markers in a combined approach to evaluating CKD.

Overall, the findings of this study emphasize the importance of combining ultrasonographic parameters with biochemical markers for the comprehensive evaluation of CKD. The strong correlations between parenchymal thickness, serum creatinine, and eGFR highlight their collective utility in diagnosing and staging the disease. Furthermore, the gender-based differences observed in the study warrant further investigation to understand the underlying causes and implications for disease management. These results underscore the critical role of early detection and monitoring in improving outcomes for CKD patients.

Conclusions

Renal parenchymal thickness, serum creatinine, and eGFR are critical indicators of CKD. Ultrasonography provides valuable insights into structural changes, complementing biochemical markers in disease evaluation. Routine ultrasound assessments should be incorporated into CKD management for early detection and monitoring.

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