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HEALTH AND REHABILITATION

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Co-RELATION OF RENAL PARENCHYMAL DISEASE WITH THE SEVERITY OF RENAL DYSFUNCTION

Original Research

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Acknowledgement: The authors gratefully acknowledge the support of Combined Military Hospital (CMH) Multan for facilitating this study.

Conflict of Interest: None
Grant Support & Financial Support: None

ABSTRACT

Background: Renal parenchymal disease (RPD) is a common cause of chronic kidney dysfunction, with diagnosis and monitoring traditionally reliant on serum biomarkers such as creatinine and estimated glomerular filtration rate (eGFR). However, these markers are influenced by non-pathological factors including age, sex, and body mass index, limiting their reliability in isolation. Ultrasonography offers a non-invasive method for evaluating renal parenchymal architecture and has emerged as a valuable adjunct in assessing the severity and progression of renal impairment.

Objective: To evaluate the correlation between ultrasonographic grading of RPD and renal function measured by eGFR.

Methods: This cross-sectional observational study was conducted at Combined Military Hospital (CMH) Multan over a nine-month period from November 2024to April 2025. A total of 100 patients aged 18 years and above, with radiologically confirmed RPD and laboratory evidence of renal dysfunction, were enrolled. Exclusion criteria included obstructive uropathy, reversible acute kidney injury, congenital renal anomalies, or inability to consent. Each patient underwent renal ultrasonography for parenchymal grading (Grade I–IV) and laboratory evaluation of serum creatinine, blood urea nitrogen (BUN), and eGFR. CKD staging was done based on eGFR ranges. Spearman's correlation was applied to assess the relationship between RPD grade and eGFR.

Results: The mean age was 54.2 ± 12.7 years, with 62% male representation. Hypertension and diabetes mellitus were present in 70% and 58% of patients, respectively. Grade III and IV RPD were noted in 35% and 20% of patients, respectively. eGFR declined progressively with increasing RPD severity: Grade I (72.5 ± 10.2), Grade II (54.3 ± 8.7), Grade III (32.4 ± 7.9), and Grade IV (18.1 ± 6.4 mL/min/1.73 m²). A strong inverse correlation between RPD grade and eGFR was found (Spearman's $\rho = -0.82$, $p < 0.001$). Most patients (75%) fell within CKD Stages 3–5.

Conclusion: There is a statistically significant inverse relationship between ultrasound-detected RPD grade and renal function as measured by eGFR. The integration of imaging and biochemical evaluation provides a comprehensive, non-invasive strategy for assessing and monitoring renal disease.

Keywords: Chronic Kidney Disease, Glomerular Filtration Rate, Renal Parenchymal Disease, Renal Ultrasonography, Serum Creatinine, Spearman Correlation, Ultrasonography.

INTRODUCTION

Accurate evaluation of renal function remains a cornerstone in the diagnosis and management of kidney diseases. Traditionally, serum markers such as creatinine and blood urea nitrogen, alongside the estimated glomerular filtration rate (eGFR), are used as primary indicators of renal function (1). While these blood-based tests offer practical value, their reliability is often compromised by confounding factors such as age, muscle mass, and body mass index. More importantly, they do not provide insight into the function of individual kidneys, limiting their diagnostic precision in certain clinical contexts. Given the limitations of biochemical parameters, medical imaging has gained increasing relevance in renal assessment (2). Among the advanced imaging modalities, diffusion-weighted magnetic resonance imaging (DW-MRI) has emerged as a non-invasive tool with significant potential. By visualizing the Brownian motion of water molecules within tissue, DW-MRI offers superior contrast between healthy and diseased renal parenchyma (3). The apparent diffusion coefficient (ADC), a quantifiable measure derived from DW-MRI, reflects both extracellular water diffusion and microvascular perfusion, making it a sensitive indicator of renal pathology (4). In addition to MRI-based techniques, ultrasound imaging remains widely employed due to its accessibility and cost-effectiveness. Renal cortical echogenicity, in particular, is considered a useful marker for interstitial fibrosis, as increased collagen deposition enhances cortical reflectivity (5). Furthermore, longitudinal monitoring of renal length, cortical thickness, and parenchymal echotexture contributes to identifying progressive kidney damage, with kidneys measuring less than 10 cm and displaying increased echogenicity often indicative of irreversible loss of function (6,7).

Spectral Doppler ultrasound adds another layer of diagnostic value by evaluating renal arterial flow patterns, which are frequently altered in conditions impacting parenchymal integrity and overall renal function (8). This integrated imaging approach is particularly relevant in the context of renal parenchymal diseases—a heterogeneous group of disorders affecting glomeruli, tubules, interstitium, and renal microvasculature (9). These disorders may manifest as acute kidney injury (AKI), characterized by a sudden decline in filtration capacity, or as chronic kidney disease (CKD), marked by progressive and often irreversible deterioration in renal performance (10,11). Despite the growing utility of both serum markers and imaging techniques, a standardized and comparative framework for assessing renal function remains underdeveloped. Therefore, this study aims to explore and correlate imaging-based parameters with conventional serum markers to enhance diagnostic accuracy in evaluating renal parenchymal disease.

METHODS

This study employed a cross-sectional observational design to evaluate the correlation between the severity of renal parenchymal disease (RPD) and renal dysfunction. It was conducted over a nine-month period, from Nov 2024 to April 2025, at the Combined Military Hospital (CMH) Multan. The target population consisted of adult patients aged 18 years and above who were diagnosed with RPD based on radiological findings, specifically renal ultrasonography, alongside laboratory evidence suggestive of renal dysfunction, such as elevated serum creatinine or a reduced estimated glomerular filtration rate (eGFR). Participants were enrolled following strict inclusion and exclusion criteria to ensure diagnostic clarity and homogeneity of the study group. Eligible participants included those with radiological signs of RPD and laboratory markers indicative of chronic renal impairment. Exclusion criteria were established to eliminate confounding conditions and included cases of obstructive uropathy, acute kidney injury due to reversible causes, congenital renal anomalies, and any patient who refused or was unable to provide informed consent.

A total of 100 patients meeting the inclusion criteria were selected through convenience sampling. Each participant underwent a thorough clinical assessment, which included documentation of demographic information, relevant medical history, and presenting symptoms. Laboratory evaluations involved serum creatinine, blood urea nitrogen (BUN), and eGFR measurements, calculated using standardized formulae. Renal ultrasonography was performed by trained radiologists using standardized protocols to assess renal size, cortical thickness, corticomedullary differentiation, and parenchymal echogenicity. The degree of parenchymal involvement was graded from I to IV based on established sonographic criteria (12,13). For analytical purposes, patients were stratified into stages of chronic kidney disease (CKD) according to their eGFR values. The core analysis explored the relationship between the sonographic grading of RPD and the severity of renal dysfunction as defined by CKD staging. Statistical analysis was conducted using SPSS, applying appropriate tests such as the chi-square test for categorical variables and Pearson correlation for continuous variables. A p-value of <0.05 was

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considered statistically significant. Ethical approval for the study was obtained from the Institutional Review Board (IRB) of CMH Multan. Informed consent was obtained from all participants after explaining the nature, purpose, and implications of the study, ensuring full compliance with ethical research standards.

RESULTS

A total of 100 patients diagnosed with renal parenchymal disease (RPD) were included in the study. The mean age of the study population was 54.2 ± 12.7 years. There was a male predominance, with 62% of participants being male and 38% female. Comorbid conditions were prevalent, with 70% of patients diagnosed with hypertension and 58% with diabetes mellitus. Assessment of renal function parameters revealed a mean serum creatinine level of 3.2 ± 1.5 mg/dL and a mean blood urea nitrogen (BUN) level of 45.6 ± 18.4 mg/dL. The estimated glomerular filtration rate (eGFR) across the cohort averaged 38.5 ± 15.2 ml/min/1.73 m², indicating a predominance of moderate to severe renal dysfunction. Ultrasound-based grading of renal parenchymal disease demonstrated that 15% of patients had Grade I changes, 30% had Grade II, 35% had Grade III, and 20% had Grade IV. Analysis of eGFR staging according to CKD classification showed that 5% of patients were in Stage 1 (eGFR ≥90), 10% in Stage 2 (60–89), 45% in Stage 3 (30–59), 30% in Stage 4 (15–29), and 10% in Stage 5 (eGFR <15). A clear and consistent decline in renal function was observed with advancing grades of parenchymal disease. Patients with Grade I changes exhibited a mean eGFR of 72.5 ± 10.2 ml/min/1.73 m², while those with Grade II had 54.3 ± 8.7, Grade III had 32.4 ± 7.9, and Grade IV had a markedly reduced mean eGFR of 18.1 ± 6.4 ml/min/1.73 m². Statistical analysis using Spearman's rank correlation demonstrated a strong inverse correlation between sonographic grade and eGFR, with a correlation coefficient (ρ) of -0.82 and a p-value < 0.001, indicating statistical significance.

Table 1: Demographic Characteristics of Study Population

Variable	Value (n = 100)
Age (mean ± SD)	54.2 ± 12.7 years
Gender (Male:Female)	62:38
Hypertension (%)	70%
Diabetes Mellitus (%)	58%

Table 2: Renal Function Parameters

Parameter	Mean ± SD
Serum Creatinine (mg/dL)	3.2 ± 1.5
Blood Urea Nitrogen (mg/dL)	45.6 ± 18.4
eGFR (ml/min/1.73 m²)	38.5 ± 15.2

Table 3: Distribution of Renal Parenchymal Disease Grades (Ultrasound Findings)

Grade of Renal Parenchymal Disease	No. of Patients (n)	Percentage (%)
Grade I	15	15%
Grade II	30	30%
Grade III	35	35%
Grade IV	20	20%

Table 4: eGFR-Based Staging of Renal Dysfunction (CKD Staging)

CKD Stage (based on eGFR)	eGFR Range (ml/min/1.73 m²)	No. of Patients (n)	Percentage (%)
Stage 1	≥90	5	5%
Stage 2	60–89	10	10%
Stage 3	30–59	45	45%
Stage 4	15–29	30	30%
Stage 5	<15	10	10%

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Table 5: Correlation Between Renal Parenchymal Disease Grade and eGFR

Renal Parenchymal Grade	Mean eGFR (ml/min/1.73 m²) ± SD
Grade I	72.5 ± 10.2
Grade II	54.3 ± 8.7
Grade III	32.4 ± 7.9
Grade IV	18.1 ± 6.4

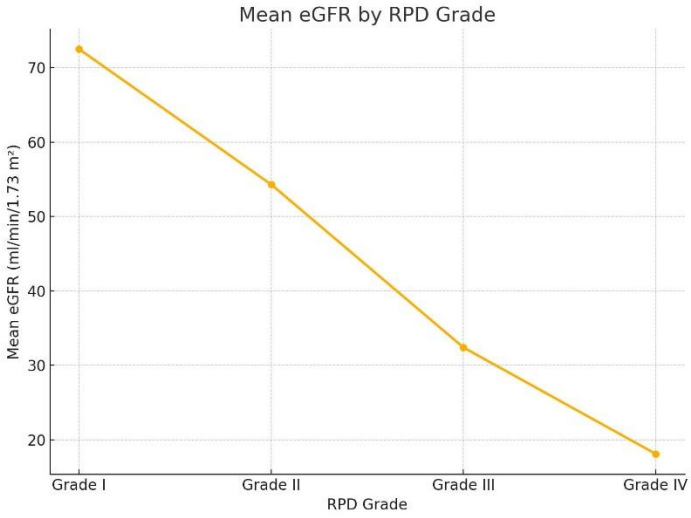

Figure 1 Mean eGFR by RPD Grade

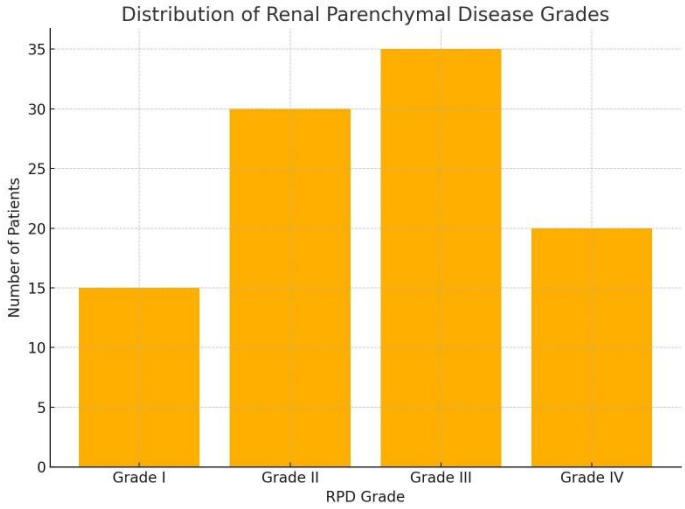

Figure 2 Distribution of Renal Parenchymal Disease Grade

DISCUSSION

The findings of this study demonstrated a significant inverse correlation between the ultrasonographic grade of renal parenchymal disease (RPD) and estimated glomerular filtration rate (eGFR), reinforcing the notion that structural deterioration of the renal parenchyma is closely associated with functional impairment. The strength of this correlation (Spearman's $\rho = -0.82$, $p < 0.001$) underlines the diagnostic value of ultrasonographic evaluation in the assessment of chronic kidney disease (CKD). The observation that the majority of patients (75%) presented with advanced CKD stages (3–5) aligns with previous research highlighting the prevalence of late-stage diagnosis in renal pathology (11). Demographic comparisons with existing literature revealed slight variations, such as a higher mean age (54.2 ± 12.7 years) and a slightly increased male predominance (62%) in the current cohort. These demographic differences, although modest, may reflect population-specific patterns in disease onset and progression (14,15). Notably, Grade III RPD was the most frequently observed in this study, accounting for 35% of cases, which contrasts with other reports where lower frequencies of high-grade RPD were documented. This discrepancy may suggest geographical or demographic variability in disease burden, health-seeking behavior, or the timing of clinical presentation (16). The linear decline in eGFR across increasing grades of RPD observed in this study is consistent with earlier findings that emphasized a parallel relationship between structural derangement and functional deterioration (17,18). The clinical implication of this observation lies in the utility of ultrasonographic grading not only as a diagnostic marker but also as a potential prognostic tool. Furthermore, similar patterns have been reported in studies evaluating diffusion-weighted MRI and apparent diffusion coefficient (ADC) values, which also revealed statistically significant changes across CKD stages, thereby corroborating the progressive nature of renal dysfunction (19,20).

Although the present study supports the integration of radiological and biochemical markers for comprehensive renal evaluation, certain limitations merit consideration. The use of convenience sampling may have introduced selection bias, potentially limiting the generalizability of the results. Additionally, the cross-sectional design restricted the ability to observe longitudinal changes or infer causality. Lack of advanced imaging such as DW-MRI or ADC quantification may have narrowed the scope of functional assessment.

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Another limitation was the absence of subgroup analysis for comorbidities like diabetes and hypertension, which are known modifiers of renal disease progression. Furthermore, multivariate statistical adjustments to control for confounders were not performed, which could have refined the observed associations. Nonetheless, the study possessed several strengths. It employed standardized ultrasonographic grading and CKD staging, ensuring consistent measurement of key variables. The sample size was adequate to detect statistically significant trends, and the correlation analysis was robust. Moreover, the study contributes valuable regional data in a field where imaging is increasingly recognized as a non-invasive and cost-effective tool for disease monitoring. Future studies should consider adopting longitudinal designs to capture disease progression over time and evaluate the predictive value of sonographic grading for renal outcomes. The incorporation of advanced imaging modalities, alongside multivariate analysis to control for comorbid influences, may provide a more nuanced understanding of the structural-functional interplay in renal pathology. In addition, expanding the study across diverse populations would enhance external validity and potentially reveal population-specific trends that could inform tailored intervention strategies. Overall, the current study affirms the clinical relevance of ultrasonographic grading in evaluating the severity of renal parenchymal disease and its functional consequences. The consistent inverse association between structural abnormalities and declining eGFR reinforces the imperative to integrate radiological findings into routine nephrological assessment and decision-making frameworks (21,22).

CONCLUSION

This study concludes that higher grades of renal parenchymal disease, as identified through ultrasonographic evaluation, are strongly associated with worsening renal function. The progressive decline in functional status with increasing structural damage highlights the clinical relevance of ultrasound as a non-invasive, accessible, and effective tool for assessing renal impairment. By combining imaging findings with biochemical markers, healthcare providers can adopt a more holistic and precise approach to diagnosing, monitoring, and managing chronic kidney disease, ultimately contributing to earlier detection and improved patient outcomes.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Sufian Pasha*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Khalid Mehmood Raja	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Ramisha Arif	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Sulaiman Pasha	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ayesha Arif	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Osama Akbar	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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