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Evaluating Renal Parenchymal Disease: A Comparative Analysis of Renal Resistive Index and Serum Creatinine

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Abstract **Original Research Article**

Background: Renal parenchymal disease leads to chronic kidney disease, and while serum creatinine rises late, Doppler-derived renal resistive index reflects intrarenal vascular resistance and correlates with worsening renal function, making it a useful non-invasive assessment tool. ***Methods:*** This comparative cross-sectional study was conducted at Ibrahim Cardiac Hospital & Research Institute, Dhaka, from January–December 2024, involving 150 adults (75 cases with renal parenchymal disease and 75 controls). Renal ultrasonography with Doppler was used to assess renal morphology and measure renal resistive index, while serum creatinine was measured by standard methods. Data were analyzed using SPSS, with $p < 0.05$ considered statistically significant, following ethical approval and informed consent. ***Results:*** Among 150 participants, cases and controls were similar in age and sex, but hypertension and diabetes were significantly more prevalent among cases. Mean renal resistive index and serum creatinine were markedly higher in cases than controls ($p < 0.001$). RRI increased progressively with worsening disease severity and higher serum creatinine levels, with significant differences on ANOVA testing. Pearson's correlation showed a strong positive linear association between RRI and serum creatinine ($r = 0.72$, $p < 0.001$), indicating that higher intrarenal vascular resistance parallels declining renal function. ***Conclusion:*** Renal resistive index was higher in patients with renal parenchymal disease, increased with disease severity, and showed a strong positive correlation with serum creatinine, making it a useful non-invasive tool to assess renal dysfunction.

Keywords: Renal Parenchymal Disease, Renal Resistive Index, Serum Creatinine.

INTRODUCTION

Renal parenchymal disease is a leading cause of chronic kidney disease worldwide and is associated with substantial morbidity and mortality [1]. Early and precise evaluation of renal parenchymal damage is crucial for prompt intervention and for slowing disease progression [2].

Serum creatinine is the most widely used biochemical indicator of renal function; however, its levels increase late in disease progression and are affected by factors such as age, muscle mass, and hydration status [3]. The resistive index (RI) is a Doppler ultrasound parameter that reflects arteriolar vascular resistance and is measured using pulsed-wave Doppler interrogation [4].

Advances in ultrasound have made renal sonography the primary, inexpensive, and radiation-free tool for evaluating kidney disease. However, conventional features of chronic renal disease are nonspecific; therefore, Doppler parameters such as the resistive index provide additional functional information

on intrarenal vascular resistance [5]. In contrast to serum creatinine, the resistive index offers real-time insight into intrarenal perfusion and may identify functional changes before irreversible structural damage develops [6].

Several studies have shown that renal resistive index (RI) measured by Doppler correlates with serum creatinine. A study result shows that higher RI in 40 patients with renal disease compared to 28 controls, indicating that increased intrarenal resistance reflects impaired renal function [7]. In a prospective cross-sectional study shows, 40 patients with renal parenchymal disease (serum creatinine >1.4 mg/dL) were compared with healthy controls, demonstrating that mean RI was significantly greater in the diseased group and correlated positively with serum creatinine levels, supporting the utility of RI in assessing renal dysfunction [8].

Research focusing on specific disease subgroups, such as diabetic nephropathy, has also shown consistent findings. A cross-sectional study of 80 patients with diabetic nephropathy reported a significant positive correlation between RI and serum creatinine ($r = 0.53$), suggesting that intrarenal vascular resistance reflects biochemical impairment in diabetic renal disease [9]. Longer-term studies have investigated prognostic implications: a follow-up study of nephropathic patients found that an elevated baseline RI was strongly correlated with subsequent increases in serum creatinine over time, indicating that higher RI may predict progressive renal failure [10].

A decade-long study in urban Bangladesh found that 24% of adults had stage 2 or higher renal insufficiency, with higher prevalence in females and older age groups, and serum creatinine levels indicating impaired kidney function in roughly one-third of the population [11]. A Bangladesh study on 53 patients with diabetic nephropathy found a mean renal resistive index (RI) of 0.71, with higher RI significantly correlating with serum creatinine ($r = 0.58$) and albuminuria, indicating worsening renal function [12].

In Bangladesh, most studies on renal resistive index focus on diabetic nephropathy with small sample sizes, while data on other chronic kidney diseases and its predictive value for disease progression remain limited. The aim of this study was to evaluate renal parenchymal disease by comparing renal resistive index measured by Doppler ultrasonography with serum creatinine levels, in order to assess their correlation and determine the utility of RI as a noninvasive marker of renal dysfunction.

METHODOLOGY

Study Design and Setting

This was a hospital-based comparative cross-sectional study conducted at Ibrahim Cardiac Hospital & Research Institute, Dhaka, Bangladesh. The study was carried out over a one-year period from January 2024 to December 2024**.**

Study Population

The study included a total of 150 participants, divided into two groups:

- **Cases (n = 75):** Patients diagnosed with renal parenchymal disease
- **Controls (n = 75):** Individuals with normal renal function and no clinical or ultrasonographic evidence of renal parenchymal disease

Cases and controls were selected from patients attending the radiology and nephrology services of the hospital during the study period.

Inclusion and Exclusion Criteria

Patients aged 18 years and above were eligible for inclusion. Cases were defined as patients with ultrasonographic evidence of renal parenchymal disease, with or without elevated serum creatinine levels. Controls were individuals with normal renal ultrasonography findings and normal serum creatinine levels.

Patients with known renal artery stenosis, congenital renal anomalies, obstructive uropathy, acute kidney injury, history of renal surgery, or poor-quality Doppler waveforms were excluded from the study.

Sampling Technique

A purposive sampling technique was employed to recruit eligible cases and controls until the required sample size was achieved.

Data Collection Procedures

After obtaining informed consent, demographic and clinical information—including age, sex, history of hypertension, and diabetes mellitus—were collected using a structured data collection form. Relevant clinical records were reviewed to document comorbid conditions.

Ultrasonographic Assessment

Renal ultrasonography and Doppler evaluation were performed using a high-resolution ultrasound machine with a low-frequency convex transducer. Both kidneys were examined in longitudinal and transverse planes to assess renal size, cortical echogenicity, and corticomedullary differentiation.

Renal parenchymal disease severity was categorized as mild, moderate, or severe based on cortical echogenicity and loss of corticomedullary differentiation on grayscale ultrasonography.

Measurement of Renal Resistive Index

Color Doppler imaging was used to obtain intrarenal arterial waveforms from the interlobar or

arcuate arteries. The renal resistive index (RRI) was calculated using the formula:

RRI=
(Peak systolic velocity – End diastolic velocity)/Peak sy stolic velocity
Measurements were taken from at least three different sites in each kidney, and the average value was used for analysis.

Laboratory Assessment

Serum creatinine levels were measured using standard laboratory methods. For analytical purposes, serum creatinine levels among cases were categorized into three groups: ≤1.5 mg/dL, 1.6–3.0 mg/dL, and >3.0 mg/dL.

Outcome Measures

The primary outcome measures were:

- Mean renal resistive index
- Serum creatinine levels

Secondary outcomes included the association of RRI with disease severity and the correlation between RRI and serum creatinine.

Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS 27) software. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequency and percentage.

Comparisons between cases and controls were performed using the independent samples t-test for continuous variables and the Chi-square test for categorical variables. Differences in mean RRI across disease severity and serum creatinine categories were analyzed using one-way analysis of variance (ANOVA). The relationship between renal resistive index and serum creatinine was assessed using Pearson's correlation coefficient.
A p-value of <0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the appropriate institutional review board of Ibrahim Cardiac Hospital & Research Institute. Written informed consent was obtained from all participants prior to enrollment, and confidentiality of patient information was strictly maintained throughout the study.

RESULTS

A total of 150 participants were enrolled in the study, comprising 75 patients diagnosed with renal parenchymal disease (cases) and 75 individuals with normal renal function (controls).

Sociodemographic and Clinical Characteristics

The table 1 shows the mean age of the case group was 47.6 ± 12.3 years, which was comparable to that of the control group (45.2 ± 11.8 years), with no statistically significant difference observed (p = 0.218). Male participants constituted the majority in both groups (61.3% among cases and 58.7% among controls), and the sex distribution did not differ significantly between the groups (p = 0.742). The prevalence of hypertension and diabetes mellitus was significantly higher among cases compared to controls (65.3% vs. 28.0% and 50.7% vs. 24.0%, respectively; p < 0.05 for both), indicating a greater burden of comorbid conditions in patients with renal parenchymal disease.

Table 1. Sociodemographic Characteristics of Study Participants (n = 150)

Variable	Category	Cases (n = 75)	Controls (n = 75)	p-value
Age (years)	Mean ± SD	47.6 ± 12.3	45.2 ± 11.8	0.218
Sex	Male	46 (61.3%)	44 (58.7%)	0.742
	Female	29 (38.7%)	31 (41.3%)	
Hypertension	Present	49 (65.3%)	21 (28.0%)	<0.001
Diabetes Mellitus	Present	38 (50.7%)	18 (24.0%)	0.001

Comparison of Renal Resistive Index and Serum Creatinine

Table 2 shows the mean renal resistive index was markedly elevated in the case group compared with the control group (0.71 ± 0.08 vs. 0.58 ± 0.04), and this difference was statistically significant (p < 0.001). Similarly, serum creatinine levels were substantially higher among cases than controls (2.36 ± 0.89 mg/dL vs. 0.91 ± 0.18 mg/dL), demonstrating a significant disparity in renal function between the two groups (p < 0.001).

Table 2. Comparison of Renal Resistive Index (RRI) and Serum Creatinine Between Cases and Controls

Parameter	Cases (n = 75) Mean ± SD	Controls (n = 75) Mean ± SD	p-value
Renal Resistive Index (RRI)	0.71 ± 0.08	0.58 ± 0.04	<0.001
Serum Creatinine (mg/dL)	2.36 ± 0.89	0.91 ± 0.18	<0.001

Renal Resistive Index According to Disease Severity

Table 3 shows among patients with renal parenchymal disease, a progressive rise in renal resistive index was observed with increasing severity of parenchymal involvement. Patients with mild disease had a mean RRI of 0.64 ± 0.05, which increased to 0.71 ± 0.06 in those with moderate disease and further to 0.79 ± 0.05 in severe disease. This trend was statistically significant on one-way ANOVA analysis ($p < 0.001$), indicating a strong association between RRI and the extent of renal parenchymal damage.

Table 3: Mean Renal Resistive Index According to Severity of Renal Parenchymal Disease (Cases Only, n = 75)

Renal Parenchymal Status	Number of Patients	Mean RRI ± SD
Mild disease	24	0.64 ± 0.05
Moderate disease	29	0.71 ± 0.06
Severe disease	22	0.79 ± 0.05
ANOVA p-value		<0.001

Association Between Serum Creatinine and Renal Resistive Index

Table 4 shows when cases were stratified according to serum creatinine levels, a corresponding increase in mean RRI was noted. Patients with serum creatinine ≤1.5 mg/dL had a mean RRI of 0.62 ± 0.04, which rose to 0.71 ± 0.05 among those with levels between 1.6 and 3.0 mg/dL, and reached 0.80 ± 0.04 in patients with serum creatinine exceeding 3.0 mg/dL. The differences across these groups were statistically significant ($p < 0.001$).

Table 4: Relationship Between Serum Creatinine Level and Renal Resistive Index (Cases)

Serum Creatinine Level (mg/dL)	Number of Patients	Mean RRI ± SD
≤1.5	19	0.62 ± 0.04
1.6–3.0	34	0.71 ± 0.05
>3.0	22	0.80 ± 0.04
ANOVA p-value		<0.001

Correlation Between Renal Resistive Index and Serum Creatinine

Table 5 shows that correlation analysis revealed a strong positive relationship between renal resistive index and serum creatinine levels among patients with renal parenchymal disease ($r = 0.72$, $p < 0.001$). This finding suggests that increasing RRI values are closely associated with worsening renal function.

Table 5: Correlation Between Renal Resistive Index and Serum Creatinine (Cases)

Variables	Correlation Coefficient (r)	p-value
RRI vs Serum Creatinine	0.72	<0.001

DISCUSSION

The mean age of our renal parenchymal disease cases was 47.6 ± 12.3 years, similar to controls (45.2 ± 11.8 years), slightly higher than reported by Ghafoori and Shiva (43.6 ± 3.1 vs. 33.6 ± 2.7 years) [13]. In our study, the sex distribution was similar between cases and controls (61.3% vs. 58.7% male), indicating balanced gender across groups. In contrast, Lin et al. (2021) reported that among patients with kidney dysfunction, women were more prevalent than men (66.3% vs. 48.5%) [14]. Hypertension was more frequent in cases (65.3% vs 28.0%) and diabetes (50.7% vs 24.0%), consistent with Lin *et al.,* (2021), who found kidney dysfunction highest in patients with both hypertension and diabetes (8.7% vs 3.4% and 5.2% with hypertension or diabetes alone) [14].

In our study, the mean renal resistive index (RRI) was significantly higher in cases than controls (0.71 ± 0.08 vs. 0.58 ± 0.04), and serum creatinine was also elevated among cases (2.36 ± 0.89 mg/dL vs. 0.91 ± 0.18 mg/dL), indicating impaired renal function. Similarly, Patel *et al.,* (2016) reported that patients with early kidney transplant dysfunction had a mean RRI of 0.73 ± 0.08 and serum creatinine of 2.48 ± 1.02 mg/dL, which were significantly higher than patients without dysfunction [15].

In our study, the mean renal resistive index (RRI) increased progressively with disease severity, from 0.64 ± 0.05 in mild, to 0.71 ± 0.06 in moderate, and 0.79 ± 0.05 in severe renal parenchymal disease, indicating a strong association between RRI and extent of renal damage. Similarly, Bigé *et al.,* (2012) reported mean RRI values of 0.62 ± 0.06 in patients with mild histological lesions, 0.70 ± 0.07 in moderate lesions, and 0.78 ± 0.05 in severe lesions, showing a significant correlation between higher RRI and more severe structural damage ($p < 0.001$) [16].

In our study, stratification of cases by serum creatinine revealed a progressive increase in mean renal resistive index (RRI): 0.62 ± 0.04 for ≤1.5 mg/dL, 0.71 ± 0.05 for 1.6–3.0 mg/dL, and 0.80 ± 0.04 for

>3.0 mg/dL, indicating that higher creatinine levels are associated with increased intrarenal vascular resistance. These findings are consistent with Kim SH *et al.,* (1992), who reported that patients with medical renal disease had significantly higher RRI (0.823 ± 0.237) than normal controls (0.627 ± 0.042) and that RRI correlated positively with serum creatinine [7].

In our study, correlation analysis demonstrated a strong positive relationship between renal resistive index (RRI) and serum creatinine in patients with renal parenchymal disease ($r = 0.72$), indicating that higher RRI closely reflects worsening renal function. This finding aligns with previous studies, including Khan A *et al.,* (2023), who reported a significant correlation between RRI and serum creatinine in patients with diabetic nephropathy ($r = 0.53$, $p < 0.001$) [9].

CONCLUSION

Renal resistive index was significantly higher in patients with renal parenchymal disease and increased progressively with disease severity. A strong positive correlation between renal resistive index and serum creatinine indicates that higher intrarenal vascular resistance is associated with worsening renal function. Renal resistive index is a useful, non-invasive adjunct to serum creatinine for assessing the presence and severity of renal parenchymal disease.

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