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RESISTIVE INDEX ON DOPPLER ULTRASOUND AFTER RENAL TRANSPLANTATION AS RENAL FUNCTION PREDICTOR

Original Research

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ABSTRACT

Background: Kidney transplantation significantly improves survival and quality of life for patients with end-stage renal disease, yet graft dysfunction remains a considerable challenge. Early identification of at-risk patients is critical to preserving graft function and enhancing long-term outcomes. Doppler ultrasonography, particularly the assessment of the resistive index (RI), has gained prominence as a non-invasive tool to evaluate renal hemodynamics. Understanding the relationship between RI and kidney function markers may guide better clinical decision-making and post-transplant monitoring.

Objective: This study aimed to assess renal function after kidney transplantation by evaluating RI and its correlation with kidney function outcomes.

Methods: A prospective study was conducted on 78 kidney transplant recipients at a tertiary care hospital. Demographic and clinical data, including age, gender, comorbidities, and immunosuppressive therapies, were recorded. Renal function was assessed at one and three months post-transplantation using RI, estimated glomerular filtration rate (eGFR), and serum creatinine levels. Doppler ultrasonography was performed with standardized protocols, and RI was calculated from interlobar arteries. Patients were categorized into two groups based on RI (<0.8 and ≥0.8). Statistical analyses were performed using SPSS v26, with $p < 0.05$ considered significant.

Results: The study population included 64.1% males, with the majority aged 31–45 years (44.9%). At one month, the mean RI was 0.74 ± 0.05, which decreased to 0.64 ± 0.04 by three months. eGFR improved from 60.5 ± 12.3 to 65.2 ± 14.1 mL/min/1.73 m², while serum creatinine decreased from 1.2 ± 0.2 to 1.1 ± 0.2 mg/dL. Patients with RI <0.8 had significantly higher eGFR at both one and three months compared to those with RI ≥0.8 ($p < 0.05$).

Conclusion: RI served as a reliable non-invasive predictor of renal function in the early post-transplant period. Lower RI values were associated with improved renal outcomes, emphasizing the importance of continuous RI monitoring alongside conventional markers to optimize post-transplant care and patient prognosis.

Keywords: Creatinine, Doppler Ultrasonography, Graft Survival, Kidney Transplantation, Prognosis, Renal Function Tests, Resistive Index.

INTRODUCTION

Renal transplantation remains the treatment of choice for patients with end-stage renal disease (ESRD), offering significant improvements in quality of life and long-term survival (1). The success of transplantation, however, relies heavily on vigilant post-operative monitoring to identify complications at an early stage and to safeguard graft longevity. Among the available diagnostic modalities, Doppler ultrasonography has emerged as a cornerstone tool because it is non-invasive, widely available, and provides detailed assessment of renal vascular dynamics (2). A central parameter derived from Doppler ultrasonography is the intrarenal resistive index (RI), which reflects resistance to blood flow within the renal arteries. This measurement, calculated from pulsatile flow-velocity waveforms, is considered reliable for evaluating renal allografts in routine clinical practice. Elevated RI values have been associated with poor outcomes in both native kidneys and transplanted grafts, including cardiovascular events, progressive renal dysfunction, and increased risk of graft loss or patient mortality (3-5). Such evidence underscores the potential of RI as a prognostic marker of transplant health. Nevertheless, interpretation of RI is complex, as it may be influenced not only by intrinsic renal pathology but also by systemic haemodynamic factors such as central blood pressure and arterial stiffness (6,7). While some studies have attempted to link RI with histopathological changes in the renal allograft, the evidence remains limited, particularly in the absence of routine renal biopsy in clinical follow-up (8,9). This interplay between renal and systemic determinants complicates the use of RI as a solitary marker of graft integrity, warranting further investigation.

Despite these challenges, Doppler ultrasonography continues to be a vital component of transplant care due to its ability to provide real-time anatomical and functional information without exposing patients to ionizing radiation. Importantly, RI has demonstrated a positive correlation with serum creatinine, a widely accepted marker of renal function, suggesting that it may serve as a valuable adjunct in assessing graft performance (10,11). Similar approaches that integrate radiological and biochemical parameters have also been applied in hepatology research, reinforcing the broader clinical value of such combined assessments (12). This correlation offers an opportunity to strengthen non-invasive monitoring strategies, particularly in resource-limited healthcare systems such as Pakistan, where access to advanced diagnostic methods is constrained. Given this context, the present study aims to evaluate the correlation between serum creatinine levels and resistive index in renal transplant recipients. By establishing RI as a reliable predictor of graft function, this research seeks to enhance clinical decision-making, improve patient outcomes, and optimize post-transplant surveillance in settings where cost-effective diagnostic approaches are essential.

METHODS

A cross-sectional study was conducted in the Radiology Department of a tertiary care hospital in Rawalpindi to evaluate the relationship between Doppler-derived resistive index (RI) and renal function among kidney transplant recipients. Patients who had undergone renal transplantation at the hospital and were attending follow-up visits for routine Doppler ultrasonography were considered for inclusion. From this group, 78 patients were selected according to predefined eligibility criteria. Inclusion was restricted to those who had received a renal transplant at the study center, provided informed consent, and possessed complete medical records, including Doppler ultrasound findings and renal function tests. Patients were excluded if they declined consent, had incomplete medical records, or had undergone transplantation at institutions other than the study hospital. Doppler ultrasonography was performed using a ProSound ALPHA 10 (Hitachi Aloka Medical) with a multifrequency convex transducer operating at 2–6 MHz. For each patient, maximal systolic velocity (Vmax) and minimal diastolic velocity (Vmin) were measured in two to three interlobar arteries. The resistive index was calculated using the formula $RI = 1 - (V_{min} \div V_{max})$. Measurements were obtained from three distinct regions of the graft: the lower pole, interpolar region, and upper pole. The mean of these three readings was recorded as the representative RI. To ensure reliability, intra-session variance between observers was reported as 3.3%, while intra-observer variation was 4.3% (13-15). Notably, the RI values recorded were not used to guide clinical management decisions. Data were retrieved retrospectively from patient records and included demographic details, transplantation history, Doppler ultrasound parameters, and results of renal function tests. Statistical analysis was carried out using SPSS version 26. Descriptive statistics were employed to summarize patient demographics and Doppler findings, while correlation analysis was performed to assess the association between RI and biochemical markers of renal function. A p-value <0.05 was considered statistically significant. The study was conducted in compliance with ethical standards and was approved by the institutional ethics review committee of the hospital. Written informed consent had been obtained from all participants at the time of their follow-up assessments, and confidentiality was maintained through anonymization of patient data during analysis.

RESULTS

The study cohort consisted of 78 patients who underwent renal transplantation. The majority of participants were between 31 and 45 years of age (44.9%), followed by those aged 18 to 30 years (25.6%), 46 to 60 years (23.1%), and more than 60 years (6.4%). The gender distribution was predominantly male, comprising 64.1% of the sample, while females accounted for 35.9%. Most patients had 3 to 4 HLA mismatches (57.7%), whereas 19.2% had 0 to 2 mismatches and 23.1% had 5 or more mismatches. Additional induction therapy was administered in 76.9% of cases. Glucocorticoids were the most frequently used therapy (89.7%), followed by tacrolimus (10.3%), mycophenolate mofetil (8.9%), and cyclosporine (3.9%). Regarding comorbidities, 29.5% of patients had diabetes and 57.7% were hypertensive. A history of graft rejection was reported in 6.4% of the study population. At one month post-transplant, the mean resistive index was 0.74 (±0.05), which declined to 0.64 (±0.04) at three months, indicating improved intrarenal hemodynamics. The estimated GFR increased from 60.5 (±12.3) mL/min/1.73 m² at one month to 65.2 (±14.1) mL/min/1.73 m² at three months. Serum creatinine showed a modest reduction from 1.2 (±0.2) mg/dL at one month to 1.1 (±0.2) mg/dL at three months. Systolic blood pressure improved from 135.2 (±15.3) mmHg to 130.5 (±13.7) mmHg, while diastolic blood pressure decreased from 89.4 (±10.1) mmHg to 85.6 (±9.8) mmHg. Pulse pressure also demonstrated a reduction from 45.6 (±8.2) mmHg at one month to 42.1 (±7.5) mmHg at three months.

Further analysis revealed that patients with an RI <0.8 had significantly better renal function compared to those with RI ≥0.8. At one month, the mean estimated GFR in patients with RI <0.8 was 68.2 (±10.5) mL/min/1.73 m² compared to 52.3 (±13.4) mL/min/1.73 m² in those with RI ≥0.8. By three months, GFR further improved to 72.1 (±11.3) mL/min/1.73 m² in the RI <0.8 group, whereas the RI ≥0.8 group achieved 57.8 (±12.9) mL/min/1.73 m². Both groups demonstrated statistically significant improvements over time, with p-values of 0.04 and 0.03, respectively. The relationship between resistive index and serum creatinine was further examined to validate the predictive capacity of RI for graft function. At one month, RI demonstrated a positive correlation with serum creatinine ($r = 0.41$, $p = 0.002$), indicating that higher RI values were associated with impaired renal clearance. This relationship persisted at three months, where the correlation remained statistically significant ($r = 0.38$, $p = 0.004$). Subgroup analyses revealed that patients with comorbid diabetes had comparatively higher mean RI values (0.76 ± 0.06) and serum creatinine (1.3 ± 0.3 mg/dL) compared to non-diabetic patients (RI 0.72 ± 0.05; creatinine 1.1 ± 0.2 mg/dL, $p = 0.03$). Similarly, hypertensive patients exhibited higher RI (0.75 ± 0.05) and creatinine levels (1.2 ± 0.3 mg/dL) than normotensive counterparts (RI 0.71 ± 0.04; creatinine 1.0 ± 0.2 mg/dL, $p = 0.04$). These findings suggest that systemic comorbidities exert a measurable influence on both RI and renal function, reinforcing the need to interpret Doppler indices within the broader clinical context.

Table 1: The demographic and clinical characteristics of the study

Characteristic	n (%) (N = 78)
Age Categories	
18-30 years	20 (25.6%)
31-45 years	35 (44.9%)
46-60 years	18 (23.1%)
>60 years	5 (6.4%)
Gender	
Male	50 (64.1%)
Female	28 (35.9%)
HLA Mismatches	
0-2 mismatches	15 (19.2%)
3-4 mismatches	45 (57.7%)
≥5 mismatches	18 (23.1%)
Additional Induction Therapy	
Yes	60 (76.9%)
No	18 (23.1%)

Characteristic	**n (%) (N = 78)**
Therapies	
Glucocorticoids	60 (76.9%)
Tacrolimus	8 (10.3%)
Mycophenolate Mofetil (MMF)	7 (8.9%)
Cyclosporine	3 (3.9%)
Comorbidities	
Diabetes	
Yes	23 (29.5%)
No	55 (70.5%)
Hypertension	
Yes	45 (57.7%)
No	33 (42.3%)
Previous Rejections	5 (6.4%)

Table 2: Post-transplantation clinical characteristics at follow-up checkups

Predictor Variable	**1 Month (Mean ± SD)**	**3 Months (Mean ± SD)**
Resistive Index	0.74 ± 0.05	0.64 ± 0.04
Estimated GFR (mL/min/1.73 m²)	60.5 ± 12.3	65.2 ± 14.1
Serum Creatinine (mg/dL)	1.2 ± 0.2	1.1 ± 0.2
Pulse Pressure (mmHg)	45.6 ± 8.2	42.1 ± 7.5
Systolic Blood Pressure (mmHg)	135.2 ± 15.3	130.5 ± 13.7
Diastolic Blood Pressure (mmHg)	89.4 ± 10.1	85.6 ± 9.8

Table 3: Correlation of Resistive Index Categories with Estimated GFR at follow-ups

Resistive Index Category	**Number of Patients n (%)**	**Estimated GFR (1 Month) (Mean ± SD)**	**Estimated GFR (3 Months) (Mean ± SD)**	**p-value**
RI < 0.8	50 (64.1%)	68.2 ± 10.5	72.1 ± 11.3	0.04*
RI ≥ 0.8	28 (35.9%)	52.3 ± 13.4	57.8 ± 12.9	0.03*

Table 4: Correlation of Resistive Index with Serum Creatinine and Comorbidities

Parameter	**RI (Mean ± SD)**	**Serum Creatinine (mg/dL) (Mean ± SD)**	**Correlation Coefficient (r)**	**p-value**
Overall (1 Month)	0.74 ± 0.05	1.2 ± 0.2	0.41	0.002*
Overall (3 Months)	0.64 ± 0.04	1.1 ± 0.2	0.38	0.004*
Diabetes (Yes)	0.76 ± 0.06	1.3 ± 0.3	–	0.03*
Diabetes (No)	0.72 ± 0.05	1.1 ± 0.2	–	–
Hypertension (Yes)	0.75 ± 0.05	1.2 ± 0.3	–	0.04*
Hypertension (No)	0.71 ± 0.04	1.0 ± 0.2	–	–

*Statistically significant at $p < 0.05$.

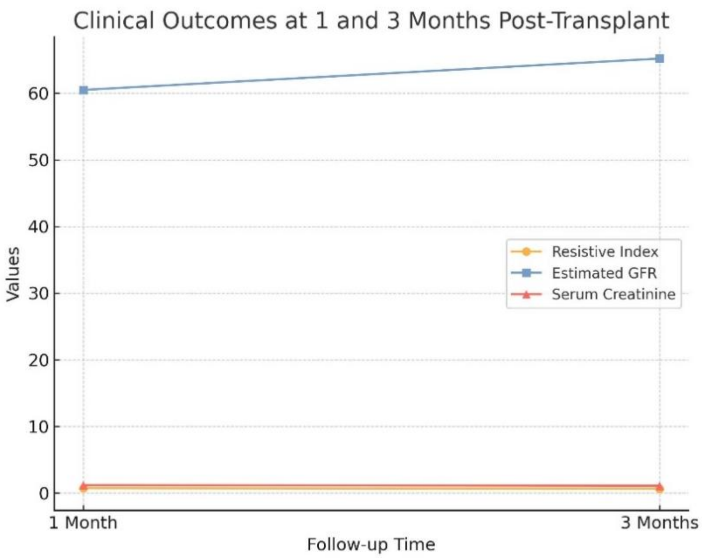

Figure 1 Clinical Outcomes at 1- and 3-Months Post-Transplant

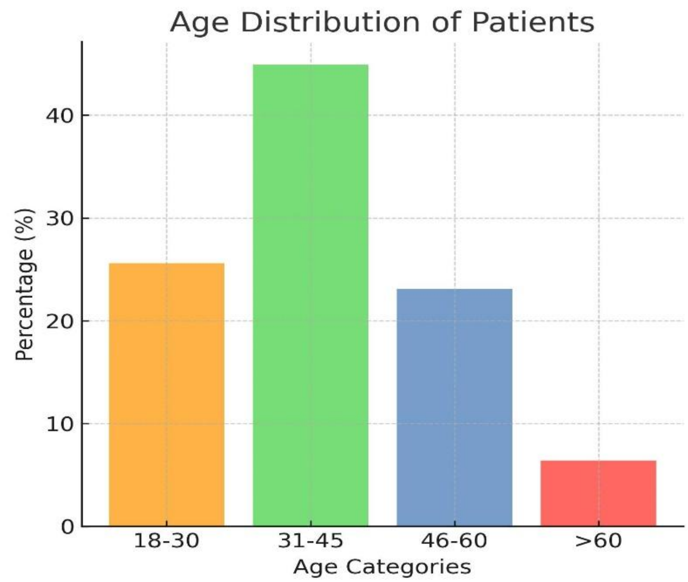

Figure 2 Age Distribution of Patients

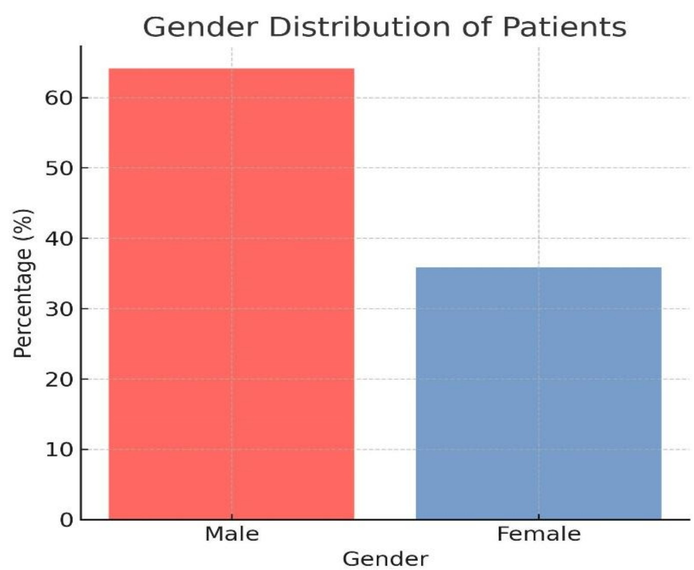

Figure 3 Gender Distributions of Patients

DISCUSSION

Renal allograft dysfunction continues to represent a major clinical challenge, with early identification remaining essential to ensure favorable treatment outcomes. The present study demonstrated a pattern of improvement in renal hemodynamics and function during the early post-transplant period, findings that are consistent with previously published literature on kidney transplantation. The majority of patients in the cohort were middle-aged males, reflecting the demographic trend seen in other populations where chronic kidney disease is more prevalent among men and those in the middle age group (11,12). The predominance of 3–4 HLA mismatches is also aligned with established evidence that complete matching is often limited in clinical practice due to donor shortages (13). The high proportion of patients receiving induction therapy and glucocorticoids mirrors global immunosuppressive regimens designed to mitigate the risk of early rejection episodes (14,15). The mean resistive index decreased significantly from one to three months post-transplantation, accompanied by improvements in estimated GFR and reductions in serum creatinine, systolic and diastolic blood pressures, and pulse pressure. These findings suggest stabilization of renal perfusion and progressive improvement in graft function over time. Comparable results have been documented in other studies, where a reduction in RI was observed as a marker of improved perfusion and decreasing vascular resistance during graft recovery (16,17). The parallel improvements in eGFR and serum creatinine reinforce the clinical relevance of RI as a surrogate marker of renal function. Further subgroup analysis revealed that patients with RI values <0.8 consistently exhibited higher GFR at both one and three months compared with those with RI ≥0.8. This observation supports the concept that lower RI values are predictive of better functional outcomes, while higher RI values are associated with impaired graft performance. These findings are in concordance with earlier studies that linked elevated RI to delayed graft function, transplant failure, and even increased recipient mortality (18–20). Although RI remains widely used, its clinical utility is still debated because of variability in reported sensitivity, specificity, and prognostic thresholds. The absence of a universally accepted cut-off value limits its applicability as a standardized tool for predicting long-term outcomes.

A notable strength of this study was the use of a homogenous patient population from a single center, which allowed for consistent Doppler measurements and follow-up protocols. Furthermore, the analysis incorporated not only RI and GFR but also serum creatinine and blood pressure parameters, providing a comprehensive evaluation of early graft function. However, limitations must be acknowledged. The retrospective nature of data collection restricts the ability to establish causality, and the sample size was modest, potentially limiting the generalizability of the findings. Moreover, the study did not extend beyond three months, thereby excluding long-term outcomes such as chronic rejection, graft survival, and mortality. Another limitation was the lack of detailed correlation analyses between RI and histopathological findings, which could have further clarified the role of RI in detecting subclinical injury. Future research should aim to validate these findings in larger, multicenter cohorts with longer follow-up durations. Studies that integrate Doppler-derived indices with histological assessments and advanced imaging modalities would provide a more robust understanding of the prognostic value of RI. There is also a need to establish consensus regarding optimal cut-off values for RI to enhance its reliability as a clinical marker. Exploration of comorbid influences such as hypertension and diabetes on RI and graft outcomes would further contribute to individualized patient care strategies. Overall, the present study reinforces the role of RI as a valuable non-invasive parameter for monitoring renal allograft function, while acknowledging its limitations. It provides supportive evidence for the correlation between RI and renal function, highlighting its utility in early post-transplant surveillance, but emphasizes the need for continued investigation to refine its predictive capacity and standardize its application in clinical practice.

CONCLUSION

This study concludes that the resistive index remains a valuable non-invasive parameter for assessing renal allograft function, with lower values reflecting more favorable graft outcomes. The findings underscore its potential role as an early predictor of graft performance, supporting its integration into routine post-transplant surveillance alongside traditional biochemical markers. While its long-term prognostic utility and precise cut-off values warrant further investigation, the study highlights the importance of continuous monitoring of RI in combination with clinical indicators to optimize patient care and improve transplant outcomes.

AUTHOR CONTRIBUTION

Author	Contribution
Mamoon Rasheed*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Nadeem Ibrahim	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
Uzma Nisar	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published

Author	Contribution
Rizwan Bilal	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Alia Shaheen	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Usman Haider	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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