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Comparative Study of Renal Artery Stenosis in Diabetic and Non-Diabetic Patients by Renal Artery Doppler

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ABSTRACT

Background: Renal artery stenosis (RAS) is a major cause of secondary hypertension and chronic kidney disease (CKD), and diabetes mellitus accelerates its development. This study aims to compare the prevalence, severity, and characteristics of RAS in diabetic versus non-diabetic patients using renal artery Doppler ultrasonography.

Method: An observational study was conducted from January 2023 to June 2024 at TS Misra Medical College and Hospital, involving 88 patients with RAS. Participants included 50 diabetic and 38 non-diabetic patients. Renal Doppler ultrasonography assessed resistive index (RI) and pulsatility index (PI) for evaluating renal vascular resistance. Demographic and clinical data were collected, and statistical analysis was performed using SPSS version 23.0.

Result: Diabetic patients showed significantly higher RI and PI values compared to non-diabetics, with RI of 0.71 ± 0.06 vs. 0.62 ± 0.041 and PI of 1.41 ± 0.31 vs. 0.97 ± 0.21 ($p<0.001$). Renal dimensions also differed, with larger volumes and altered measurements in diabetics. Prevalence of RAS was noted to be higher in diabetics with hypertension.

Conclusion: Diabetes is associated with increased renal vascular resistance and altered renal hemodynamics. Early detection and management of RAS in diabetic patients are crucial for preventing progression to end-stage renal disease.

Keywords: Renal artery stenosis, Diabetes mellitus, Resistive index; Pulsatility index, Doppler ultrasonography, Chronic kidney disease

INTRODUCTION

Renal artery stenosis (RAS) is a significant cause of secondary hypertension and chronic kidney disease (CKD), characterized by the narrowing of one or both renal arteries. This condition can lead to reduced blood flow to the kidneys, triggering a cascade of pathophysiological responses that may result in renal ischemia, hypertension, and progressive renal dysfunction. Early detection and management of RAS are crucial in preventing long-term renal damage and associated cardiovascular complications.[1,2]

Diabetes mellitus, a prevalent metabolic disorder, is known to accelerate the development of vascular complications, including atherosclerosis, which is a major underlying cause of RAS. Diabetic patients are particularly susceptible to developing RAS due to the combined effects of hyperglycemia-induced endothelial dysfunction

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and the chronic inflammatory state associated with diabetes. The presence of RAS in diabetic patients can further complicate their clinical management, as it may exacerbate hypertension and accelerate the decline in renal function, leading to end-stage renal disease (ESRD).[3,4] Non-diabetic patients, while also at risk for RAS, may have different etiological factors contributing to the condition, such as fibromuscular dysplasia, atherosclerosis, or congenital anomalies. The comparative analysis of RAS between diabetic and non-diabetic populations is essential to understand the differential impact of these conditions on the renal vasculature and to tailor diagnostic and therapeutic approaches accordingly.[5,6] Renal artery Doppler ultrasonography is a non-invasive imaging modality that has emerged as a valuable tool for the assessment of RAS. It provides detailed information on renal blood flow dynamics and can help identify hemodynamically significant stenoses, thus guiding clinical decision-making.[7]

This study aims to conduct a comparative analysis of the prevalence, severity, and characteristics of renal artery stenosis in diabetic versus non-diabetic patients using renal artery Doppler. By understanding the differences in RAS between these two groups, we seek to provide insights that could enhance the management strategies for patients with RAS, particularly in those with coexisting diabetes.

MATERIALS AND METHODS

This observational study was conducted at the Department of Radio-diagnosis and General Medicine, TS Misra Medical College and Hospital, Lucknow (UP), from January 2023 to June 2024. It involved 88 patients diagnosed with renal artery stenosis. All participants underwent detailed history taking and clinical examination to gather comprehensive data.

The study was designed as an observational analysis. Participants were selected based on specific inclusion and exclusion criteria. The inclusion criteria comprised patients aged 30-60 years, both diabetic and non-diabetic, presenting with accelerated hypertension, resistant hypertension (failure of three drug regimens), new azotemia or worsening renal failure (more than a 30% rise in creatinine), unexplained atrophic kidney or size discrepancy greater than 1.5 cm between the kidneys, abdominal or flank bruits, peripheral vascular disease, or aortic aneurysm/dissection. Exclusion criteria included individuals outside the 30-60 age range, those with excessive bowel gas, anatomically deformed kidneys, chronic kidney disease on dialysis, or polycystic kidney disease.

The sample size of 88 cases was determined based on a specific formula for sample size estimation, which included factors such as critical value, expected prevalence, and margin of error. The study involved 50 known type 2 diabetic patients, diagnosed according to the American Diabetes Association criteria, and 38 age- and sex-matched hypertensive non-diabetic subjects as controls. Written informed consent was obtained from all participants. Baseline socio-demographic data such as age and gender were collected using a structured questionnaire. Additional data collected included blood pressure, height (in meters), weight (in kilograms), and body mass index (BMI), calculated as weight/height² (kg/m²).

Ultrasound and color Doppler imaging were used to assess the renal arteries. Two approaches were utilized with Doppler Ultrasound. The direct approach involved evaluating the major renal artery and taking spectral traces from the stenotic region. Criteria for diagnosing significant stenosis included a peak systolic velocity greater than 180 cm/sec, a renal artery/aortic ratio exceeding 3.5, turbulent flow in the post-stenotic area, and the absence of a detectable Doppler signal indicating occlusion. The indirect approach involved assessing arterial waveforms from the segmental renal arteries.

Findings suggestive of renal artery stenosis included a Parvus-Tardus waveform, an acceleration time greater than 0.07 seconds, an acceleration index less than 3 m/s², and a change in Resistive Index greater than 5%. Findings indicative of chronic kidney disease included an intra-renal Resistive Index greater than 0.7 and an acceleration time less than 70 seconds.

The study was approved by the institutional human ethics committee (H.O.S./15/433-year 2015) on 30-11-22. Written informed consent was obtained from all participants, who were informed of the study's risks, benefits, and the voluntary nature of their participation. Confidentiality was maintained throughout the study.

To ensure validity and reliability, expert opinions and reputable literature were consulted for the selection and specification of clinical parameters relevant to the study's objectives. Data collection involved detailed medical histories, clinical assessments, and investigations, all recorded systematically. Data analysis was performed using the Statistical Package for Social Sciences (SPSS) version 23.0 for Windows. Quantitative data were presented as mean ± standard deviation, while qualitative data were presented as frequencies (percentages). Statistical comparisons between groups were made using the t-test. A P-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1 shows the distribution of cases based on group and sub-division reveals key insights into the composition of the study population. Among the total 88 cases, 50 patients were categorized as diabetic and 38 as non-diabetic. Within the diabetic group, 30 patients, representing 34.1% of the total, were classified as only diabetics, while 20 patients (22.7%) had both diabetes and hypertension. In the non-diabetic group, 24 patients (27.3%) were diagnosed with only hypertension, and 8 patients (9.1%) presented with both coronary artery disease (CAD) and hypertension. Additionally, 6 patients

(6.8%) across the groups had peripheral vascular disease, indicating the presence of vascular complications in the study population.

As seen in tabe-2, In terms of age, most patients fell within the 51–60-year range, with 78% of diabetics and 63.2% of non-diabetics belonging to this category. A smaller proportion of patients were aged 41-50 years (18% diabetics, 28.9% non-diabetics), and an even smaller group was aged 30-40 years (4% diabetics, 7.9% non-diabetics). The mean age of diabetic patients was slightly higher at 58.90 ± 10.31 years compared to 55.98 ± 8.72 years for non-diabetics, though this difference was not statistically significant (p=0.124). Gender distribution was fairly balanced in both groups, with 46% males and 54% females in the diabetic group, and 44.7% males and 55.3% females in the non-diabetic group (p=0.348). Regarding clinical parameters, the diabetics had significantly higher HbA1c levels (8.12 ± 2.4% vs. 5.87 ± 1.7%, p<0.001), indicating poorer glycemic control. Serum creatinine was also higher in diabetics (1.6 ± 0.4 mg/dL vs. 1.3 ± 0.3 mg/dL, p=0.023), suggesting more pronounced renal impairment. There was no significant difference in body mass index (BMI), with diabetics averaging 27.67 ± 5.4 kg/m² and non-diabetics 26.6 ± 5.1 kg/m² (p=0.874). Blood pressure measurements revealed significant differences: systolic blood pressure (SBP) was lower in diabetics (133.89 ± 11.4 mmHg) compared to non-diabetics (141.89 ± 14.5 mmHg, p=0.017), while diastolic blood pressure (DBP) was also lower in diabetics (86.58 ± 6.9 mmHg vs. 90.58 ± 7.4 mmHg, p=0.044). These findings highlight key cardiovascular and renal differences between the groups.

Table 1: Distribution of cases based on group and subdivision (N=88)

Group	Cases (%)
Diabetic (n=50)	
Only Diabetics	30 (34.1)
Diabetics + Hypertensive	20 (22.7)
Non-Diabetic (n=38)	
Only Hypertensive	24 (27.3)
CAD + Hypertensive	8 (9.1)
Peripheral Vascular Disease	6 (6.8)

Table 2: Distribution of patients based on demographic details

Variables	Diabetics (%) (n=50)	Non-Diabetics (%) (n=38)	p-value
Age Group (years)			
30-40	2 (4.0%)	3 (7.9%)	0.497
41-50	9 (18.0%)	11 (28.9%)	
51-60	39 (78.0%)	24 (63.2%)	
Mean Age (years)	58.90 ± 10.31	55.98 ± 8.72	0.124
Gender			
Male	23 (46.0%)	17 (44.7%)	0348
Female	27 (54.0%)	21 (55.3%)	
HbA1c (%)	8.12 ± 2.4	5.87 ± 1.7	<0.001*
Serum Creatinine (mg/dL)	1.6 ± 0.4	1.3 ± 0.3	0.023*
BMI (kg/m²)	27.67 ± 5.4	26.6 ± 5.1	0.874
SBP (mmHg)	133.89 ± 11.4	141.89 ± 14.5	0.017*
DBP (mmHg)	86.58 ± 6.9	90.58 ± 7.4	0.044*

Table 3: Renal Doppler findings by direct approach

Parameter	Diabetics (mean ± sd) (n=50)	Non-Diabetics (mean ± sd) (n=38)	p-value
Peak Systolic Volume	180.7 ± 50.1	173.8 ± 58.7	0.554
Renal Artery/Aortic Ratio	3.5 ± 1.1	3.9 ± 0.9	<0.05*

Table 4: Comparison of renal dimensions between diabetic and non-diabetic groups

Parameter	Diabetics (mean ± sd) (n=50)	Non-Diabetics (mean ± sd) (n=38)	p-value
Right Kidney			
Longitudinal (cm)	10.23 ± 0.79	10.27 ± 0.63	0.378
Antero-posterior (cm)	4.29 ± 0.69	4.03 ± 0.55	0.031*
Transverse (cm)	5.31 ± 0.66	5.17 ± 0.68	0.197
Volume (cm³)	122.1 ± 35.4	111.12 ± 28.4	0.023*
Left Kidney			
Longitudinal (cm)	10.81 ± 0.81	10.72 ± 0.72	0.687
Antero-posterior (cm)	4.89 ± 0.67	5.23 ± 0.71	0.003*
Transverse (cm)	5.19 ± 0.63	4.62 ± 0.66	<0.001*
Volume (cm³)	142.1 ± 33.2	137.14 ± 38.4	0.147

As seen in Table 3, The **peak systolic volume** in the diabetic group was slightly higher at 180.7 ± 50.1 compared to 173.8 ± 58.7 in the non-diabetic group, though this difference was not statistically significant (p=0.554). However, the **renal artery/aortic ratio** was found to be significantly lower in the diabetic group (3.5 ± 1.1) compared to the non-diabetic group (3.9 ± 0.9), with a p-value of less than 0.05, indicating a meaningful difference in the vascular structure and function between the two groups. This suggests that diabetes may have an impact on renal vascular dynamics as reflected in these Doppler findings.

As seen in Table 4, For the right kidney, the longitudinal dimension was nearly identical between diabetics (10.23 ± 0.79 cm) and non-diabetics (10.27 ± 0.63 cm), with no statistically significant difference (p=0.378). However, the antero-posterior dimension was significantly larger in diabetics (4.29 ± 0.69 cm) compared to non-diabetics (4.03 ± 0.55 cm, p=0.031). The transverse dimension did not differ significantly between the two groups (5.31 ± 0.66 cm in diabetics vs. 5.17 ± 0.68 cm in non-diabetics, p=0.197). The volume of the right kidney was notably larger in diabetics (122.1 ± 35.4 cm³) compared to non-diabetics (111.12 ± 28.4 cm³), with a significant p-value of 0.023. For the left kidney, the longitudinal dimension was similar in both groups (10.81 ± 0.81 cm in diabetics vs. 10.72 ± 0.72 cm in non-diabetics, p=0.687). However, the antero-posterior dimension was significantly smaller in diabetics (4.89 ± 0.67 cm) compared to non-diabetics (5.23 ± 0.71 cm, p=0.003). Additionally, the transverse dimension was significantly larger in diabetics (5.19 ± 0.63 cm) compared to non-diabetics (4.62 ± 0.66 cm, p<0.001). The volume of the left kidney was not significantly different between the two groups (142.1 ± 33.2 cm³ in diabetics vs. 137.14 ± 38.4 cm³ in non-diabetics, p=0.147). These findings highlight variations in renal dimensions, especially in antero-posterior and transverse measurements, with statistical significance in certain aspects, indicating the potential impact of diabetes on kidney morphology.

As per Table 5, For the Resistive Index (RI), the values for the right kidney were notably higher in diabetics (0.71 ± 0.06) compared to non-diabetics (0.62 ± 0.041), with a highly significant p-value of <0.001. Similarly, the left kidney also showed higher RI values in diabetics (0.68 ± 0.05) compared to non-diabetics (0.58 ± 0.043), with the same level of statistical significance (p<0.001). When the combined RI for both kidneys was assessed, diabetics had a mean of 0.69 ± 0.06, significantly higher than non-diabetics (0.57 ± 0.038), with a p-value of <0.001.

For the Pulsatility Index (PI), the right kidney in diabetics showed a higher mean value (1.41 ± 0.31) compared to non-diabetics (0.97 ± 0.21), again with a p-value of <0.001. The left kidney also had a higher PI in diabetics (1.32 ± 0.22) compared to non-diabetics (0.962 ± 0.14), with a highly significant difference (p<0.001). The combined PI was significantly elevated in diabetics (1.30 ± 0.28) compared to non-diabetics (0.98 ± 0.15), with a p-value of <0.001. These findings indicate that both RI and PI values are considerably higher in diabetics, suggesting increased vascular resistance and altered renal hemodynamics in this group.

Table 5: Combined Mean RI and PI in Diabetic and Non-Diabetic Groups

Parameter	Diabetics (n=50)	Non-Diabetics (n=38)	p-value
Resistive Index (RI)			
Right Kidney	0.71 ± 0.06	0.62 ± 0.041	<0.001*
Left Kidney	0.68 ± 0.05	0.58 ± 0.043	<0.001*
Combined RI	0.69 ± 0.06	0.57 ± 0.038	<0.001*
Pulsatility Index (PI)			
Right Kidney	1.41 ± 0.31	0.97 ± 0.21	<0.001*
Left Kidney	1.32 ± 0.22	0.962 ± 0.14	<0.001*
Combined PI	1.30 ± 0.28	0.98 ± 0.15	<0.001*

DISCUSSION

In the present study, a total of 88 cases were analyzed, consisting of 50 diabetic patients (56.8%) and 38 non-diabetic patients (43.2%). Among the diabetic group, 30 patients (34.1%) had only diabetes, while 20 patients (22.7%) had both diabetes and hypertension. In contrast, the non-diabetic group was primarily composed of patients with hypertension (24 patients, 27.7%), followed by those with coronary artery disease (CAD) and hypertension (8 patients, 9.09%), and peripheral vascular disease (6 patients, 6.81%). Age distribution analysis revealed a higher percentage of diabetics (78.0%) in the 51-60 age group compared to non-diabetics (63.2%). The mean age of diabetic patients was slightly higher (58.90 ± 10.31 years) compared to non-diabetics (55.98 ± 8.72 years). Gender distribution was similar across both groups, and there were statistically significant differences between the groups in terms of HbA1c, serum creatinine levels, systolic blood pressure (SBP), and diastolic blood pressure (DBP) (p<0.05).

These findings align with the results of Dawha S et al., who studied 160 participants (80 with diabetes and 80 healthy controls matched for age and sex). In their study, the mean age of the diabetic group was 59.1±9.9 years, compared to 57.4±10.1 years in the control group, with no statistically significant difference in age (p=0.281). Similarly, gender distribution did not differ significantly between the two groups (p=0.873). The fasting blood sugar levels and HbA1c levels were significantly higher in the diabetic group compared to the controls (p<0.0001).[8]

Atalabi OM et al. also reported consistent findings in a study with 217 participants (107 diabetics and 110 controls). Their results showed no significant difference in the male-to-female ratio (p=0.9) and demonstrated that diabetic patients had higher BMI and significantly higher systolic and diastolic blood pressures (p<0.001) compared to non-diabetic controls.[9]

In the present study, the peak systolic velocity (PSV) and renal artery/aortic ratio (RAR) were higher in diabetic patients compared to non-diabetics. However, only the renal artery/aortic ratio showed a statistically significant difference between the two groups (p<0.05). These findings suggest that while PSV may not differ substantially, RAR could be a more reliable indicator of vascular changes in diabetics.

Atalabi OM et al. reported that pulsed Doppler was used to measure end-diastolic and peak systolic velocities, with a PSV greater than 200 cm/sec and a renal artery/aortic velocity ratio greater than 3.5 indicating renal artery stenosis (RAS). [9] Hua HT et al. achieved a sensitivity of 91% and specificity of 75% in detecting RAS using a PSV cut-off of 200 cm/sec and a renal artery diameter reduction of more than 60%. [10] It has been proposed that a PSV larger than 200 cm/sec could serve as a criterion for diagnosing a 60% decrease in renal artery diameter.[11]

A meta-analysis by Hoffmann U et al. found that PSV was the best predictor of RAS, with a sensitivity of 85% and specificity of 92%. Since hypertension can elevate PSV in all arteries, the renal/aortic ratio (RAR) is recommended over absolute PSV values. Typically, RAR is less than 3.5, but if PSV in the prerenal abdominal aorta is unusually low (less than 40 cm/sec), RAR cannot be used effectively.[12] Studies have shown that RAR is highly sensitive and specific for detecting significant RAS. In one investigation, RAR values of 3.5 or higher were associated with a sensitivity and specificity of 91-92% and 75-95%, respectively. [13] Similarly, Chain S et al. reported that an RAR greater than 3 had a sensitivity of 77%, specificity of 90%, positive predictive value (PPV) of 90%, and negative predictive value (NPV) of 76%.[14] In a more recent study, an RAR greater than 3.5 demonstrated both sensitivity and specificity of 91%. These studies highlight the utility of RAR in diagnosing RAS, particularly in hypertensive patients.[15]

In this study, significant differences were observed in renal dimensions between diabetic and non-diabetic patients. Specifically, in the right kidney, the measurements for longitudinal length (cm) and volume (cm³) exhibited statistically significant differences between the two groups (p<0.05). For the left kidney, significant differences were found in the antero-posterior (cm) and transverse (cm) dimensions (p<0.05). These findings align with the results of Atalabi OM et al., who also noted that renal dimensions were greater in diabetic patients compared to controls. In their study, the mean renal volume in the diabetic group was 120.1 ± 34.4 cm³ on the right and 143.5 ± 37.16 cm³ on the left. In contrast, the control group had mean renal volumes of 110.34 ± 26.2 cm³ on the right and 135.72 ± 33.65 cm³ on the left. The variation in renal volume was statistically significant on the right side (p=0.02), but not on the left (p=0.12).[9]

The present study highlights that both the Resistive Index (RI) and Pulsatility Index (PI) were significantly higher in the diabetic group compared to the non-diabetic group for both the right and left kidneys (p<0.05). These resistance parameters, obtained through duplex Doppler sonography, are frequently used in clinical practice due to their lower coefficients of variation and standard deviations.[16]

Supporting these findings, studies by Sari A et al. and Dawha S et al. reported higher RI values in diabetic patients compared to healthy controls. Sari A et al. observed mean RI values of 0.56 in non-diabetic individuals and 0.69 in diabetics (p<0.001), while Dawha S et al. found mean RI values of 0.63 in non-diabetics and 0.72 in diabetics (p<0.001). [8,17] Platt JF et al. focused on diabetic patients and found RI values of 0.62 ± 0.09 in those without nephropathy, 0.64 ± 0.09 in those with early diabetic nephropathy, and 0.83 ± 0.11 in those with overt diabetic nephropathy. This indicates that while RI is elevated in established nephropathy, it may still fall within the normal range in early nephropathy.[18] The positive association between the duration of diabetes and RI (r=0.28, p=0.004) aligns with the findings of Dawha S et al., who also observed that RI and PI values increased with the duration of diabetes. Long diabetes duration is a significant risk factor for advanced arteriosclerosis, which, along with age and hypertension, may contribute to increased RI. [8]

Additionally, diabetic patients with concurrent hypertension exhibited significantly higher RI and PI readings compared to those without hypertension (p<0.05). This elevation is likely due to the compounded effects of hypertension on atherosclerosis and arterial wall stiffness, which increase vascular resistance.[19] The study by Dawha S et al. also supports that renal Doppler indices rise with the duration of diabetes and that hypertension exacerbates these indices. [8] This finding is clinically relevant as it underscores the increased risk of nephropathy in elderly and long-term diabetic patients, highlighting the importance of managing both diabetes and hypertension to mitigate renal complications.

CONCLUSION

The study reveals that renal Doppler indices, specifically the Resistive Index (RI) and Pulsatility Index (PI), were significantly higher in patients with diabetes compared to non-diabetic individuals. This indicates elevated renal vascular resistance in diabetics. Moreover, patients with both diabetes and coexisting hypertension showed even higher intrarenal vascular resistance. The incidence of Renal Artery Stenosis (RAS) was approximately 10% in diabetic patients, 12.5% in non-diabetic hypertensive patients, and 16% in patients with peripheral vascular diseases, with an overall prevalence of about 11.36%. Although the prevalence of RAS was higher among hypertensive patients in this study, the small sample size suggests that a larger, community-based study is needed to more accurately assess RAS prevalence in both diabetic and non-diabetic populations.

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