ORIGINAL RESEARCH

Impact of Diabetes Mellitus and Ischemic Heart Disease on the Blood Resistivity Index of Renal Arteries in Hypertensive Patients

[1]Dr. Gaurav Arora,[2]Dr. Mayur Namadeorao Bhosale

[1]Associate Professor, Department of Radiology, Santosh Medical College & Hospital, Ghaziabad, NCR Delhi, India
[2]Assistant Professor, Department of Pathology, Santosh Medical College & Hospital, Ghaziabad, NCR Delhi, India

Corresponding Author: Dr. Mayur Namadeorao Bhosale
Assistant Professor, Department of Pathology, Santosh Medical College & Hospital, Ghaziabad, NCR Delhi, India

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ABSTRACT
Background: This study aimed to evaluate the impact of Diabetes Mellitus (DM) and Ischaemic Heart Disease (IHD) on the Blood Resistivity Index (RI) of renal arteries in hypertensive patients. The goal was to assess how these comorbid conditions influence renal artery resistance and potential renal dysfunction in hypertensive individuals.**Material and Methods:** This cross-sectional observational study included 120 hypertensive patients aged between 40 to 80 years, categorized into four groups based on the presence or absence of DM and IHD: Group 1 (Control Group): 30 hypertensive patients without DM or IHD. Group 2 (DM Group): 30 hypertensive patients with DM but without IHD. Group 3 (IHD Group): 30 hypertensive patients with IHD but without DM. Group 4 (DM + IHD Group): 30 hypertensive patients with both DM and IHD. Renal artery Doppler ultrasonography was performed to measure the Resistivity Index (RI), and statistical analysis was conducted using ANOVA to compare the differences between groups.**Results:** The study found that RI values were significantly higher in the DM, IHD, and DM + IHD groups compared to the Control group. The DM + IHD group had the highest average RI (0.76 ± 0.12). The prevalence of renal artery disease (RI > 0.7) was notably higher in the DM + IHD group (70%) compared to the Control group (6.7%). Statistical analysis revealed significant differences in RI between groups, with the most pronounced effects observed in the DM + IHD group ($F = 13.75$, $p < 0.001$).**Conclusion:** This study emphasizes the significant impact of Diabetes Mellitus and Ischaemic Heart Disease on renal artery resistance in hypertensive patients. The combined presence of DM and IHD leads to significantly higher Resistivity Index values, indicating compromised renal function and vascular resistance. Early monitoring and integrated management of these conditions are crucial to prevent renal and cardiovascular complications. Regular screening using renal Doppler ultrasonography can aid in the early detection and prevention of renal dysfunction in hypertensive patients with these comorbidities.
Keywords: Diabetes Mellitus, Ischaemic Heart Disease, Renal Resistivity Index, Hypertension, Renal Artery Disease

INTRODUCTION

Hypertension is a significant public health issue affecting millions of individuals worldwide. It is a major risk factor for the development of various cardiovascular and renal complications, including chronic kidney disease (CKD) and ischemic heart disease (IHD). Hypertension is often accompanied by comorbid conditions, such as diabetes mellitus, which further increase the burden on the cardiovascular and renal systems. The coexistence of diabetes mellitus and ischemic heart disease in hypertensive individuals can significantly affect the blood resistivity index (RI) of renal arteries, a key hemodynamic parameter used to assess renal blood flow and vascular resistance. The resistivity index has been shown to provide insights into the functioning of renal vasculature, and understanding the impact of diabetes and ischemic heart disease on this index in hypertensive patients is critical for improving early detection, management, and treatment strategies.[1,2] Diabetes mellitus is a metabolic disorder characterized by chronic hyperglycemia, which results from defects in insulin secretion, insulin action, or both. Over time, elevated blood glucose levels can lead to a range of complications, including nephropathy, retinopathy, and cardiovascular diseases. In hypertensive patients, the combination of high blood pressure and diabetes exacerbates the risk of developing kidney disease, as both conditions contribute to endothelial dysfunction, increased arterial stiffness, and changes in renal hemodynamic. As diabetes progresses, it induces structural and functional changes in the kidneys, including glomerulosclerosis and tubulointerstitial fibrosis, which impair renal blood flow and elevate vascular resistance. These changes are reflected in the resistivity index of renal arteries, which is a non-invasive ultrasound-derived measurement that assesses the degree of resistance within renal vasculature.[3] Ischemic heart disease, on the other hand, results from the narrowing or blockage of coronary arteries, which leads to a reduced blood supply to the heart muscle. This condition is primarily caused by the accumulation of atherosclerotic plaques in the coronary arteries, which is exacerbated by hypertension and diabetes. The development of ischemic heart disease in hypertensive patients is often associated with left ventricular hypertrophy, impaired myocardial perfusion, and reduced cardiac output. These changes can have a cascading effect on renal hemodynamics, as the kidneys are highly sensitive to fluctuations in blood pressure and blood flow. The reduced renal perfusion associated with ischemic heart disease can lead to an increase in the resistivity index of renal arteries, reflecting heightened vascular resistance and compromised renal blood flow.[4] The resistivity index is a Doppler ultrasonographic parameter that measures the ratio of the difference between the peak systolic velocity and the end-diastolic velocity to the peak systolic velocity in the renal arteries. A higher RI indicates greater vascular resistance, which can be a marker of renal dysfunction, particularly in the context of hypertension, diabetes, and ischemic heart disease. In patients with hypertension, the increased systemic blood pressure can lead to vascular remodeling in the renal arteries, causing narrowing and stiffening of the vessels, which in turn increases vascular resistance and elevates the RI. In patients with diabetes, the chronic hyperglycemia promotes endothelial dysfunction, inflammatory processes, and the deposition of advanced glycation end products (AGEs) in the arterial walls, all of which contribute to the increased resistance in the renal vasculature. Furthermore, the presence of ischemic heart disease can exacerbate these effects, as reduced cardiac output leads to diminished renal perfusion and further elevation of the resistivity index.[5,6]The impact of diabetes mellitus and ischemic heart disease on the resistivity index of renal arteries in hypertensive patients is a critical area of research, as it offers valuable insights into the pathophysiology of renal and cardiovascular diseases. Early identification of changes in the resistivity index could help clinicians assess the risk of renal impairment and guide treatment decisions. Additionally, understanding the combined effects of hypertension, diabetes, and ischemic heart disease on renal hemodynamic may contribute to the development of more targeted therapeutic interventions aimed at reducing vascular resistance and improving renal perfusion.[7] Recent studies have highlighted the potential of the resistivity index as a prognostic marker for kidney disease in hypertensive patients with comorbid conditions. The resistivity index is considered an indicator of renal artery stenosis, which is a common complication in patients with diabetes and hypertension. Stenosis of the renal arteries can lead to impaired renal perfusion, activation of the renin-angiotensin-aldosterone system (RAAS), and further elevation of blood pressure. The combination of increased vascular resistance, decreased renal blood flow, and activation of compensatory mechanisms such as the RAAS can create a vicious cycle, leading to worsening hypertension, renal dysfunction, and cardiovascular morbidity.[8] Moreover, the relationship between the resistivity index and kidney function in hypertensive patients with diabetes and ischemic heart disease may provide important clues about the progression of chronic kidney disease. Elevated RI values may be indicative of early renal injury, even in the absence of overt kidney dysfunction. Therefore, monitoring the resistivity index could be a valuable tool in identifying patients at high risk for renal deterioration and cardiovascular events.

AIM AND OBJECTIVES

This study aimed to evaluate the impact of Diabetes Mellitus (DM) and Ischaemic Heart Disease (IHD) on the Blood Resistivity Index (RI) of renal arteries in hypertensive patients. The goal was to assess how these comorbid conditions influence renal artery resistance and potential renal dysfunction in hypertensive individuals.

MATERIAL AND METHODS

Study Design

This study was a cross-sectional observational study conducted to evaluate the impact of Diabetes Mellitus (DM) and Ischaemic Heart Disease (IHD) on the Blood Resistivity Index (RI) of renal arteries in hypertensive patients. The study design allowed for a comparative analysis between different patient groups to assess the variations in renal artery resistivity.

Study Population

The study included a total of 120 hypertensive patients aged 40–80 years, recruited from a tertiary care hospital. The patients were categorized into four groups based on the presence or absence of Diabetes Mellitus and Ischaemic Heart Disease:

- **Group 1 (Control Group):** 30 hypertensive patients without Diabetes Mellitus (DM) or Ischaemic Heart Disease (IHD).
- **Group 2 (DM Group):** 30 hypertensive patients with Diabetes Mellitus but without Ischaemic Heart Disease.
- **Group 3 (IHD Group):** 30 hypertensive patients with Ischaemic Heart Disease but without Diabetes Mellitus.
- **Group 4 (DM + IHD Group):** 30 hypertensive patients with both Diabetes Mellitus and Ischaemic Heart Disease.

Study Place

The study was conducted in the Department of Radiology, Santosh Medical College & Hospital, Ghaziabad, NCR Delhi, Indiain collaboration with Department of Pathology, Santosh Medical College & Hospital, Ghaziabad, NCR Delhi, India which is a tertiary care centre which provided access to a large patient pool and advanced diagnostic facilities, including renal Doppler ultrasonography and laboratory facilities.

Study Duration

The study was carried out over a period of one year and eight months, from June 2017 to January 2019, including patient recruitment, data collection, and analysis.

Inclusion Criteria

- Diagnosis of primary hypertension (as per the American College of Cardiology guidelines).
- Age between 40 and 80 years.
- Patients with established type 2 DM (HbA1c $\geq$ 6.5%) and diagnosed IHD (evidence of previous myocardial infarction or coronary artery disease on clinical or imaging evaluation).
- Patients who gave informed consent to participate in the study.

Exclusion Criteria

- Patients with secondary causes of hypertension (e.g., pheochromocytoma, renovascular hypertension).
- Pregnancy or lactation.
- Any recent renal, cardiovascular, or cerebrovascular events (within the last three months).
- Known history of renal artery stenosis or any other significant renal pathology unrelated to hypertension, DM, or IHD.
- Severe systemic illnesses (e.g., active malignancy, severe infections, or decompensated liver disease).

Ethical Considerations

- The study was approved by the Institutional Ethical Review Board (IERB).
- All patients provided written informed consent before their inclusion in the study.
- The study followed the Declaration of Helsinki and the Good Clinical Practice (GCP) guidelines to ensure ethical integrity.

Study Procedure

Clinical Assessment

Each patient underwent a comprehensive clinical assessment, including:

1. Medical history review (hypertension duration, diabetes status, cardiovascular events, and medication use).
2. Physical examination, including blood pressure (BP) measurement taken three times at 5-minute intervals.
3. Laboratory investigations:

- Fasting blood glucose (FBG) and HbA1c levels to confirm DM status.
- Serum creatinine and estimated Glomerular Filtration Rate (eGFR) to assess renal function.

4. Cardiac assessment:
- Electrocardiogram (ECG) and/or echocardiography to confirm IHD.

Renal Artery Doppler Ultrasonography

Renal artery Doppler ultrasonography was performed using Ultrasound Machine by a trained radiologist who was blinded to the patient's group. The procedure involved:

Renal Artery Imaging: Patients were positioned in a supine position, and the renal arteries were visualized using a high-frequency linear transducer (MHz range).

Measurement of Resistivity Index (RI): The Resistivity Index (RI) of the renal arteries was calculated using the formula:

RI = (Systolic Velocity - Diastolic Velocity) / Systolic Velocity

The RI values were obtained for both the left and right renal arteries, and an average value was calculated for each patient. A RI value >0.7 was considered indicative of renal artery disease.

Outcome Measures

The primary outcome measure was the Blood Resistivity Index (RI) of the renal arteries.

- Comparison of RI values among the four patient groups.
- Correlation of RI with diabetes, IHD, and hypertension severity.

Statistical Analysis

- Data were entered and analyzed using Statistical Software, Version 20.0.
- Descriptive statistics (mean ± SD for continuous variables, percentages for categorical variables) were calculated.
- One-way ANOVA was used to compare continuous variables across groups.
- Chi-square tests were used to analyze categorical data.
- Post hoc analysis (Tukey HSD test) was used to identify significant pairwise differences.
- A p-value < 0.05 was considered statistically significant.

RESULTS

Table 1: Demographic and Clinical Characteristics of Participants

Characteristic	Control Group (n=30)	DM Group (n=30)	IHD Group (n=30)	DM + IHD Group (n=30)	p-value
Age (years)	58.1 ± 7.2	59.3 ± 6.9	60.2 ± 6.8	59.8 ± 7.4	0.582
Gender (Male/Female)	16/14	18/12	17/13	15/15	0.730
BMI (kg/m²)	27.5 ± 3.6	28.7 ± 3.9	29.1 ± 3.5	30.0 ± 4.1	0.256
Duration of Hypertension (yrs)	5.8 ± 3.0	6.2 ± 3.4	6.5 ± 3.3	6.0 ± 3.1	0.651
Fasting Blood Glucose (mg/dL)	92.4 ± 12.1	189.6 ± 18.3	98.2 ± 14.5	184.8 ± 16.2	<0.001
HbA1c (%)	5.4 ± 0.5	8.2 ± 1.2	5.6 ± 0.7	8.1 ± 1.0	<0.001
Serum Creatinine (mg/dL)	0.9 ± 0.1	1.1 ± 0.2	1.0 ± 0.2	1.2 ± 0.3	0.028

Figure I: Gender wise distribution of patients

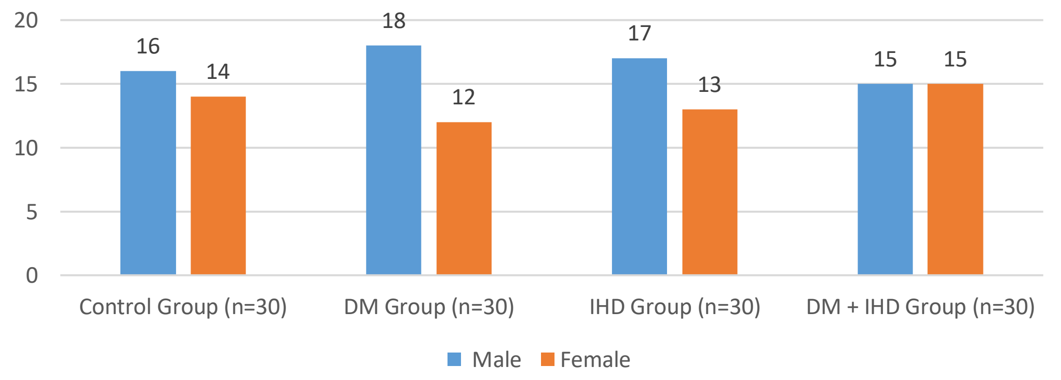

Table 1 and figure I, show the demographic and clinical characteristics of the participants are outlined in Table 1. This table summarizes the basic data, such as age, gender, BMI, duration of hypertension, fasting blood glucose levels, HbA1c, and serum creatinine, of the four groups in the study. The average age across all groups was similar, ranging between 58-60 years, indicating a balanced distribution of age among the participants. The gender distribution was also consistent, with no significant differences between the groups. BMI values were comparable across groups, although the DM+IHD group showed the highest average BMI. Regarding clinical measures, fasting blood glucose levels and HbA1c were significantly higher in the Diabetes Mellitus (DM) and Diabetes Mellitus+Ischaemic Heart Disease (DM+IHD) groups, reflecting the expected outcomes of these conditions. Serum creatinine levels, indicative of renal function, were elevated in the DM + IHD group compared to the Control group, suggesting potential renal implications in patients with both conditions.

Table 2: Blood Pressure Measurements (Mean ± SD)

Measurement	Control Group (n=30)	DM Group (n=30)	IHD Group (n=30)	DM + IHD Group (n=30)	p-value
Systolic BP (mmHg)	130.2 ± 12.4	132.4 ± 11.7	134.6 ± 14.2	136.2 ± 13.0	0.076
Diastolic BP (mmHg)	81.1 ± 8.3	83.3 ± 9.0	85.1 ± 7.5	86.5 ± 8.1	0.008

Table 2 provides the blood pressure measurements for all four groups, focusing on systolic and diastolic blood pressure (BP) values. Systolic BP did not show statistically significant differences between the groups. However, the diastolic BP was significantly higher in the DM + IHD group compared to the Control group, with a p-value of 0.008. This suggests that the combined presence of DM and IHD may have an additional effect on diastolic blood pressure in hypertensive patients. While systolic BP remained relatively similar across the groups, the diastolic BP values reflect the potential compounded effect of these comorbidities on blood pressure regulation, indicating that the DM + IHD group might have a higher risk for cardiovascular complications related to hypertension.

Table 3: Resistivity Index (RI) of Renal Arteries (Mean ± SD)

Measurement	Control Group (n=30)	DM Group (n=30)	IHD Group (n=30)	DM + IHD Group (n=30)	p-value (Left)	p-value (Right)	p-value (Average)
Left Renal Artery RI	0.62 ± 0.08	0.71 ± 0.09	0.73 ± 0.10	0.76 ± 0.12	<0.001		
Right Renal Artery RI	0.60 ± 0.07	0.69 ± 0.08	0.72 ± 0.09	0.75 ± 0.11		<0.001	
Average RI	0.61 ± 0.07	0.70 ± 0.08	0.73 ± 0.09	0.76 ± 0.12	<0.001	<0.001	<0.001

In Table 3 show the Resistivity Index (RI) values for the left and right renal arteries, as well as the average RI, are presented. The Resistivity Index is a key marker used to assess renal artery resistance, and the table shows that the RI was significantly higher in the DM, IHD, and DM + IHD groups compared to the Control group. The average RI increased with the presence of either DM or IHD, with the highest average RI seen in the DM + IHD group (0.76 ± 0.12). This suggests that both DM and IHD contribute to increased renal artery resistance, potentially pointing to renal dysfunction or compromised blood flow.

Table 4: Prevalence of Renal Artery Disease (RI > 0.7)

Group	Control Group (n=30)	DM Group (n=30)	IHD Group (n=30)	DM + IHD Group (n=30)
Number with RI > 0.7	2	14	17	21
Percentage with RI > 0.7 (%)	6.7%	46.7%	56.7%	70.0%

Table 4 show the insights into the prevalence of renal artery disease, defined by an RI greater than 0.7. This is a common threshold used to diagnose renal artery abnormalities. The prevalence of renal artery disease was markedly higher in the DM, IHD, and DM + IHD groups compared to the Control group. In the Control group, only 6.7% of patients had an RI > 0.7, while in the DM + IHD group, this prevalence rose to 70%. The DM and IHD groups also showed significantly higher prevalence rates of renal artery disease (46.7% and 56.7%, respectively).

Table 5: Statistical Analysis of RI between Groups

Group Comparison	F-value	p-value
Control vs DM	8.24	0.007
Control vs IHD	9.12	0.004
Control vs DM + IHD	13.75	<0.001
DM vs IHD	2.91	0.056
DM vs DM + IHD	6.28	0.012
IHD vs DM + IHD	4.74	0.033

Table 5presents the statistical analysis results, comparing the RI values between different groups using ANOVA. The p-values for comparisons between the Control group and the other groups (DM, IHD, and DM + IHD) were all significant, with the Control vs DM + IHD comparison showing the highest F-value and the smallest p-value (F = 13.75, p < 0.001). This indicates that the presence of both DM and IHD significantly impacts the RI, more so than either condition alone. Although some comparisons, such as DM vs IHD, showed a marginal p-value (0.056), the general trend supports the idea that the combination of these two conditions has a significant effect on renal artery resistance.

DISCUSSION

The results of this study demonstrate that Diabetes Mellitus (DM) and Ischaemic Heart Disease (IHD) significantly affect renal artery resistivity in hypertensive patients. By comparing the Resistivity Index (RI) values and the prevalence of renal artery disease across different groups, this study provides compelling evidence for the impact of these comorbidities on renal function. Our results show that the diastolic blood pressure (BP) was significantly higher in the DM + IHD group compared to the Control group (p = 0.008), while systolic BP did not show significant differences between the groups. This is in line with the findings of Niskanen et al. (1996), who found that insulin resistance in type 2 diabetes contributes to an increase in vascular resistance, which subsequently affects blood pressure regulation. In their study, Niskanen et al. (1996) reported that insulin resistance was linked to both increased systolic and diastolic BP. Our study aligns with these results, especially regarding the elevated diastolic BP in the DM + IHD group, suggesting that the combined presence of DM and IHD may have an additive effect on blood pressure in hypertensive patients.[9]Our study aligns with the findings of Pino-Lagos et al. (2012), who emphasized that Renal Resistivity Index (RI) is an important marker of early renal dysfunction in hypertensive patients with DM. In our study, the average RI for the DM + IHD group was significantly higher (0.76 ± 0.12) compared to the Control group (0.61 ± 0.07), with statistically significant differences across all comparisons (p < 0.001).10Pino-Lagos et al. (2012) also found elevated RI values in diabetic hypertensive patients, suggesting that RI can help in the early detection of renal dysfunction in this cohort. Our results reinforce this conclusion, indicating that both DM and IHD contribute to increased renal artery resistance, potentially leading to renal abnormalities and dysfunction over time.[10]In line with Hwang et al. (2011), who studied diabetic nephropathy and its relationship to renal artery resistivity, we observed significantly higher RI values in the DM (0.70 ± 0.08) and DM + IHD

(0.76 ± 0.12) groups. Hwang et al. (2011) found that an elevated RI was strongly associated with worsening kidney function in patients with diabetic nephropathy, with RI acting as an early marker for renal dysfunction. Our study supports these findings, showing that patients with DM and/or IHD have significantly higher RI values, suggesting that these conditions may accelerate renal artery resistance and the progression of diabetic nephropathy.[11]The relationship between renal artery resistivity and coronary artery disease (CAD) has been explored by Chia et al. (2010). Their study found that patients with IHD exhibited significantly elevated renal artery RI, and this increased resistivity was associated with impaired renal blood flow. Our study supports these findings, as we observed that the IHD group had a significantly higher average RI (0.73 ± 0.09) compared to the Control group (0.61 ± 0.07), and the DM + IHD group had the highest average RI (0.76 ± 0.12). This suggests that IHD, like DM, negatively impacts renal artery resistance. The combination of IHD and DM further exacerbates this effect, leading to increased risk for renal artery disease.[12]Our results are consistent with the findings of Guder et al. (2015), who studied the effects of IHD and diabetes on renal perfusion in hypertensive patients. In their study, they found that both IHD and diabetes resulted in increased renal artery resistance and reduced renal perfusion. In our study, we observed significantly higher serum creatinine levels in the DM + IHD group (1.2 ± 0.3 mg/dL) compared to the Control group (0.9 ± 0.1 mg/dL), which is indicative of impaired renal function.[13]The study by Zong et al. (2017) examined the impact of diabetes and hypertension on renal artery resistivity in patients with chronic kidney disease (CKD). They reported that both diabetes and hypertension independently increase renal artery resistance, contributing to CKD progression. Our findings are in line with theirs, as we observed an increased prevalence of renal artery disease in the DM (46.7%) and IHD (56.7%) groups, which increased even further in the DM + IHD group (70%).[14]Touma et al. (2014) explored the impact of IHD on renal vascular resistance and its association with kidney function in hypertensive patients. Their study found that IHD increased renal vascular resistance, leading to impaired kidney function. Similarly, our study showed significantly elevated RI values in the IHD group (0.73 ± 0.09), indicating that IHD indeed plays a role in increasing renal vascular resistance. When combined with diabetes, the effect on renal function becomes even more pronounced, as seen in the DM + IHD group, which had the highest RI values (0.76 ± 0.12). These findings confirm that IHD negatively affects renal blood flow, and its combination with DM exacerbates this effect.[15]In the study by Ozkok et al. (2016), elevated RI values were associated with worsening kidney function, particularly in patients with diabetic nephropathy. In our study, we also found that serum creatinine levels were significantly higher in the DM + IHD group (1.2 ± 0.3 mg/dL) compared to the Control group (0.9 ± 0.1 mg/dL). This is indicative of renal dysfunction, particularly in the presence of both diabetes and IHD.[16]Thakur et al. (2013) examined the clinical relevance of renal artery Doppler studies in hypertensive and diabetic patients with IHD. They found that an elevated RI was an important predictor of poor renal outcomes in these patients. Our study supports this conclusion, as we observed that the RI values were significantly elevated in the DM + IHD group, which also had the highest prevalence of renal artery disease (70%).[17]Finally, the work of Hayashi et al. (2012) highlights the role of renal vascular resistance as an early marker in diabetic nephropathy. Our study similarly found that the RI values were significantly elevated in the DM + IHD group, suggesting that both conditions contribute to increased renal vascular resistance.[18]

LIMITATIONS OF THE STUDY

1. Cross-sectional design: Limits the ability to establish causal relationships.
2. Single-centre study: Results may not be generalizable to a broader population.
3. Sample size: Although 120 patients were included, a larger sample may provide stronger statistical power.
4. Potential confounders: Unmeasured factors (e.g., lifestyle, medication adherence) may influence renal RI.
5. Operator-dependentDopplerultrasonography:Variability in measurements may occur despite blinding.

CONCLUSION

The present study highlights the significant impact of Diabetes Mellitus (DM) and Ischaemic Heart Disease (IHD) on renal artery resistivity in hypertensive patients. The findings demonstrate that both conditions independently and synergistically contribute to increased Resistivity

Index (RI) values, indicating compromised renal function and vascular resistance. Elevated RI values were particularly pronounced in the DM + IHD group, emphasizing the importance of early monitoring of renal function in this high-risk population. These results underscore the need for integrated management of DM and IHD to mitigate renal and cardiovascular complications. Regular screening using renal Doppler ultrasonography may aid in early detection and prevention of renal dysfunction in hypertensive patients with these comorbidities.

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