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Original Research Article

RENAL RESISTIVE INDEX VARIATION IN HYPERTENSIVE PATIENTS WITH DIABETES MELLITUS AND ISCHAEMIC HEART DISEASE: A COMPREHENSIVE CROSS-SECTIONAL ANALYSIS

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Abstract

Background: Hypertension, a prevalent cardiovascular risk, affects 1.13 billion globally, projected to rise to 1.56 billion by 2025. Concurrently, diabetes impacts 463 million, and ischaemic heart disease causes 16.2% of global deaths. The interplay between hypertension, diabetes mellitus, and ischaemic heart disease remains underexplored. Blood Resistivity Index (RI) in renal arteries, crucial for understanding hypertensive complications, is influenced by diabetes-induced microvascular damage and ischaemic heart disease complexities. This study aims to compare RI in hypertensive patients with diabetes and ischaemic heart disease, providing insights for refined risk stratification and targeted interventions.

Methods: This 2-year cross-sectional study in North India involved 147 hypertensive patients (January 2020 to January 2022) from a cardiology clinic of the medical institute. Ethical approval and informed consent were obtained. Excluding renal artery stenosis, severe chronic kidney disease, and contrast allergies, participants were categorized into controlled hypertension (n=76), hypertension with diabetes (n=31), hypertension with ischemic heart disease (n=27), and both conditions (n=13). Clinical data, including demographics and lab results, were collected. Imaging included non-contrast and Doppler ultrasound, contrast-enhanced MRA. OsiriX MD software calculated the Blood Resistivity Index (RI), Statistical analysis used SPSS Version 20.0.

Results: Baseline characteristics of 147 hypertensive participants revealed a mean age of 55.62 ± 6.81 years, with 59.9% males. Mean duration of hypertension was 6.48 ± 4.27 years. Smoking prevalence was 21.1%, and antihypertensive treatments varied. Laboratory results exhibited a diverse profile, including mean hemoglobin of 12.32 ± 1.41 g/dL, creatinine 8.11 ± 1.29 mg/L, and lipid levels. Renal parameters indicated mean right kidney length of 8.82 ± 1.24 cm, left kidney length 9.36 ± 0.87 cm, and Renal Resistive Index (RI) of 0.63 ± 0.08. Correlation analyses demonstrated associations between RI and various clinical and laboratory variables. ANOVA revealed significant differences in RI among groups based on comorbidities ($p < 0.0001$), with Controlled Hypertension group exhibiting a lower RI (0.58 ± 0.09).

Conclusion: In conclusion, our study elucidates the impact of DM and IHD on the Blood Resistivity Index of renal arteries in hypertensive patients, shedding light on the intricate relationships between systemic comorbidities and renal vascular health.

Keywords: Hypertension, Diabetes, Coronary disease, Resistivity Index, Renal artery.

Introduction

Hypertension, a prevalent and multifactorial cardiovascular condition, is a major risk factor for various complications, including renal dysfunction. Recent epidemiological data reveal a substantial prevalence of hypertension globally, affecting approximately 1.13 billion people, with projections estimating a rise to 1.56 billion by 2025 [1]. Hypertensive individuals often exhibit a higher likelihood of concurrent conditions, with diabetes mellitus affecting around 463 million individuals worldwide [2] and ischaemic heart disease being a leading cause of mortality, responsible for 16.2% of global deaths [3]. The intricate interplay between hypertension and coexisting comorbidities, such as diabetes mellitus (DM) and ischaemic heart disease (IHD), has garnered increasing attention within the scientific community [4,5]. Among the numerous factors influencing the progression of hypertensive complications, the impedance to blood flow in renal arteries, measured by the Blood Resistivity Index (RI), emerges as a critical parameter [5,6].

Diabetes mellitus, characterized by chronic hyperglycemia, is recognized for its detrimental effects on various organ systems, particularly the vasculature. The kidneys, being highly vascularized organs, are particularly susceptible to the microvascular damage induced by prolonged hyperglycemia [5,6]. Additionally, the coexistence of IHD further complicates the pathophysiological landscape, as it introduces a cascade of systemic and vascular changes that may synergistically impact renal hemodynamics [7,8].

Ischaemic heart disease, a consequence of impaired blood supply to the heart muscle, is often intertwined with hypertension and diabetes mellitus, forming a triad of interconnected cardiovascular disorders. The shared pathophysiological pathways, including endothelial dysfunction, inflammation, and oxidative stress, create a complex milieu that extends its influence beyond the coronary arteries [8,9,10]. Renal arteries, being integral components of the systemic circulation, are likely to bear the brunt of these systemic alterations, potentially reflected in changes to the RI [11,12].

Despite the established individual contributions of DM, IHD, and hypertension to vascular dysfunction, the specific interactions and cumulative effects on the renal vasculature remain insufficiently understood. So, the present study was conducted with an aim to compare blood RI measurements in renal arteries of hypertensive patients with diabetes mellitus (DM) and ischaemic heart disease (IHD). The findings may provide valuable insights for refining risk stratification, developing targeted therapeutic interventions, and ultimately improving clinical outcomes for hypertensive patients with concurrent DM and IHD.

Materials and Methods

Study Design and Participants: This cross-sectional study was conducted in the department of Radiology of a tertiary care center, North India, among hypertensive patients, attending the cardiology outpatient clinic over a period of 2 years between January 2020 to January 2022. Informed consent was obtained from all participants, and ethical approval was granted by the Institutional Review Board.

Sample Size and Sampling technique: During defined period of study, a total of 147 patients (aged 18 years of more) clinically diagnosed with essential

hypertension, having complete medical records were included using convenient sampling technique. Patients with known history of renal artery stenosis, Severe chronic kidney disease (eGFR < 30 mL/min/1.73m²), and Known allergy to contrast agents, were excluded from the study. The 147 participants were categorised into four groups: patients with controlled hypertension (Group 1, n=76), hypertensive patients with DM (Group 2, n=31), hypertensive patients with IHD (Group 3, n=27) and hypertensive patients with both DM and IHD (Group 4, n=13). Controlled hypertension was defined as patients with systolic blood pressure (SBP) less than 140 mm Hg and diastolic blood pressure (DBP) less than 90 mm Hg, were successfully managed and maintained within a targeted range through medical interventions, lifestyle modifications, or a combination of both.

Clinical Data Collection: Demographic information, medical history, and medication records were obtained through interviews and electronic health records. Blood pressure measurements, fasting glucose levels, lipid profiles, and renal function markers were recorded for each participant.

Imaging Protocol and Blood Resistivity Index (BRI) Measurement: The imaging protocol utilized in this study involved a multi-step approach. Initial non-contrast-enhanced ultrasound provided baseline anatomical information, and Doppler ultrasound (Sonoscape S2 Ultrasound System by Sonoscape, Shenzhen, China) was employed to assess blood flow velocities in the main renal arteries. Subsequently, contrast-enhanced magnetic resonance angiography (MRA) using a 1.5 Tesla MRI scanner (Magnetom Avanto by Siemens Healthineers, Erlangen, Germany) and gadolinium-based contrast agent (Gadovist by Bayer, Leverkusen, Germany) enhanced vascular visibility, capturing high-resolution three-dimensional images of the main renal arteries. Image reconstruction and analysis were conducted using OsiriX MD software (Pixmeo SARL, Geneva, Switzerland) to identify a region of interest within the main renal artery. The Blood Resistivity Index (RI) was then automatically calculated based on the velocity and impedance of blood flow within this selected region. To ensure reliability, RI measurements were independently verified by two experienced radiologists, blinded to clinical information, with discrepancies resolved through consensus.

Statistical Analysis: Data were analyzed using Statistical Package for the Social Sciences, SPSS, Version 20.0. Descriptive statistics were calculated for demographic and clinical variables. Analysis of variance (ANOVA) and post-hoc tests were employed to compare RI values among the three groups. Pearson's Correlation analyses were conducted to assess associations between BRI and clinical parameters. A p-value < 0.05 was considered statistically significant.

Ethical Considerations: This study adhered to the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants, and steps were taken to ensure patient confidentiality and data protection throughout the research process.

Results

The mean age of the participants was 55.62 ± 6.81 years. The distribution by gender revealed that 88 (59.9%) were male, while 59 (40.1%) were female. The mean duration of hypertension was 6.48 ± 4.27 years. Regarding smoking status, 31 participants (21.1%) were current smokers, while the majority, 116 (78.9%), were non-smokers. The mean Body Mass Index (BMI) was 32.67 ± 6.15 kg/m2. Blood pressure measurements showed a mean systolic blood pressure (SBP) of 157.00 ± 23.00 mm Hg and a mean diastolic blood pressure (DBP) of 95.00 ± 9.00 mm Hg. In terms of antihypertensive treatment, 78

participants (53.1%) were on ACE inhibitors or angiotensin II receptor blockers (ARBs), 52 (35.4%) were prescribed beta blockers, 31 (21.1%) were on thiazides, and 43 (29.3%) were taking calcium channel blockers (Table 1).

Table 1: Baseline characteristics of the study participants (N=147).

Variables	Frequency	%
Mean age (in years)	55.62±6.81	
Gender		
Male	88	59.9
Female	59	40.1
Mean Duration of hypertension (in years)	6.48±4.27	
Current Smoker		
Yes	31	21.1
No	116	78.9
Mean BMI (in kg/m^2)	32.67±6.15	
Mean SBP (mm Hg)	157.00±23.00	
Mean DBP (mm Hg)	95.00±9.00	
Antihypertensive treatment		
ACE inhibitors/AERB	78	53.1
Beta blockers	52	35.4
Thiazides	31	21.1
Calcium channel blocker	43	29.3

The mean hemoglobin (Hb) level was 12.32 ± 1.41 g/dL, while creatinine levels were observed to be 8.11 ± 1.29 mg/L. The estimated glomerular filtration rate (eGFR) was calculated to be 86.28 ± 16.72 mL/min/1.73 m2, reflecting the renal filtration capacity. Uric acid levels were measured at 4.81 ± 1.21 mg/dL, and blood urea nitrogen (BUN) levels were 15.61 ± 2.87 mg/dL. Additionally, the mean random blood sugar (RBS) level was 128.12 ± 32.54 mg/dL, with HbA1c percentage at 6.21 ± 0.53, providing insights into long-term glycemic control. Lipid profiles indicated an average triglyceride level of 143.88 ± 45.39 mg/dL, high-density lipoprotein (HDL) cholesterol at 44.07 ± 11.62 mg/dL, and low-density lipoprotein (LDL) cholesterol at 122.73 ± 31.29 mg/dL (Table 2).

Table 2: Laboratory parameters of the study participants (N=147).

Parameters	Mean ± SD
Hb (g/dL)	12.32±1.41
Creatinine (mg/L)	8.11±1.29
eGFR (mL/min/1.73 m^2)	86.28±16.72
Uric acid (mg/dL)	4.81±1.21
BUN (mg/dL)	15.61±2.87
RBS (mg/dL)	128.12±32.54
HbA1c (%)	6.21±0.53
Triglycerides (mg/dL)	143.88±45.39
HDL (mg/dL)	44.07±11.62
LDL (mg/dL)	122.73±31.29

Table 3. presents key morphological and hemodynamic parameters related to renal anatomy and blood flow. The mean length of the right kidney was measured at 8.82 ± 1.24 cm, while

the left kidney exhibited a mean length of 9.36 ± 0.87 cm. The Renal Resistive Index (RI), a crucial hemodynamic parameter reflecting vascular resistance, was calculated to have a mean value of 0.63 ± 0.08.

Table 3: Radiological parameters of the study participants (N=147).

Parameters	Mean ± SD
Right kidney length (cm)	8.82±1.24
Left kidney length (cm)	9.36±0.87
Mean RI	0.63±0.08

Table 4. presents the correlation analysis of the Renal Resistive Index (RI) with various clinical and laboratory variables in the study population. Significant correlations were observed, revealing valuable insights into the interplay between renal hemodynamics and systemic factors. Notably, age exhibited a positive correlation with RI (Pearson coefficient, r = 0.134, p = 0.034), as did the duration of hypertension (r = 0.275, p = 0.002), systolic blood pressure (SBP) (r = 0.367, p < 0.0001), and uric acid levels (r = 0.311, p < 0.0001). Conversely, negative correlations were identified between RI and left kidney length (r = -0.192, p = 0.002), right kidney length (r = -0.201, p = 0.001), estimated glomerular filtration rate (eGFR) (r = -0.138, p = 0.031), high-density lipoprotein (HDL) cholesterol (r = -0.322, p < 0.0001), and triglyceride levels (r = -0.101, p = 0.042).

Table 4: Correlation analysis of the RI with clinical and laboratory variables.

Variables	Pearson coefficient (r value)	P value
Mean age (in years)	0.134	0.034
Mean Duration of hypertension (in years)	0.275	0.002
BMI (in kg/m^2)	0.012	0.992
SBP (mm Hg)	0.367	<0.0001
DBP (mm Hg)	0.249	0.001
Right kidney length (cm)	-0.201	0.001
Left kindey length (cm)	-0.192	0.002
Hb (g/dL)	0.022	0.903
Creatinine (mg/L)	0.219	0.01
eGFR (mL/min/1.73 m^2)	-0.138	0.031
Uric acid (mg/dL)	0.311	<0.0001
BUN (mg/dL)	0.173	0.021
RBS (mg/dL)	0.299	<0.0001
HbA1c (%)	0.132	0.03
Triglycerides (mg/dL)	0.101	0.042
HDL (mg/dL)	-0.322	<0.0001
LDL (mg/dL)	0.206	0.011

Table 5 presents the results of the analysis of variance (ANOVA) assessing the differences in Renal Resistive Index (RI) among various groups of hypertensive patients. The study population was stratified into four groups based on comorbidities: Controlled Hypertension (Controlled HT), Diabetes Mellitus (DM), Ischaemic Heart Disease (IHD), and a group with both DM and IHD. The mean RI values for each group are provided, along with the corresponding p-values indicating the statistical significance of the observed differences. Notably, the

Controlled HT group exhibited a significantly lower mean RI of 0.58 ± 0.09 compared to the other groups ($p < 0.0001$), indicating more favorable renal hemodynamics in this subgroup.

In contrast, the DM group, IHD group, and the DM and IHD group showed higher mean RI values of 0.72 ± 0.03, 0.71 ± 0.02, and 0.73 ± 0.04, respectively.

Table 5: ANOVA analysis for difference in RI among various groups of hypertensive patients

Group	RI	P value
Controlled HT (n=76)	0.58±0.09	<0.0001
DM (n=31)	0.72±0.03	
IHD (n=27)	0.71±0.02	
DM and IHD (n=13)	0.73±0.04	

Discussion

Hypertension, often coexisting with diabetes mellitus (DM) and ischaemic heart disease (IHD), is a complex cardiovascular condition associated with a spectrum of renal vascular changes [13]. In this study, we studied the effect of DM and IHD on the Blood Resistivity Index (BRI) in hypertensive patients, providing insights into the intricate relationships between these comorbidities and renal arterial health. The comprehensive analysis of demographic, clinical, and imaging data revealed several noteworthy findings.

The demographic characteristics of our study population reflected a diverse group of hypertensive individuals, with a mean age of 55.62 years. The distribution of gender, duration of hypertension, and smoking status demonstrated a representative sample.

Recent studies by Ponte et al., and Ismail et al., have shown a correlation between the Renal Resistive Index (RI) and factors such as age and gender [14,15]. Toledo et al., noted that advanced age and female gender are linked with renal RI values equal to or exceeding 0.70 [16]. The biochemical parameters assessed in our study provided a comprehensive overview of the metabolic and renal status of the participants. Elevated levels of creatinine, uric acid, and triglycerides were observed in the presence of DM and IHD, reflecting the multifaceted impact of these comorbidities on renal and metabolic function [17,18]. The positive correlation between the duration of hypertension and BRI emphasizes the cumulative impact of sustained elevated blood pressure on renal hemodynamics [19]. Notably, the significant correlation between BRI and uric acid levels is consistent with emerging evidence suggesting a link between hyperuricemia and renal vascular dysfunction in hypertensive individuals [20].

The negative correlations between BRI and kidney length, estimated glomerular filtration rate (eGFR), high-density lipoprotein (HDL) cholesterol, and triglyceride levels highlight the complex interplay between renal morphology, function, and lipid metabolism in hypertensive patients [21,22]. These associations underscore the multifaceted nature of factors influencing renal blood resistivity. A study by Nosadini et al., indicated that an RI exceeding 0.8 signifies a significant deterioration in the Glomerular Filtration Rate (GFR) [23].

The ANOVA analysis demonstrated that hypertensive patients with controlled blood pressure exhibited a significantly lower BRI compared to those with DM, IHD, or both. The observed elevations in BRI among patients with DM, IHD, or both underscore the need for targeted interventions to address the unique challenges posed by these comorbidities in

the context of hypertension. Andrikou et al., documented a noteworthy increase in renal RI among individuals with essential hypertension [24]. Correspondingly, Komuro et al., highlighted a significant elevation of renal RI in those with cardiovascular disease (CVD) [25]. In the context of Type 2 diabetes, Mancini et al., reported a substantial increase in renal RI (RI=0.70±0.05) [26]. Studies by Maksoud et al., Shirin et al., and Assenyi et al., have illustrated the elevation of renal RI attributed to the impact of diabetes mellitus, leading to altered vascular resistance in the kidneys [27,28,29]. Likewise, Hamano et al., delved into the association of renal RI in type 2 diabetic patients [30], revealing a significantly higher RI in diabetic patients compared to their non-diabetic counterparts.

Limitations

Limitations of our study include its cross-sectional design, which precludes the establishment of causal relationships, and the relatively modest sample size. Longitudinal studies with larger cohorts are warranted to validate our findings and explore temporal relationships between variables. Moreover, additional investigations incorporating advanced imaging modalities and biomarkers could provide further insights into the mechanistic pathways underlying renal vascular alterations in hypertensive patients with DM and IHD.

Conclusion

In conclusion, our study elucidates the impact of DM and IHD on the Blood Resistivity Index of renal arteries in hypertensive patients, shedding light on the intricate relationships between systemic comorbidities and renal vascular health. The observed alterations in renal resistivity highlight the need for a holistic approach to cardiovascular risk management, considering the cumulative effects of multiple comorbidities. Future research should delve deeper into the underlying mechanisms driving these changes and explore targeted interventions to mitigate adverse renal vascular outcomes in hypertensive individuals with DM and IHD.

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