

A comparative ultrasonographic evaluation of intrarenal artery resistive index among hypertensive and normotensive adults in north-western Nigeria

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Abstract

Introduction: Hypertension is a sustained systolic blood pressure equal to or above 140 mmHg or diastolic blood pressure equal to or above 90 mmHg. The kidneys play a central role in the control of high blood pressure through the renin–angiotensin system. Thus, renovascular changes of myointimal hyperplasia in the intrarenal arteries may cause an increase in renal arterial impedance and eventually irreversible hypertensive nephropathy.

The early detection of these renovascular changes using ultrasonography can provide opportunity for immediate intervention toward preventing or at least delaying the irreversible hypertensive nephropathy.

Aims and Objectives: The objective of this study is to determine and compare intra-renal resistive index (RRI) in normotensive and hypertensive adults within the age range of 35–70 years at Aminu Kano Teaching Hospital, Kano, Nigeria.

Materials and Methods: A prospective case–control study of intra-RRI using ultrasound in 150 hypertensive patients and 150 normotensive controls. The mean RRI of the interlobar arteries of both kidneys was measured and recorded. The data were analyzed with the aid of computer-based SPSS 16.0 software for windows.

Results: The ages of the study participants ranged between 35 and 70 years. The age difference was not statistically significant ($P = 0.88$). The mean interlobar artery resistive index (RI) values were 0.59 ± 0.04 and 0.59 ± 0.03 on the right and left sides, respectively, in normotensive controls while those of hypertensive patients were 0.73 ± 0.03 and 0.73 ± 0.03 for the mean interlobar artery RI values on the right and left sides, respectively, and both were statistically significant.

Conclusion: The intra-RRIs were lower in normotensive participants when compared with the hypertensive patients which were statistically significant. These showed that hypertension has significant effects on the kidneys, and with early detection and intervention, irreversible renal damage may be prevented.

Keywords: Doppler, hypertension, intrarenal artery

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INTRODUCTION

Guidelines for diagnosis and when to commence treatment for hypertension, a sustained elevation of systolic blood

pressure (SBP) of ≥ 140 mmHg or diastolic blood pressure (DBP) of ≥ 90 mmHg, have been extensively reviewed.^[1]

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Although the kidneys play a central role in the control of high blood pressure, hypertension is a significant risk factor for renal injury and end-stage irreversible renal damage by inducing myointimal hyperplasia of the intrarenal arteries.^[2] The early detection of its effects on the kidneys such as the renovascular changes using ultrasonography may prevent or at least delay irreversible renal damage through early treatment intervention.

The prevalence of hypertension in the United Kingdom has been reported to increase significantly from 35.8% to 41.4% among Black people and from 24.3% to 28.1% among White people over a 3-year period and remains significantly higher among Black people.^[3] Most studies in the United Kingdom and the United States reported not only a higher prevalence but also a higher awareness of hypertension in black people than in white people.^[3] The black population who are hypertensive have higher morbidity and mortality risks compared with their white counterparts.^[4] Africans have a higher prevalence and incidence of hypertension than Caucasians.^[5] People of African descent tend to develop hypertension at an earlier age and have lower renin activity; target organ damage also differs in black people from that in white people.^[6] Black men are at greater risk than white men for developing end-stage renal disease at every level of blood pressure, due to genetic variation in the renal epithelial sodium channels among the black people of African origin.^[6,7]

The overall prevalence of hypertension in Nigeria (2013) was 22.7%.^[8] It is more prevalent in the urban cities of Nigeria with a rate of 32.7% than in the rural areas where a prevalence rate of 12.9% was noted.^[8] This may be attributable to the change in lifestyle due to modernization which has swept across most urban cities in Nigeria. The last published report of a national survey in 1997 by Akinkugbe under the auspices of the Federal Ministry of Health showed that Kano has the highest prevalence of essential hypertension in Nigeria,^[9] making it important to study the effect, it has on the kidneys.

There are several imaging methods used to evaluate hypertensive nephropathy, but grayscale sonography is often used as the initial imaging procedure.^[10] It is readily available, affordable, and noninvasive. Doppler ultrasound is an advanced form of ultrasound that can evaluate blood flow. It can be displayed in variable formats such as color and pulsed wave Doppler.^[11] Power Doppler is also a special type of color Doppler, which is more sensitive in detecting blood flow through the vessel than the standard color Doppler protocol. However, it does not display flow direction unlike the standard color Doppler. Doppler ultrasonography of the renal vessels has been found

useful in the diagnosis of renal artery stenosis in the face of equivocal angiogram.^[11] It is also useful in the differentiating real renal tumors from pseudotumors such as a hypertrophied column of Bertin.^[11] The analysis of intrarenal arterial Doppler flow profile provides a noninvasive method of investigating renal medical diseases including hypertensive nephropathy.^[12] Color and power Doppler ultrasound easily demonstrates the general increase or decrease of renal parenchymal blood flow, and hemodynamic changes of the renal blood flow can be assessed by Doppler spectral analysis.^[13] The intrarenal artery resistive index (RI) is one of the sonographic parameters used to assess hypertension-induced renovascular changes^[13] because it measures the resistance of arterial blood flow to the organs, making it more preferable in this study. The early change in hypertensive nephropathy is an increase in renal arterial impedance.^[12]

It is, therefore, important to detect this early renovascular change through routine surveillance since intervention at this stage may prevent or at least delay the renal damage. This study was aimed to determine the values of renal RI (RRI) in detecting the early hypertensive nephropathy.

MATERIALS AND METHODS

This was a prospective case-control study carried out over 12 months at the Radiology Department of Aminu Kano Teaching Hospital Kano in North-western Nigeria. Ethical approval for the study was obtained from the institutional ethical review committee.

Methodology

Informed consent of the participants was obtained. To ensure adequate compliance with inclusion and exclusion criteria, brief clinical history and physical examination (such as blood pressure and pulse rate) of the participants were taken. Height and weight were measured and body mass index (BMI) was calculated. All the hypertensive patients' hospital case files were crosschecked to ascertain their renal biochemistry status. Each of the participants was psychologically reassured and the procedure comprehensively explained to them.

Participants were scanned using a real-time/color-coded scanner (Mindray DC-6 Shenzhen, China) coupled with 3.5 MHz transducer. The participant lay down supine on the examining couch. Scanning was done in supine and then prone positions after the application of adequate amount of coupling gel on the area of interest to permit sound conduction, with subsequent placement of the transducer. A global examination of the kidneys was performed [Figure 1].

Color mapping was performed to image blood flow in the kidneys [Figure 2]. First of all, the main renal artery was assessed for exclusion of atherosclerosis before proceeding to the area of interest (interlobar arteries). Three Doppler waveforms were obtained from each kidney by sampling the interlobar artery (along the border of medullary pyramids) of the superior, middle, and inferior portions of the kidney, and average value calculated manually since intraobserver variability is a potential limitation in the measurement of RRI. This variability was reduced to the minimum by taking the average of three measurements.

The flow velocity waveform was obtained at an optimal insonating angle of 20° so that the early systolic peak could be visualized. The Doppler tracing was also obtained and recorded by placing a gate of 2–4 mm (adjusted when necessary) over the interlobar artery, and low filter was utilized and selecting smallest scale that displayed the flow without aliasing. The height of the Doppler waveforms was maximized to facilitate measurement. A trend of 3–5 similar sequential Doppler waveforms were obtained during suspended respiration. Then, the measurement of RI was determined using the internal callipers and analytical software of the sonography unit. RIs from these five waveforms were averaged to arrive at mean RI values for each kidney [Figure 3]. This was obtained by adding the RI from upper, mid, and lower pole intrarenal arteries and dividing by 3. The resistance parameter, RI, could also be manually calculated as follows:

$$RI = \frac{PSV - EDV}{PSV} [14]$$

where RI = Resistive index; PSV = Peak systolic flow velocity; EDV = End-diastolic flow velocity.

The generated data were analyzed with the statistical package for social sciences (SPSS version 16 Inc. Chicago, Illinois) software for windows. In addition to descriptive statistics,

possible associations such as the age, height, weight, BMI, SBP, and DBP were examined with analysis of variance, Chi-square test, and correlation coefficient. All values in the text and tables are expressed as means ($\pm$ standard deviation [SD]). Pearson's correlation was used to analyze the association between RRI, age, SBP, DBP, and duration of hypertension.

Multivariate analysis was used to identify predictive factors of RRI using age, BMI, Systolic blood pressure (SBP), and DBP as the independent variables. Findings were presented numerically and in tabular form. $P < 0.05$ was considered to be statistically significant at 95% confidence interval.

RESULTS

A total of 300 participants (150 hypertensives and 150 normotensives) that fulfilled the inclusion criteria were recruited in this study [Table 1]. The age range of the participants (hypertensive and normotensive) in this study was between 35 and 70 years. The control group (normotensive) was made up of 75 males and 75 females. The hypertensive group also consisted of 75 males and 75 females. This sample population was selected through randomization method.

Majority of the hypertensive patients (20.7%) in this study were within the age of 61–65 years while the majority of the normotensive participants (20%) were within 51–55 years' age group as illustrated in Table 1 and Figure 4. In both the hypertensive and normotensive cases, only 7.3% of the participants were within the lower limit of 35–40 years as also shown in [Figure 4]. The mean ($\pm$ SD) ages of both hypertensive and normotensive groups were 56.51 ± 8.71 years and 56.17 ± 7.86 years, respectively. This age difference was not statistically significant ($P = 0.88$) [Table 1].

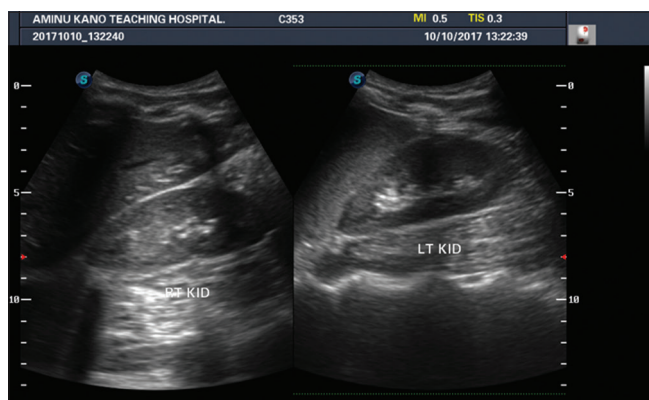


Figure 1: Normal renal sonograms

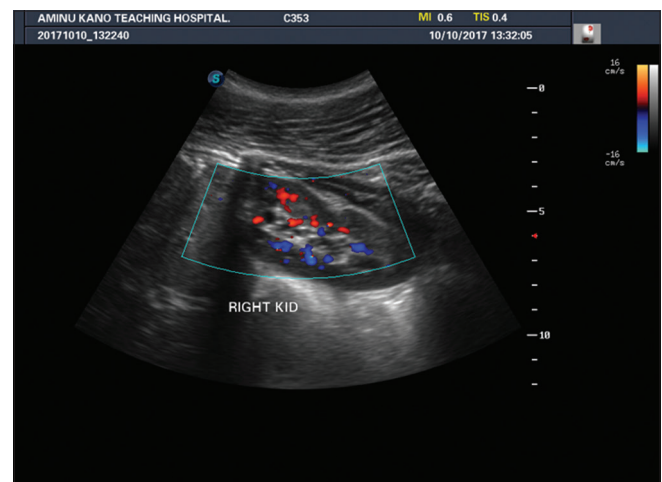


Figure 2: Color Doppler of the intrarenal arteries

Table 1: Age distribution of participants in the study groups (n=300)

Parameters	Frequency (%)		Mean±SD		P
	Hypertensive (n=150)	Normotensive (n=150)	Hypertensive (n=150)	Normotensive (n=150)	
Age (years)					
35-40	11 (7.3)	11 (7.3)	56.51±8.71	56.17±7.86	0.88
41-45	16 (10.7)	13 (8.7)			
46-50	20 (13.3)	17 (11.3)			
51-55	24 (16)	30 (20)			
56-60	23 (15.3)	29 (19.3)			
61-65	31 (20.7)	28 (18.7)			
66-70	25 (16.7)	22 (14.7)			
Total	150 (100)	150 (100)			

The *P* value was not statistically significant. SD – Standard deviation

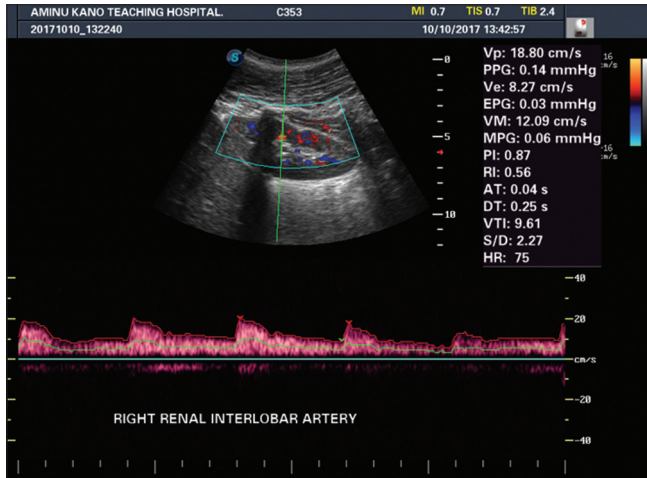


Figure 3: The normal Doppler spectrum of the renal interlobar artery, showing upward systolic upstroke, gradual diastolic decay, and forward flow throughout the cardiac cycle

The mean intrarenal (interlobar) artery RI was the same on the right and left sides in both groups. In the normotensive group, the mean intrarenal (interlobar) artery resistive indices were 0.59 ± 0.04 and 0.59 ± 0.03 on the right and left sides, respectively, which were lower than that of the hypertensive patients with mean intrarenal (interlobar) resistive indices of 0.73 ± 0.03 and 0.73 ± 0.03 on the right and left sides, respectively. Their differences were statistically significant with $P < 0.001$ in each side [Table 2].

The duration of hypertension ranged between 6 months and 30 years with a mean of 7.2 years. Less than half of the patients (70; 46.7%) have had hypertension for more than 5 years, 45 (30%) have had it for 1–5 years, and 35 (23.3%) had it for <1 year [Table 3].

Table 4 shows the comparison between the mean height, weight, BMI, SBP, and DBP in the two groups. There is statistically significant difference in the mean height (0.040), weight (0.038), BMI ($P = 0.013$), SBP ($P = 0.001$), and DBP ($P = 0.001$) of the hypertensive patients compared with the normotensive participants.

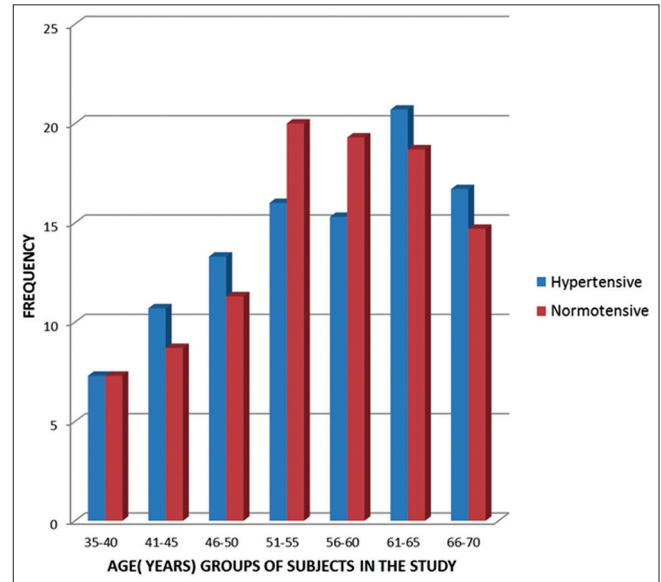


Figure 4: Histogram showing age distribution among hypertensive (150) and normotensive (150) participants

The mean RRI shows positive significant correlation with the BMI ($P = 0.018$), SBP ($P = 0.001$), and DBP ($P = 0.001$). However, the age and duration of hypertension did not show a statistically significant correlation as shown in Table 5, using Pearson's correlation coefficient.

In the multivariate regression analysis, RRI values correlated independently with the SBP ($P = 0.001$). Moreover, other variables such as age, BMI, and DBP showed no statistically significant correlation as noted in Table 6.

DISCUSSION

The renal RI provides information about arterial blood flow impedance. The range of the normal values of intrarenal artery Doppler parameters such as RI in normotensive healthy group has been established,^[15] to appreciate the abnormal intrarenal Doppler findings in hypertensive patients.

As noted in this study, the mean renal RI of the normotensive participants was 0.59 ± 0.04 (range

Table 2: Ultrasonographic intrarenal (interlobar) artery resistive index for the normotensive and hypertensive groups (n=300)

Renal parameters	Mean±SD		P
	Normotensive participants	Hypertensive patients	
Right intrarenal (interlobar) artery RI	0.59±0.04	0.73±0.03	< 0.001
Left intrarenal (interlobar) artery RI	0.59±0.03	0.73±0.03	< 0.001

The P values were statistically significant. SD – Standard deviation; RI – Resistive index

Table 3: Duration of hypertension by gender

Duration of hypertension (years)	Males, n (%)	Females, n (%)	Total, n (%)
<5	17 (22.7)	18 (24)	35 (23.3)
1–5	22 (29.3)	23 (30.7)	45 (30)
>5	36 (48)	34 (45.3)	70 (46.7)
Total	75 (100)	75 (100)	150 (100)

Table 4: Comparison between the mean height, weight, body mass index, systolic blood pressure, and diastolic blood pressure in the hypertensive and normotensive groups

Characteristic	Mean±SD		Test	P
	Hypertensive patients (n=150)	Normotensive participants (n=150)		
Height	1.56±0.21	1.61±0.37	0.542	0.040
Weight	67.51±12.90	69.33±11.62	1.800	0.038
BMI	28.13±4.11	26.77±4.73	2.642	0.013
SBP	168.51±32.86	108.43±0.77	23.609	0.001
DBP	110.59±12.71	76.55±6.79	11.007	0.001

BMI – Body mass index; SBP – Systolic blood pressure; DBP – Diastolic blood pressure; SD – Standard deviation

Table 5: The strength of association between age, body mass index, blood pressure, duration of hypertension, and renal resistive index

Characteristics	Pearson's correlation coefficient (r)	P
Age	0.172	0.112 (NS)
BMI	0.201	0.018
SBP	0.289	0.001
DBP	0.322	0.001
Duration of hypertension	0.119	0.216 (NS)

NS – Not significant; BMI – Body mass index; SBP – Systolic blood pressure; DBP – Diastolic blood pressure

Table 6: Multivariate analysis between renal resistive index and some independent variables

Independent variables	Multiple correlation Coefficient (R)	P
SBP	0.611	0.001
Age	0.28	0.523 (NS)
BMI	0.163	0.301 (NS)
DBP	1.220	0.152 (NS)

NS – Not significant; BMI – Body mass index; DBP – Diastolic blood pressure; SBP – Systolic blood pressure

0.48–0.69) on the right and 0.59 ± 0.04 (range 0.46–0.68) on the left side. These findings were comparable to,

although slightly higher than, that of Yusuf and Atalabi^[15] in Ibadan, Southwestern Nigeria, who reported 0.56 ± 0.04 (range 0.48–0.67) and 0.56 ± 0.04 (range 0.48–0.65) on the right and left sides, respectively. Adama *et al.*^[16] in Senegal showed that the renal RI values are raised in hypertensive patients with no known renal abnormalities, indeed a predictor of renal dysfunction especially in those with higher values, which is highly comparable with the findings of this study.

In this study, the mean renal RI value in the hypertensive group was 0.73 on each side; this agrees with that of Okura *et al.*,^[17] who reported that the participants were divided into 2 groups according to RI value: the low (normal value) RI group (RI <0.7) and the high (abnormal value) RI group (RI ≥0.7); this finding suggests that the renal RI may be a marker of future renal dysfunction in essential hypertension. A study done by Viazzi *et al.*^[18] also reported that an increased RRI is the predictor of renal and extrarenal organ damage in primary hypertensive patients.

However, Pearce *et al.*^[19] noted in their study that higher values of RI >0.70 can also be seen in the elderly (seventh decade and above) with no renal dysfunction. This could be due to the fact that, with aging, there is the tendency of vascular compromise that may occur from atherosclerosis which may be responsible for elevation of RRI.^[20] Although this pathology (atherosclerosis) was excluded from this study by first of all, evaluating the main renal arteries for plaques before proceeding to the area of interest (interlobar artery).

This study showed that in the normotensive group, both right and left kidneys had the same mean RI values of 0.59 on each side. This finding agrees with that of the studies conducted by Yusuf and Atalabi^[15] in Ibadan which reported that both sides had the same mean RRI values in the normotensive healthy adults they studied.

The relatively higher mean renal resistive indices among hypertensive group (0.73 ± 0.03 on each side) when compared with the normotensive participants (0.59 ± 0.04 on each side) are in consonance with the findings of a study done in Ibadan, Southwestern Nigeria by Atalabi and Yusuf,^[21] which reported that the mean RRI in hypertensive patients was 0.60 ± 0.04 ($\pm$ SD) which is higher than that of the healthy normotensive participants (mean RI = 0.56 ± 0.04 [$\pm$ SD]) ($P \leq 0.001$). According to Okura *et al.*,^[17] this increase in mean RRI value is an early sign seen in adults with essential hypertension as a result of hypertension-induced myointimal hyperplasia of the renal arterioles.

In this study, the BMI, SBP, and DBP showed positive correlation with the RRI, which is in consonance with the findings noted in other studies.^[17,21]

CONCLUSION

This study established that the values of the mean intra-RRI were lower in normotensive participants when compared with the hypertensive patients. These showed that hypertension has significant effects on the kidneys by causing renovascular changes such as increase in renal arterial impedance, and with early detection and intervention, irreversible hypertensive renal damage may be prevented.

This study also showed a positive correlation between SBP, DBP, BMI, and RRI. However, there is no correlation between the RRI, age, and duration of hypertension.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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