Kidney Morphometry in Hypertensive and Normotensive Adults: A Comparative B-Mode Ultrasonographic Analysis in a Nigerian Tertiary Hospital.

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Abstract

Background: Prolonged hypertension can induce changes in renal size hence, early detection of these renal changes by ultrasonography may aid early intervention, thereby preventing or minimizing renal damage. This study aimed to sonographically assess kidney parameters in adults with hypertension and compare them with age and sex matched normotensive controls.

Materials and Methods: This was a cross-sectional comparative study involving 330 individuals comprising 165 hypertensives and 165 controls, conductedat the Radiology unit of Delta State University Teaching Hospital (DELSUTH), Oghara, Delta State, Nigeria. Measurements were obtained using an electronic caliper on a DC-30 Mindray ultrasound. Renal cortical echogenicity was assessed by comparison with the echogenicity of the liver and spleen respectively, and graded into four categories: Grade 0 - Normal, Grade 1 - mild, Grade 2 - moderate and Grade 3 – severe. Data were analyzed using IBM SPSS version 22. Statistical tests were considered significant with $p < 0.05$ at 95% confidence interval.

Results: Hypertensives had greater mean weight, BMI, blood pressure, and serum creatinine but lower eGFR compared to controls ($p<0.05$). The mean right renal length (9.60±0.50 cm) and left renal length (10.19±0.53 cm) in hypertensives were lower than those measured in controls for the right kidney (9.79±0.63 cm) as well as the left (10.43 ± 0.63 cm), with these differences being statistically significant ($p<0.05$). This was also recorded for the kidney width, volume and cortical thickness. In the hypertensive group, eGFR exhibited statistically significant positive relationships with right and left renal cortical thickness, renal volume, and renal length, while serum creatinine showed weak negative associations with bilateral cortical thickness. For both kidneys, renal echogenicity varied significantly between cases and controls.

Conclusion: This study showed significantly lower renal volume and cortical thickness among hypertensives compared to controls. Routine imaging assessment in conjunction with sensitive biomarkers may aid the early detection of hypertension and improve clinical management.

Keywords: Essential Hypertension, Normotensives, Renal Parameters, Ultrasonography.

Introduction

Hypertension is a major risk factor for cardiovascular disease (CVD) and overall annual mortality rate of about 10 million deaths globally.[1–4] The definition of hypertension has evolved, initially set at a systolic blood pressure (SBP)/diastolic blood pressure (DBP) of ≥160/90 mmHg in 1984, revised to ≥140/90 mmHg in 1993, and subsequently adjusted to ≥130/80 mmHg in 2017.[4]

In Africa, there is an observed steady rise in the burden of this condition, ranging from 54.6 million in 1990, to about 130.2 million in 2010 (41% increase from 2000),[5]and Nigeria contributes significantly to this burden due to the large population of about 198 million.[6] The incidence of hypertension in Nigeria over numerous previous decades has increased, with recent estimates ranging between 22% and 44%, varying by demographics.[2]

The kidney is one of the prime targets of hypertensive end organ damage and uncontrolled hypertension has been identified globally, as the second leading cause of end stage renal disease after diabetic nephropathy.[7] Numerous disorders negatively impact the kidney, resulting in either hypertrophy or atrophy.[8] A recent study in Nigeria has shown that elevated blood pressure is the commonest risk factor for chronic kidney disease and end stage renal failure.[9]

Histologically, hypertension-induced renal damage can be grouped into benign and malignant nephrosclerosis.[10] The primary anatomical change is a reduction in kidney size, [8] attributed to chronic ischaemia resulting from sustained increased intravascular pressure, leading to vascular remodeling.[11] In addition to blood pressure status, age, gender, and body mass index (BMI) also have a significant impact on renal dimensions.[8]

Advances in imaging have enhanced the clinical evaluation of renal disorders by enabling noninvasive assessment of renal morphology and function.[12] Ultrasound is a noninvasive and cost-effective modality for diagnosing renal pathologies. It provides comprehensive anatomical insights without exposing patients to radiation or contrast chemicals, making it a recommended alternative to traditional radiography both nationally and globally.[13]Early ultrasound diagnosis of renal abnormalities can offer opportunities for prompt treatment to prevent or at least delay irreversible hypertension nephropathy.[14]

Several studies[8,12,15] have been done on sonographic evaluation of renal size in hypertensives and healthy adults, but there is paucity of local data in Oghara, Delta State, Nigeria where the prevalence of hypertension ranges between 21-38%.[16–18] Kidney morphometry may vary based on ethnicity and geographical location as well as disease conditions and this highlights a need for region specific data. This study therefore aimed to compare the renal parameters among adults with hypertension and normotensive individuals in Oghara, Delta State, Nigeria, using ultrasonography, in order to evaluate potential structural differences associated with chronic elevated blood pressure and to correlate renal volume and cortical thickness with eGFR in the hypertensive subjects.

Materials and Methods

This was a comparative, cross-sectional study conducted in the Radiology department of DELSUTH, Oghara, Delta State, Nigeria. The study involved 330 individuals comprising 165 hypertensives and 165 normotensive controls. Subjects aged 18 years and above with a known history of hypertension on antihypertensives attending the Cardiology outpatient clinicin DELSUTH were included as cases, while those without a history of hypertension were included as controls. The history of the duration of hypertension was obtained from the study participants (cases), and calculated from the date of first diagnosis and recorded as: <1 year, 1-5 years, 6-10 years and >10years.

Patients who were less than 18 years and those with renal masses, hydronephrosis, fatty liver or those who had undergone a renal surgery were excluded from the study. Sociodemographic data were obtained using a structured, interviewer administered questionnaire. Blood pressure was measured using a standard Welch Allyn adult cuff manual sphygmomanometer; while fasting blood sugar was assessed with a calibrated ACCU-CHEK glucometer. Height and weight were measured using a stadiometer and calibrated weighing scale, and these measurements were used to calculate BMI - weight in kilogram/ (height in meter)^{2}and body surface area (BSA) - calculated as $0.007184 \times \text{height(m)}^{0.725} \times \text{weight(kg)}^{0.425}$.

Renal function was assessed by estimating the glomerular filtration rate using the Chronic Kidney Disease Epidemiology Collaboration.[19] Real time grey scale ultrasound examination of the kidneys was performed using a 2.5-5MHz curvilinear transducer of a DC-30 Mindray machine (Shenzhen Mindray Bio-Medical Electronic Co. LTD. China, 2019, Serial number: 9P-11008360) by a single investigator under the guidance of a consultant radiologist. The scans were obtained in supine, lateral decubitus, and prone positions using the liver and spleen as acoustic windows for the right and left kidneys respectively.

The length - the longest distance between the renal poles on the longitudinal scan (Figure 1a), width - the maximum transverse diameter on the transverse scan (Figure 1b), and anteroposterior diameter -the maximum distance between the anterior and posterior walls of the mid-portion of the kidney in the longitudinal scan (Figure 1a) were measured and recorded using an electronic caliper. The kidneys' maximal longitudinal, transverse, and anteroposterior dimensions were measured, and the ellipsoid formula (L×W×AP×0.523) was used to determine the renal volume.

As shown in Figure 2a, renal parenchymal thickness (RPT) was assessed in the longitudinal scan at the upper, lower, and mid-level poles of the kidneys from the outer renal cortical edge to the outer margin of the sinus echoes. In a longitudinal scan, cortical thickness was obtained as the distance measured perpendicularly between the renal capsule at the midsection of the kidney and the base of a medullary pyramid (Figure 2b).

In the supine position, the renal cortical echogenicity of the right and left kidney was assessed by comparing with the echogenicity of the liver and spleen respectively as shown in Figures 3, and was graded into four (4) categories as follows: grade 0 (Normal), grade 1 (Mild), grade 2 (Moderate), and grade 3 (Severe).[20]

The Health Research and Ethics Committee of the teaching hospital granted ethical approval for this study (HREC/PAN/2021/054/0441). Informed written consent was also obtained from subjects before inclusion in the study. IBM SPSS Statistics Version 22.0 (SPSS, IBM Corporation, Armonk, New York, USA, 2016) was used to analyze the data. For numerical variables, descriptive statistics were displayed as means and standard deviations. Frequencies and percentages were used to summarize categorical variables. Inferential statistics was performed using independent t test, ANOVA, Chi-square or Fisher's Exact test as was required, Pearson's correlation test was employed to assess significant associations between variables. P ≤5% was considered statistically significant at 95% confidence interval.

Results

Socio-demographics and Clinical parameters

This study evaluated 330 participants including 165 hypertensives (cases) and 165 normotensives (controls). The gender frequency distribution and age range of the hypertensives and that of the controls are depicted in Table 1.

The mean height varied significantly (p=0.034) with higher values for controls compared to cases. The hypertensives' body weight and BMI were higher than those of the control group, and these differences were statistically significant ($p<0.001$). The findings on BSA, blood pressure, comorbidity, alcohol consumption, smoking history and mean creatinine levels in cases and controls are summarized in Table 2.

Renal parameters of the study participants

All measured renal dimensions were higher in the normotensive group compared to hypertensives for both kidneys, except the anteroposterior diameter which demonstrated greater mean values among cases compared to controls. These differences were statistically significant for all the variables ($p<0.05$) except the right renal volume, left anteroposterior diameter and left parenchymal thickness (Table 3).

Gender comparisons of kidney measurements in the study participants

Table 4 shows comparison of renal parameters of cases and control with gender of the study participants.

Renal echogenicity grading of study participants

The frequency of renal echogenicity for cases and controls based on grades are summarized in Table 5. Renal cortical echogenicity differed significantly between hypertensive and normotensive participants for both kidneys with greater values among cases compared to control ($P<0.05$). None of the participants had grade 3 echogenicity.

Age group comparison of renal parameters

The right and left renal volumes of hypertensive participants were significantly lower than those of controls in males aged 50 to 59 and 60 to 69 years ($p < 0.05$). Only the left renal volume showed a significant decrease among males between the ages of 70 and 79 ($p = 0.018$). Women with hypertension aged 60-69 exhibited a statistically significant reduction in right kidney volume compared to controls ($p=0.029$). Total renal volumes were significantly decreased in hypertensive males for both kidneys (right, $p = 0.008$; left, $p = 0.013$), although no significant difference was noted in females (Table 6).

Association between renal parameters with eGFR and serum creatinine

In the hypertensive group, eGFR exhibited weak yet statistically significant positive relationships with right and left renal cortical thickness, renal volume, and renal length ($p < 0.05$). No significant associations were seen between eGFR and any kidney parameter in the control group ($p > 0.05$).

Serum creatinine in the cases exhibited statistically significant weak negative associations with right and left renal cortical thickness, as well as with left renal length. There was no significant correlation between serum creatinine and renal volume in the hypertensive group, likewise none of the renal parameters demonstrated statistically significant relationships with serum creatinine in the normotensive group ($p>0.05$) (Table 7).

Relationship between the duration of hypertension and sonographic renal volume in the study population

This study found a decline in renal volume with increase in the duration of hypertension ranging from less than a year to greater than 10 years for both the right and left kidneys. However, these differences were not statistically significant for both the right kidney ($F=0.437$, $p=0.727$) and left kidney ($F=0.738$, $p=0.531$).

Correlation analysis of sonographic kidney measurements with age, and anthropometric parameters in the study participants

Among hypertensives, right renal length had a statistically significant weak positive correlation with age, weight, height and BSA ($p<0.05$), while left renal length exhibited a significant weak negative association with age and weak positive correlations with weight, height, and body surface area ($p < 0.05$). The bilateral renal length demonstrated no significant relationship with BMI. Both right and left renal volumes exhibited significant weak negative associations with age and significant positive correlations with weight, height, and BSA ($p < 0.05$).

Further details on the correlation analysis the renal measurements with age, sex, and body surface area among hypertensive subjects are seen in Table 8a (Supplementary Files).

In normal subjects, both the right and left renal length demonstrated significant positive correlations with weight, BMI, and BSA (p<0.001), but showed no significant association with age or height. Renal volume displayed significant strong positive correlations with height, weight, BMI, and BSA on both sides (p≤0.05). Age however, did not show any significant association with renal volume. Bilaterally, the renal parenchymal thickness correlated positively with weight and BSA (p<0.05). Table 8b (Supplementary Files) provides further information on the correlation analysis of kidney measures with age, sex, and body surface area among normotensives.

Discussion

Recently, the prevalence and overall impact of the recognized modifiable risk factor for renal failure, hypertension, is increasing internationally, particularly in low- and middle-income countries.[21] This study evaluated the effect of hypertension on renal morphometry by comparing measurements of kidney parameters among hypertensives and controls. The findings showed significant reductions in renal volume and cortical thickness among cases compared to controls.

The age of the study population ranged from 20-88years, with a mean age of 54.1±14.0 years and 51.0±14.8 years for the hypertensives and control groups respectively. This was higher than the findings of Alhassan *et al*.[8] in Northern Nigeria but lower than the reports of Ajana *et al*.[14] in Southwestern Nigeria. The similar findings in the aforementioned study and the index study could be due to the increase in prevalence of hypertension with advancing age.[22] In this study, the mean BMI was significantly higher in the hypertensives than the control groups. This was similar to the findings documented in previous literatures.[8,23,24] This observed difference may be attributed to the positive relationship between obesity and hypertension as documented in a previous study.[25]This finding aligns with the theory that hypertension results in increased BMI.[12]

Although both kidneys demonstrated lower mean volumes among hypertensives, statistical significance was observed only for the left renal volume. This corroborates with the reports of Njoku *et al*.[15] who observed statistically significant difference in bilateral renal volumes between cases and controls. Similarly, the findings in Alhassan *et al*.[8] demonstrated higher mean right and left renal volumes although they did not test for statistically significant difference. In contrast, Shaik and Jain[12] observed greater mean renal volumes in cases compared to controls for the right and left kidneys with these differences being statistically significant. These observed differences could possibly be ascribed to observer bias, ethnic and geographical differences. The presence of hypertension in the study cohort could also be an explanation for the variances reported.[21] The findings concerning renal volume between case and controls in our study align with the statement that bilateral renal shrinkage supports the diagnosis of CKD in cases of chronic illness.[21]

In agreement with previous studies,[23,24] this study observed a progressive increase in renal volume up to the 4th and 5th decade of life and a gradual decrease from the 6th decade of life in the hypertensive and normotensive group respectively. This decrease in renal volume with advancing age was attributed to ischaemia in hypertensives, which led to a decrease in renal parenchymal volume, and a decrease in the number of nephrons with aging in normotensives.[23] Congruent with the reports of Njoku *et al*.[15] the mean renal parenchymal thickness for the right and left kidneys in the index study were significantly higher among controls compared to hypertensives. The values of the mean bilateral renal parenchymal thickness among the normotensive group are comparable to the values reported by Eze *et al*.[26] in Enugu, Nigeria. However, lower values were documented by Jabbari *et al*.[27] in Iran and Raza *et al*.[28] in Pakistan. The difference in values of the mean renal parenchymal thickness in the above studies may be due to genetic, racial and geographical variations. This may also be due to the larger sample size of 4,035 in the Pakistani study population.[28]

In agreement with the findings by Nwafor *et al*.[23] and Ajana *et al*.[14] the right and left mean renal cortical thickness were significantly higher in the normotensives compared to the hypertensives ($p<0.001$). The reduction in cortical thickness among the hypertensive group is possibly due to hypertensive ischemic injury, resulting in glomerular nephrosclerosis and consequently leading to cortical thinning.[37]Comparatively, cortical echogenicity grading was significantly higher in the hypertensives than the controls ($p<0.001$), which corroborates with findings by Nwafor *et al*.[23] The higher echogenicity grading among the hypertensives in both studies may be an indication of early onset renal changes among both study populations. This implies that renal echogenicity is an indicator of anatomical changes in renal parenchyma, including glomerulo-tubular changes, fibrosis and inflammation. The poor discrimination of grade 1 echogenicity between hypertensives and controls may be attributed to the subjective nature of visual echogenicity grading.[29]

Consistent with the reports of several studies,[22,30] the left mean renal parameters in this study were higher than the right in both hypertensives and normotensives. The difference in size is possibly due to the impact of the liver on the growth of the right kidney compared to the spleen on the left.[31] In addition, the left renal artery is shorter and straighter than the right, which is said to increase blood flow in the left renal artery with resultant increased left renal size.[30]In alignment with the findings by Nwafor *et al*.[23] , hypertensives had significantly higher serum creatinine compared to the controls ($p<0.001$). This could be attributed to background renal parenchymal disease observed in both study cohort.

In the index study, it was observed that a serum creatinine had a statistically significant weak negative correlation with bilateral renal cortical thickness in hypertensives. Ahmed *et al*.[32] also reported a significant negative association between serum creatinine level and renal cortical thickness in their population. Serum creatinine is an important indicator utilized in diagnosis and monitoring of renal function due to its sensitivity to variations in renal clearance,[33] hence, this finding may indicate an underlying renal parenchymal disease in our study population. Conversely, a study conducted in India[34] observed a weak positive correlation between cortical thickness and serum creatinine although this association was not significant. This may be due to their relatively small sample size and also inclusion of diabetic patients in their study, where diabetes is thought to be associated with increased kidney size and GFR.[35]

Congruent with the reports of Alhassan *et al*.,[8] this study noted a statistically significant weak positive correlation between eGFR and the bilateral mean renal volumes in cases. Similarly, the reports of Korkmaz *et al*.[36] aligned with the findings in this study, where eGFR in hypertensive groups demonstrated significant weak positive correlation with the right and left renal cortical thickness respectively ($p<0.05$). These observations may be ascribed to ischemic changes induced by hypertension, resulting in nephrosclerosis, tubular atrophy and interstitial fibrosis[37] usually associated with eGFR decline. Normotensives however did not show significant association between eGFR and the cortical thickness in both kidneys.

Weight, height, BMI and BSA demonstrated statistically significant weak to moderate positive correlations with the renal dimensions. This was similarly reported in previous studies conducted in Nigeria.[25,27,30] This study found a weak negative correlation between the right and left mean renal volumes with duration of hypertension, which was not statistically significant ($p>0.05$). This observation agreed with the findings from previous works conducted in Southern Nigeria.[23,24] In the index study, the duration of hypertension was calculated from the time of diagnosis, which may not reflect the actual onset of the disease, as hypertension is a chronic disease with insidious onset and largely asymptomatic,[38] and the disease may have been ongoing before clinical detection.

Serum cystatin C is recognized as an early and precise biomarker of CKD, especially beneficial for patients in whom creatinine is an insufficient marker or if more complex methods of GFR assessment are unfeasible.[39] This study however employed serum creatinine as a biomarker for renal function dues to its low cost and easy accessibility compared to serum cystatin C. Interobserver reliability was not estimated and this could be a limitation for reproducibility. Multiple comparisons were performed in this study; hence the findings should be interpreted within this context.

Conclusion

This study established baseline sonographic values for renal parameters in our population and demonstrated structural differences between hypertensive and normotensive adults. It further demonstrated reduced renal dimensions in hypertensives, particularly the left renal volume and bilateral cortical thickness, which showed weak significant positive correlations with eGFR and negative association with serum creatinine, indicating early structural and functional changes in the kidneys in association with hypertension.

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Tables

Table 1: Socio-Demographic characteristics of the study participants

Variable	Descriptor	Hypertensives	Normotensives	Statistics		
		N (%)	N (%)	χ^2/t	Df	p value
Age	20-29	7 (4.2)	8 (4.8)	0.456	6	0.998
	30-39	23 (13.9)	25 (15.2)			
	40-49	29 (17.6)	30 (18.2)			
	50-59	42 (25.5)	41 (24.8)			
	60-69	45 (27.3)	44 (26.7)			
	70-79	14 (8.5)	13 (7.9)			
	≥80	5 (3.0)	4 (2.4)			
Mean age ± SD		53.82 ±14.29	52.70 ± 14.46	0.705	328	0.482
Gender	Female	82 (49.70)	82 (49.70)	0.000	1	1.000
	Male	83 (50.30)	83 (50.30)			

SD = standard deviation, df=degree of freedom, χ^2=chi-square, t=student t-test

Table 2: Clinical and Laboratory Characteristics of the Study Population

Variable	**Descriptor**	**Hypertensives**	**Normotensives**	**Statistics**		
		[Mean ± SD]	[Mean ± SD]	**X^2/t**	**df**	**p value**
Height (m)		1.65±8.0	1.67 ± 8.5	–2.129	328	0.034*
Weight (kg)		77.2±15.0	71.4 ± 13.9	3.655	328	<0.001*
BMI (kg/m²)		28.3±5.2	25.6 ± 4.8	4.904	328	<0.001*
BSA (m²)		1.83± 0.20	1.79 ± 0.19	1.659	328	0.098
Systolic blood pressure (mmHg)		145.9 ± 21.4	120.5 ± 11.4	13.471	328	<0.001*
Diastolic blood pressure (mmHg)		83.9 ± 15.5	74.2 ± 8.9	6.966	328	<0.001*
Serum creatinine (mg/dl)		1.1 ± 0.3	0.8 ± 0.2	10.341	328	<0.001*
eGFR (ml/min/1.73m²)		84.5 ± 28.5	118.7 ± 26.3	–11.322	328	<0.001*
		N (%)				
Duration of hypertension (years)	< 1	26 (15.8)				
	1—5	84 (50.9)				
	6 – 10	35 (21.2)				
	>10	20 (12.1)				
Co-morbidity	None	154 (93.3)	165(100.0)	11.392§	NA	0.001*
	Stroke	7 (4.2)	0 (0.0)			
	CCF	4 (2.4)	0 (0.0)			
Alcohol use	Yes	52 (31.5)	46 (27.9)	0.523	1	0.470
	No	113 (68.5)	119 (72.1)			
Alcohol limit	<Safe Limit	48 (92.3)	40 (88.9)	0.052‡	1	0.820
	>Safe Limit	4 (7.7)	6 (11.1)			
Smoking	Yes	2 (1.2)	0 (0.0)	0.503	1	0.478
	No	163 (98.8)	165 (100.0)			
Number of Packs smoked/year	<5 packs	1 (50.0)				
	>5-10 packs	1 (50.0)				

NA: degree of freedom not applicable in Fisher's Exact Test, df=degree of freedom; eGFR= Estimated glomerular filtration rate, BMI=Body mass index, BSA= Body surface area, CCF= Congestive cardiac failure, X^2= Pearson's Chi-square; § =Fisher's Exact Test, t=student t-test, ‡ chi-square test with Yates Continuity Correction, *p*=probability value, *=p value ≤ 0.05 is statistically significant.

Table 3: Comparison of the Renal Parameters in Hypertensives and Normotensives

Renal parameters	Mean ± SD		t-test	p -value
	Hypertensives	Normotensives		
Right kidney				
Length (cm)	9.60 ± 0.50	9.79 ± 0.63	-3.627	<0.001*
Width (cm)	4.99 ± 0.55	5.20 ± 0.47	-3.837	<0.001*
Anteroposterior diameter (cm)	3.99 ± 0.05	3.85 ± 0.05	2.557	0.011*
Volume (cm^3)	100.52 ± 19.92	105.05 ± 23.27	-1.900	0.058
Parenchymal thickness (cm)	1.71 ± 0.23	1.80 ± 0.22	-3.658	<0.001*
Cortical thickness (cm)	0.86 ± 0.09	1.00 ± 0.02	-20.710	<0.001*
Left Kidney				
Length (cm)	10.19 ± 0.53	10.43 ± 0.63	-3.756	<0.001*
Width (cm)	5.33 ± 0.49	5.53 ± 0.39	-4.029	<0.001*
Anteroposterior diameter (cm)	4.44 ± 0.43	4.41 ± 0.51	0.680	0.497
Volume (cm^3)	125.84 ± 20.35	132.31 ± 24.20	-2.625	0.009*
Parenchymal thickness (cm)	1.89 ± 0.19	1.92 ± 0.22	-1.491	0.137
Cortical thickness (cm)	1.0 ± 0.1	1.1 ± 0.64	-11.606	<0.001*

T-test - Independent sample test value, p-value - probability value, *p-value is statistically significant.

Table 4: Comparison of Sonographic Renal Dimensions in Hypertensives and Normotensives by Gender.

Renal parameters	Males				Females			
	Mean □ SD		t-test	*p*-value	Mean □ SD		t-test	*p*-value
	Case	Control			Case	Control		
Right Kidney								
Length (cm)	9.57 □ 0.51	9.84 □ 0.62	-3.005	0.003*	9.56 □ 0.49	9.74 □ 0.65	-2.120	0.036*
Width (cm)	4.90 □ 0.56	5.29 □ 0.40	-5.178	<0.001*	5.07 □ 0.52	5.11 □ 0.52	-0.439	0.661
Anteroposterior diameter (cm)	4.05 □ 0.50	3.92 □ 0.49	1.710	0.089	3.92 □ 0.46	3.78 □ 0.47	1.942	0.054
Volume (cm^3)	100.72 □ 20.90	109.01 □ 22.44	-2.463	0.015*	100.32 □ 19.01	101.04 □ 23.53	-0.217	0.829
Parenchymal thickness (cm)	1.73 □ 0.23	1.82 □ 0.23	-2.423	0.016*	1.67 □ 0.23	1.79 □ 0.20	-2.759	0.006*
Cortical thickness (cm)	0.85 □ 0.09	1.00 □ 0.01	-14.332	<0.001*	0.86 □ 0.09	1.00 □ 0.02	-14.907	0.001*
Left Kidney								
Length (cm)	10.17 □ 0.53	10.44 □ 0.64	-3.036	0.003*	10.21 □ 0.53	10.41 □ 0.62	-2.253	0.026*
Width (cm)	5.32 □ 0.52	5.59 □ 0.56	-3.770	<0.001*	5.64 □ 0.46	5.46 □ 0.40	-1.900	0.059
Anteroposterior diameter (cm)	4.48 □ 0.56	4.44 □ 0.50	0.503	0.616	4.40 □ 0.40	4.47 □ 0.51	-0.459	0.647
Volume (cm^3)	126.33 □ 20.77	135.12 □ 24.35	2.503	0.013*	125.36 □ 20.04	129.46□23.86	-1.193	0.235
Parenchymal thickness (cm)	1.91 □ 0.21	1.93 □ 0.25	-0.544	0.586	1.86 □ 0.18	1.91 □ 0.20	-1.686	0.094
Cortical thickness (cm)	0.97 □ 0.10	1.10 □ 0.10	-8.252	<0.001*	0.97 □ 0.09	1.10 □ 0.10	-8.11	<0.001*

T-test - Independent sample test value, p-value - probability value, *p-value is statistically significant.

Table 5: Comparison of Renal Echogenicity Between Hypertensives and Normotensives

Echo grading	N (%)		X^2	P value
Right kidney	Hypertensive	Normotensive		
0	25 (15.2)	77 (46.7)	52.538	<0.001*
1	109 (66.1)	85 (51.5)		
2	31 (18.8)	3 (1.8)		
Left kidney				
0	35 (21.2)	45 (47.4)	32.314	<0.001*
1	98 (59.4)	50 (52.6)		
2	32 (19.4)	0 (0.0)		

X^2 = Chisquare test value, *p-value is statistically significant, N=frequency.

Table 6: Age Range and Renal Volume in Hypertensive Patients and Normotensives According to Gender

Age Group (years)	Gender	Renal Volume (cm^3)							
		Right Kidney				Left Kidney			
		Mean □ SD		t-test	*p*-value	Mean □ SD		t-test	*p*-value
		Case	Control			Case	Control		
20 – 29	Male	97.64 □ 9.69	103.12 □ 13.27	-0.747	0.479	117.19 □ 10.58	141.84 □ 20.39	-2.400	0.043*
	Female	111.47 □ 21.29	78.73 □ 9.69	2.453	0.091	126.84 □ 18.14	122.69 □ 18.30	0.249	0.820
30 – 39	Male	103.34 □ 13.83	96.99 □ 15.15	1.092	0.286	127.23 □ 15.26	121.32 □ 24.24	0.722	0.478
	Female	101.14 □ 15.98	94.66 □ 34.04	0.575	0.571	125.55 □ 19.12	127.38 □ 31.49	-0.192	0.850
40 – 49	Male	112.30 □ 21.78	102.00 □ 17.63	1.424	0.166	139.32 □ 17.85	126.77 □ 17.24	1.958	0.060
	Female	114.28 □ 16.51	111.39 □ 22.23	0.394	0.696	145.92 □ 16.13	135.52 □ 23.67	0.373	0.181
50 – 59	Male	107.58 □ 17.80	124.78 □ 24.28	-2.617	0.012*	136.40 □ 16.60	153.35 □ 26.06	-2.513	0.016*
	Female	106.30 □ 17.63	102.28 □ 23.43	0.622	0.537	129.46 □ 13.39	132.10 □ 21.95	0.467	0.643
60 – 69	Male	89.77 □ 21.66	109.49 □ 23.38	-2.633	0.012*	116.19 □ 20.84	131.88 □ 20.39	-2.313	0.027*
	Female	93.00 □ 15.01	103.58 □ 18.61	2.254	0.029*	119.07 □ 14.90	153.35 □ 26.08	-1.647	0.106
70 – 79	Male	88.68 □ 19.88	107.53 □ 21.30	-1.941	0.070	111.00 □ 18.80	134.60 □ 19.12	-2.640	0.018*
	Female	86.96 □ 17.43	82.85 □ 4.72	0.452	0.665	102.71 □ 19.19	120.79 □ 20.23	-1.371	0.213
>80	Male	92.00 □ 43.43	91.38 □ 10.40	0.020	0.986	105.76 □ 41.63	110.62 □ 5.35	-0.164	0.885
	Female	68.59 □ 17.39	86.33 □ 17.54	-1.113	0.371	92.25 □ 26.30	113.92 □ 10.00	-1.067	0.364
Total	Male	100.72 □ 20.90	109.01 □ 22.44	-2.674	0.008*	126.33 □ 20.77	135.12 □ 24.35	-2.506	0.013*
	Female	100.32 □ 19.01	101.04 □ 23.53	-0.216	0.830	125.36 □ 20.04	129.46 □ 23.86	-1.192	0.235

t-test - Independent sample test value, p-value - probability value, *p-value is statistically significant.

Table 7: Correlation of Renal Volume, Cortical Thickness and Renal Length with Renal Function (eGFR) and serum creatinine levels in Hypertensives and Normotensives

Variables		eGFR (ml/min/1.73m2)		Serum creatinine (mg/dl)	
		Case	Control	Case	Control
Right renal cortical thickness	r	0.215	0.076	-0.173	0.034
	p-value	0.006*	0.330	0.026*	0.669
Left renal cortical thickness	r	0.230	0.003	-0.196	0.005
	p-value	0.003*	0.967	0.012*	0.951
Right renal volume	r	0.208	0.003	-0.089	-0.019
	p-value	0.011*	0.969	0.258	0.806
Left renal volume	r	0.204	0.032	-0.082	-0.007
	p-value	0.013*	0.686	0.297	0.931
Right renal length	r	0.237	0.088	-0.149	-0.136
	p-value	0.002*	0.259	0.057	0.081
Left renal length	r	0.234	0.113	-0.208	-0.128
	p-value	0.002*	0.147	0.007*	0.102

eGFR - estimated glomerular filtration rate, r - Pearson's correlation coefficient, p-value - probability value, *p-value is statistically significant