Original Article

Sonographic Evaluation of Renal Parameters in Individuals with Essential Hypertension and Correlation with Normotensives

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Abstract

Background: Hypertension can secondarily involve the kidneys, and renal sonographic parameters can be used to indirectly assess renal function or status. Ultrasound is an inexpensive and safe modality for evaluating the kidneys. The purpose of this study was to sonographically assess renal parameters in patients with essential hypertension to determine the parameters that may indicate increased risk of renal damage. **Materials and Methods:** One hundred and fifty individuals (96 females and 54 males) with essential hypertension attending consultant outpatient clinic in University of Benin Teaching Hospital were evaluated. An equal number of nonhypertensive volunteers comprising of 80 females and 70 males were studied as controls. For individuals and controls, the renal length, width, anteroposterior diameters, renal parenchymal volume, cortical thickness, and echogenicity were assessed. Serum creatinine was also obtained. Statistical Package for the Social Sciences (SPSS version 17.0) was used in data analysis. **Results:** The mean renal parenchymal volume and cortical thickness were 99.1 ± 25.8 cm^3 and 1.0 ± 0.2 cm on the right and 113.8 ± 35.8 cm^3 and 1.0 ± 0.2 cm on the left for the hypertensive individuals. The values for the normotensives were 100.5 ± 19.8 cm^3 and 1.2 ± 0.2 cm on the right and 118.7 ± 27.4 cm^3 and 1.3 ± 0.2 cm on the left. The difference in cortical thickness between the two groups was statistically significant. No significant difference was noted between renal parenchymal volume of the right and left kidneys in the individuals and controls. The variation in cortical echogenicity between the hypertensives and controls was statistically significant; 74.0% and 75.3% of hypertensives and 28.0% and 26.0% of normotensives had increased cortical echogenicity on the right and left kidneys, respectively. The serum creatinine value was significantly higher in the hypertensive group. **Conclusion:** Cortical echogenicity grading was significantly higher among hypertensives than normotensives while renal parenchymal volume and cortical thickness were lower among hypertensives. In the hypertensives and normotensives, renal parenchymal volume, cortical thickness, and renal length were higher in males compared to the females and in the left kidney compared to the right. Hypertension seems to have more effect in the renal cortex than the medulla.

Keywords: *Cortical thickness, essential hypertension, renal parenchyma, ultrasound*

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Introduction

Hypertension is a chronic, noncommunicable multisystemic disease that affects many organs including the kidneys and can be defined as measured

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blood pressure exceeding 140 mmHg for systolic or 90 mmHg for diastolic or both.[1] The high prevalence of hypertension in Nigeria, which is estimated to be about 10%–30%,[2] is an indication to study its effect on vital organs such as the kidneys. Renal-related complications were the third highest following stroke and congestive cardiac failure.[2] The renal length is the most widely used and most easily reproducible parameter in assessing kidney size. Other renal parameters have been found to be more affected in disease conditions such as hypertension. Renal cortical thickness has been shown to decrease early in patients with chronic renal disease secondary to hypertension.[3] Renal parenchymal thickness has also been assessed and found to correlate well with renal function.[4]

A previous study using ultrasound in South-East Nigeria by Okoye *et al*.[5] found renal parenchymal thickness of normal individuals between 18 and 80 years to be strongly correlated to renal length on ultrasound while a similar study in the United States by Cost *et al*.[4] found renal parenchymal area measured on ultrasound to be a more accurate estimate of renal size and function.

In a study by Kojima *et al*.[6] carried out in Japan, renal cortical volume was found to be smaller and the renal cortex more heterogeneous on the contrast phase of contrast-enhanced computed tomography (CT) scan of individuals with essential hypertension when compared with normotensive individuals while a study in France by Mounier-Vehier *et al*.[7] using spiral CT angiography reported significant cortical atrophy as a reliable marker of early ischemic nephropathy in individuals with hypertension secondary to unilateral renal artery stenosis. The changes in the renal cortex are observed earlier than changes in other commonly used morphological parameters such as renal length.

There is the need to establish a safe and affordable method of assessing the effect of hypertension on the kidneys and their function. Ultrasound offers such advantages and being nonionizing permits serial monitoring and follow-up of patients.

This study aimed to compare renal sonographic parameters in hypertensives and normotensive controls and to identify the parameters that may indicate increased risk of possible renal damage in individuals with essential hypertension. These parameters include length, width, anteroposterior thickness, echotexture as well as renal cortical thickness and renal parenchymal volume.

Materials and Methods

This study was carried out in the Department of Radiology, University of Benin Teaching Hospital (UBTH) from October 2013 to May 2014. Three hundred adults between the ages of 24–86 years consisting of 150 hypertensives and equal number of normotensive individuals were recruited into this study. Hypertensive patients were patients on management for essential hypertension recruited from cardiology consultant outpatient clinic while the normotensives were recruited from the general outpatient clinic. Diabetics, pregnant women, patients with renal masses, renal malformation, and hydronephrosis were excluded. All the individuals were Nigerians and 50% of them were of Bini origin.

A written informed consent was obtained from each participant, and a brief questionnaire was administered. Blood pressure was measured using Welch Allyn adult cuff manual sphygmomanometer with mercury device, and 3M Littmann classic stethoscope and biometric parameters including height and weight were taken. Body mass index (BMI) and body surface area (BSA) were calculated. 2 ml of venous blood was collected under aseptic conditions from the antecubital vein and was placed in a lithium heparin bottle. This was used for serum creatinine analysis.

A curvilinear probe with transducer frequency of 2–8 MHz of a Sonoace X6 (Medison Inc, Korea 2010) ultrasound machine was used. Each individual was laid supine on the couch with the abdomen adequately exposed from upper abdomen to the symphysis pubis. Longitudinal, coronal, and transverse scans of the kidneys were obtained in the supine, supine-oblique, and prone positions.

Renal dimensions including length, width, anteroposterior thickness as well as renal cortical thickness and renal parenchymal volume/echogenicity/echotexture were assessed.

Cortical echogenicity was assessed using the supine views only and graded as follows:[8]

- Grade 0 = normal, renal cortical echogenicity less than the echotexture of the liver on the right and spleen on the left
- Grade 1 = renal cortical echogenicity equal to echotexture of the liver on the right and spleen on the left
- Grade 2 = renal cortical echogenicity greater than echotexture of the liver on the right and spleen on the left but less than the renal sinus echo
- Grade 3 = renal cortical echogenicity equal to the renal sinus.

For renal dimensions, images were acquired in the longitudinal plane with both renal poles clearly demonstrated and on the transverse plane at the level of the hilum. Using electronic calipers, the renal length (L) was taken as the longest distance between the renal poles on the longitudinal scan and the renal width (W) as the maximum transverse diameter on the transverse scan. The renal thickness or depth (D) was taken as the average of the maximum distance between the anterior and posterior walls of the midportion of the kidney in the longitudinal and transverse scans (D1 and D2). The kidney volume was obtained using the prolate ellipsoid formula[9] (L × W × D1 + D2/2 × 0.523).

Cortical thickness was assessed on a longitudinal scan as the perpendicular distance from the base of a pyramid to the renal capsule, 2 cm away from the renal poles and at the midportion of the kidney.[3]

The renal parenchymal volume was obtained by using longitudinal and transverse scans. The maximum longitudinal, transverse, and anteroposterior dimensions of the kidney and the central sinus echo were obtained, the ellipsoid formula was used to calculate the renal volume and the volume of the central sinus echo, respectively. The renal parenchymal volume is the volume obtained by subtracting the volume of the central sinus echo from the renal volume. All measurements were done by one observer, the values were measured three times, and the average value was taken to reduce intraobserver errors.

Data analysis was carried out using Statistical package for social sciences version 17.0 incoporated Chicago, Illinois, USA. Data comparison (statistical test of significance) was done with Chi-square test for categorical data and *t*-test for continuous variables. At 95% interval, two-tailed $P \leq 0.05$ was considered statistically significant.

Ethical approval was obtained from UBTH ethical committee.

Results

A total of 300 adults consisting of 150 hypertensives and equal number of normotensive individuals were recruited into this study over a period of 8 months from October 2013 to May 2014; comprising 176 females (58.7%) and 124 males (41.3%). The gender difference of the study population was not statistically significant ($P = 0.060$). Among the hypertensive individuals, there were 96 females and 54 males, representing 64% and 36%, respectively. For the normotensives, there were 80 females (53.3%) and 70 males (46.7%).

The age range of the study population was 24–86 years with a median of 62 and 49 for the hypertensives and normotensives, respectively. The mean age of the hypertensives was 60.4 ± 12.5 years, while the mean age for the normotensive controls was 50.4 ± 12.4 years. This difference in age distribution between the hypertensives and controls was statistically significant; $P = 0.001$.

The modal age group for all respondents was 40–49 years and 50–59 years for males and females, respectively, while for the hypertensives and normotensive groups, the modal age was 60–69 years and 40–49 years, respectively.

The mean clinical (weight, height, BMI, BSA, and blood pressure) and laboratory (serum creatinine) parameters were compared between the hypertensive and normotensive groups as shown in Table 1.

There was statistically significant difference in the mean weight of hypertensives and normotensives; 76.2 ± 15.0 kg and 71.5 ± 13.9 kg for the hypertensives and normotensives, respectively ($P = 0.005$).

Table 1: Clinical and laboratory parameters of the study population

	Group	Mean±SD	*t*-test	*P*
Systolic blood pressure (mmHg)	Hypertensives	142.1±20.1	11.1	0.0001
	Normotensives	116.8±13.5		
Diastolic blood pressure (mmHg)	Hypertensives	83.6±15.3	5.8	0.0001
	Normotensives	74.47±9.6		
Weight (kg)	Hypertensives	74.7±15.0	2.8	0.005
	Normotensives	71.5±13.9		
Height (m)	Hypertensives	1.6±0.1	0.9	0.303
	Normotensives	1.7±0.1		
BMI (kg/m^2)	Hypertensives	28.8±6.3	4.4	0.0001
	Normotensives	26.1±4.5		
BSA (m^2)	Hypertensives	1.9±0.9	0.8	0.440
	Normotensives	1.8±0.2		
Serum creatinine (mg/dl)	Hypertensives	0.9±0.2	2.6	0.010
	Normotensives	0.8±0.03		

BMI=Body mass index; BSA=Body surface area; SD=Standard deviation

Table 2: Comparison of renal parameters between hypertensives and normotensives

	Group	Mean±SD	*t*-test	*P*
Parenchymal volume right (cm^3)	Hypertensive	99.1±25.8	−0.5	0.604
	Normotensive	100.5±19.8		
Parenchymal volume left (cm^3)	Hypertensive	113.8±35.8	−1.3	0.128
	Normotensive	118.7±27.4		
Cortical thickness right (cm)	Hypertensive	1.0±0.2	−10.5	0.0001
	Normotensive	1.2±0.2		
Cortical thickness left (cm)	Hypertensive	1.0±0.2	−10.1	0.0001
	Normotensive	1.3±0.2		
Kidney length right (cm)	Hypertensive	9.9±0.9	−1.7	0.094
	Normotensive	10.1±0.7		
Kidney length left (cm)	Hypertensive	10.3±0.7	−1.5	0.138
	Normotensive	10.5±0.6		

SD=Standard deviation

Table 3: Renal parameters of study population according to gender

Group	Parameter measured	Sex	Mean±SD	*t*-test	*P*
Hypertensives	Parenchymal volume right	Male	106.4±24.7	2.7	0.008
		Female	95.0±25.4		
	Parenchymal volume left	Male	119.9±34.7	1.6	0.119
		Female	110.3±36.1		
	Kidney length right	Male	10.1±0.8	1.4	0.700
		Female	9.8±1.1		
	Kidney length left	Male	10.5±0.9	1.6	0.118
		Female	10.3±0.8		
	Cortical thickness right	Male	1.0±0.1	0.2	0.829
		Female	1.0±0.2		
	Cortical thickness left	Male	1.0±0.2	−0.1	0.932
		Female	1.0±0.2		
Normotensives	Parenchymal volume right	Male	123.8±19.5	2.9	0.005
		Female	96.1±19.7		
	Parenchymal volume left	Male	130.5±23.3	2.0	0.044
		Female	114.5±30.0		
	Kidney length right	Male	10.3±0.6	3.7	0.000
		Female	9.9±0.7		
	Kidney length left	Male	10.6±0.5	2.0	0.048
		Female	10.4±0.7		
	Cortical thickness right	Male	1.3±0.2	5.1	0.000
		Female	1.1±0.2		
	Cortical thickness left	Male	1.3±0.2	4.4	0.000
		Female	1.2±0.2		

SD=Standard deviation

Table 4a: Frequency table for cortical echogenicity

Group	Echo grading	Frequency (%)
	Right kidney	
Hypertensive	0	39 (26.0)
	1	88 (58.7)
	2	23 (15.3)
	Total	150 (100.0)
Normotensive	0	108 (72.0)
	1	41 (27.3)
	2	1 (0.7)
	Total	150 (100.0)
	Left kidney	
Hypertensive	0	37 (24.7)
	1	95 (63.3)
	2	18 (12.0)
	Total	150 (100.0)
Normotensive	0	111 (74.0)
	1	38 (25.3)
	2	1 (0.7)
	Total	150 (100.0)

0=Cortical echogenicity less than liver/spleen echotexture; 1=Cortical echogenicity equal to liver/spleen echotexture; 2=Cortical echogenicity greater than liver/spleen echotexture but less than renal sinus echoes

The mean height was 1.6 ± 0.6 m and 1.7 ± 0.9 m for the hypertensives and normotensives, respectively. This was not statistically significant ($P = 0.303$).

The mean BMI was 28.8 ± 6.3 kg/m^2 and 26.1 ± 4.5 kg/m^2 for the hypertensives and normotensives, respectively. This was statistically significant ($P = 0.001$).

The difference in the mean BSA of the two groups (1.9 ± 0.9 m^2 and 1.8 ± 0.2 m^2 for the hypertensives and normotensives, respectively) was not statistically significant ($P = 0.440$).

The mean systolic blood pressure was 142.1 ± 20.1 mmHg and 116.8 ± 13.5 mmHg for the hypertensives and normotensives, respectively. This was statistically significant ($P = 0.001$). The mean diastolic blood pressure was 83.6 ± 15.3 mmHg and 74.6 ± 9.6 mmHg for the hypertensives and normotensives, respectively. The difference was also statistically significant, ($P = 0.001$). The mean serum creatinine was 0.9 ± 0.03 mg/dl and 0.8 ± 0.03 mg/dl for the hypertensives and normotensives, respectively. This was statistically significant ($P = 0.010$).

Table 2 compares mean renal parameters between hypertensives and normotensives. The mean parenchymal volume on the right and left, respectively, were 99.1 ± 25.8 cm^3 and 113.8 ± 35.8 cm^3 for the hypertensives and 100.5 ± 19.84 cm^3 and 118.7 ± 27.4 cm^3 for the control group ($P = 0.604$ and 0.128, respectively). The difference in these values was not statistically significant.

Table 4b: Effect of hypertension on cortical echogenicity

	Group	n	Mean rank	Sum of ranks	Mann-Whitney U-test	P
Echo right kidney	Case	150	184.9	27738.0	5043.0	0.0001
	Control	150	106.6	15993.0		
	Total	300				
Echo left kidney	Case	150	184.5	27681.0	4644.0	0.0001
	Control	150	102.8	15414.0		
	Total	300				

The mean cortical thickness on the right and left, respectively, was 1.0 ± 0.2 cm and 1.0 ± 0.2 cm for the hypertensives and 1.2 ± 0.2 cm and 1.3 ± 0.2 cm for the controls. The difference was statistically significant ($P = 0.000$).

The mean renal length for the right and left kidneys was 9.9 ± 0.9 cm and 10.3 ± 0.7 cm for the hypertensives and 10.1 ± 0.7 cm and 10.5 ± 0.6 cm for the controls ($P = 0.090$ and 0.138, respectively). The difference was not statistically significant.

Table 3 shows gender variation of renal parameters. In the hypertensive group, the mean value for the renal parenchymal volume was higher on the left and also higher in males compared to females. The difference in values was statistically significant for the right parenchymal volume but not the left. The mean renal parenchymal volume on the right was 106.4 ± 24.7 cm^3 and 95.0 ± 25.4 cm^3 for males and females, respectively; $P = 0.008$. The values for cortical thickness were similar (1.0 cm) and were not statistically significant ($P = 0.829$ and 0.932 on the right and left, respectively). The mean values for the renal length did not show any statistically significant gender variation ($P = 0.700$ and 0.118 for the right and left, respectively).

For the controls, the mean renal parameters were higher in males compared to females and on the left compared to the right. The mean renal parenchymal volumes are 123.8 ± 19.5 m^3 and 130.5 ± 23.3 cm^3 for males and 96.1 ± 19.7 m^3 and 114.5 ± 30.0 cm^3 for females on the right and left, respectively, and the values were statistically significant ($P = 0.005$ and 0.044) for the right and left parenchymal volumes.

The mean cortical thickness on the left and right is 1.3 ± 0.2 cm and 1.3 ± 0.2 cm for males and 1.2 ± 0.2 cm and 1.1 ± 0.2 cm for females. These values are statistically significant ($P = 0.000$). The renal length showed significant gender variation in the normotensive group ($P = 0.000$ and 0.048).

The cortical echogenicity of hypertensives and normotensives was compared. Twenty-six percent (39) and 24.7% (37) of the hypertensives had echo grading of 0, 58.7% (88) and 63.3% (95) had echo grading of 1, while 15.3% (23) and 12.0% (18) had echo grading of 2 on the right and left kidneys, respectively. For the normotensives, 72% (108) and 74% (111) had echo grading 0, 27.3% (41) and 25.3% (38) had echo grading of 1, while 0.7% (1) had echo grading of 2 in the right and left kidneys, respectively. The variations in the echopattern of the kidneys in both groups were statistically significant, $P = 0.0001$ on the left and right. These are shown in Tables 4a and b.

Discussion

This present study showed mean left renal parenchymal volume to be higher than the right and the same parameters to be higher in males compared to females for both hypertensive and normotensive (control) groups. The difference in the right and left renal parenchymal volume was statistically significant in the normotensive group but not in the hypertensive. Dixit *et al*.[10] measured renal parenchymal volume using ultrasound and the ellipsoid formula in their study among healthy children in India and found a significant correlation between renal parenchymal volume and body somatometric parameters such as age, height, weight, and BSA. The difference in findings between the two studies is because the Indian study population comprised of children. Gao *et al*.[11] measured renal parenchymal volume in normotensive adults using nonenhanced multidetector CT in China. The values obtained in their study were higher than the values found in this study probably because these are two different imaging modalities; also, the radiographic and contrast-induced renal magnification associated with CT may be contributory. Ultrasound has also been documented to underestimate renal volume in some studies because the kidney is not a true ellipsoid.[10,12] CT was not employed in this study due to cost and use of ionizing radiation. Since renal parenchymal volume varies to meet metabolic demands of the individual and is closely related to renal function as documented in a study by Johnson *et al*.,[13] the lower values in the hypertensive group in this study may be related to reduced renal function, which possibly occurs in long-standing, poorly controlled hypertension.

This study also showed that mean cortical thickness was higher in normotensives than hypertensives and also higher in males of both groups compared to the females. The difference in the values among hypertensive and normotensives as well as gender variation was statistically significant. Comparatively, these values were higher than those found in the study by Beland *et al*.[3] in Rhode Island probably because the study population in the latter study consisted of individuals with chronic renal failure (CRF). Similarly, Siddappa *et al*.[14] in India also measured cortical thickness in adults with CRF, and although their values were higher than those found by Beland *et al*.,[3] they also reported that cortical thickness decreased with increased cortical echogenicity in their individuals. Mounier-Vehier *et al*.[7] in France also studied renal cortical thickness among other renal parameters in hypertensives with unilateral renal artery stenosis and found significant cortical atrophy in the kidneys with stenosed renal arteries. Buchholz *et al*.[15] in Karachi Pakistan found the left renal cortical thickness to be higher than the right in their study. Kojima *et al*.[6] in Japan documented decreased cortical tissue and increased heterogeneity in patients with essential hypertension compared with age-matched normotensives in their study using CT to be due to early involvement of the renal cortex in hypertension which seems to affect the renal cortex more than the renal medulla.

The cortical echogenicity in the hypertensives was also higher than the controls in this study. The difference in cortical echogenicity between the two groups was statistically significant (P = 0.0001) for both kidneys. Siddappa *et al*.[14] recorded increased cortical echogenicity on ultrasound in chronic kidney disease patients. Increased cortical echogenicity, though not a specific sign, has been documented to be a pointer to renal parenchymal disease in many studies. A study by Araujo *et al*.[16] found increased cortical echogenicity on ultrasound in various disease conditions and reported that increase in cortical echogenicity progressed as the disease condition worsened. Furthermore, cortical echogenicity was found to be the sonographic parameter that correlated best with renal histopatholological findings such as glomerular sclerosis, tubular atrophy, interstitial fibrosis, and interstitial inflammation in a study by Moghazi *et al*.[17] in Atlanta, USA.

Serum creatinine values were significantly higher among the hypertensive group in this study despite the fact that most of the hypertensive patients were already on therapy with stable blood pressure control; this may be a pointer to underlying hypertension-induced renal damage in the individuals.

Limitations

There were more females than males in the study; this disparity is more marked among the hypertensive group. Although the difference was not statistically significant, there is still a possibility that this may have affected the results obtained in the study.

Conclusion

This study has provided baseline values for renal parenchymal volume and cortical thickness among hypertensives and nonhypertensives in this environment. The values for the renal parameters such as the renal length, renal parenchymal volume, and cortical thickness were found to be lower in hypertensives, but only the cortical thickness was statistically significant. The cortical echogenicity was significantly increased in hypertensives when compared to normotensive individuals. Gender variation in the parameters was significant among the normotensive but not among the hypertensives. Values were higher in the male individuals and on the left in both groups. This study has shown that cortical thickness and cortical echogenicity are strongly affected by essential hypertension. Knowing that these parameters are related to renal function, they may be useful to predict renal involvement in hypertensives. Ultrasonography of the kidneys will be useful, especially in resource-poor settings where sophisticated renal scans with imaging modalities which require ionizing radiation are usually expensive and unavailable.

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Conflicts of interest

There are no conflicts of interest.

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