Original Article

Correlation of renal volume on ultrasound with renal function tests in hypertensives in University of Benin Teaching Hospital

Nkem Nnenna Nwafor, Ademola Adeyemi Adeyekun[1]

Department of Radiology, University of Uyo Teaching Hospital, Uyo, Akwa Ibom State, [1]Department of Radiology, University of Benin Teaching Hospital, Benin City, Edo State, Nigeria

Abstract

Background: Long-standing essential hypertension can initiate changes in renal size and alteration in renal function which can be assessed using ultrasound and biochemical tests, respectively. Ultrasound is a noninvasive and affordable investigative modality that is readily available.

Patients and Methods: One hundred and fifty patients consisting of 54 (36%) males and 96 (64%) females with essential hypertension attending cardiology outpatient clinic were recruited and investigated after obtaining an informed consent. Renal volume was calculated from ultrasound measurement of renal dimensions. Blood sample was assessed for serum creatinine and estimated glomerular filtration rate calculated using the Cockcroft and Gault (CG) and modification of diet in renal disease (MDRD) formulae. Data analysis was performed using Statistical package for Social Sciences version 17.0.

Results: The mean renal volume was 115.7 ± 29.2 cm^3 on the right and 132.4 ± 40.2 cm^3 on the left. The mean renal volumes for males were 126.1 ± 27.9 cm^3 and 141.1 ± 40.6 cm^3 while values for female patients were 109.9 ± 28.2 cm^3 and 127.5 ± 9.4 cm^3 on the right and left, respectively. Differences in renal sizes on both sides were not statistically significant, $P = 0.120$ and 0.063. Values were significantly higher in male patients compared to the female patients, for both sides ($P = 0.001$ and 0.046 on the right and left, respectively). Mean serum creatinine was 0.9 ± 0.03 mg/dl.

Conclusion: Male hypertensive patients had significant higher renal volume values than females. However, renal volume did not correlate with duration of hypertension for all the patients. There was no correlation between renal volume and renal function using CG and MDRD formula.

Keywords: Essential hypertension, renal function, renal volume, ultrasound

Address for correspondence: Dr. Nkem Nnenna Nwafor, Department of Radiology, University of Uyo Teaching Hospital, Uyo, Akwa Ibom State, Nigeria.
E-mail: lovelynenaforever@yahoo.com

INTRODUCTION

Systemic hypertension can be defined as measured blood pressure exceeding 140 mmHg for systolic or 90 mmHg for diastolic or both after three measurements and can be classified into primary or essential hypertension with no known underlying medical cause and secondary hypertension with possible etiologies. Its effect on the kidneys results in decreased renal function that can lead to end-stage renal disease.[1]

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Systemic hypertension is a chronic morbid condition with a high prevalence worldwide. It is a common, important, and major global health problem.[2] It has been documented as a threat to the health of the people in Sub-Saharan African and a major contributor to the morbidity and mortality in the subregion.[3] The prevalence in people of African descent has been found to be higher than in whites even in the same geographical location. The prevalence in a hospital and community-based studies in Benin-City was found to be 20.2%.[4,5] The incidence of end organ damage, especially cardiovascular and renal is on the increase despite advances in management. There is no specific level where cardiovascular and renal complications start to occur, thus the definition of hypertension is arbitrary but is needed for practical reasons in patient assessment and treatment.[6]

Hypertension has been found to cause a change in renal size; a study reported increase in renal size in early stages and decrease in renal size as the disease progresses.[7]

Kidney length is the most easily reproducible parameter in assessing the kidney size; however, kidney volume is superior to length in assessing the kidney size because the shape of the kidneys varies considerably.[8] Creatinine, a breakdown product of muscle cells which is excreted by the kidneys is still the most widely used method of assessing renal function despite criticism. Serum levels of creatinine increase in renal impairment and can be used to calculate estimated glomerular filtration rate (eGFR) using the Cockcroft-Gault (CG) and the modification of diet in renal disease study (MDRD) equations. Serum creatinine has been found in many studies to be a good indicator of true GFR in good health and is a better guide to GFR than serum urea.[1]

Studies have been carried out on renal volume in healthy, hypertensive individuals, transplant patients as well as other chronic renal conditions to establish a relationship between renal volume and function. Various imaging modalities were used to achieve these. There are reports in international and local literature on ultra sound scan assessment of renal volume in normotensive and hypertensive individuals, with some correlating renal volume with levels of renal function.[9,10] Biochemical tests are expensive and may not be readily available in our environment, thus there is need to devise a readily available and affordable method of indirect assessment of renal function in hypertensives.

Ultrasound is a safe imaging modality that is noninvasive, affordable, fast, and readily available for assessing the renal volume and can be repeated frequently during the follow-up of the patient.

The aim of this study is to assess renal volume in hypertensives and correlate it with eGFR.

PATIENTS AND METHODS

This was a prospective cross-sectional descriptive study carried out in the Department of Radiology, University of Benin Teaching Hospital from October 2013 to May 2014. One hundred and fifty adults between the ages of 24 and 86 years who are known hypertensive patients on management for essential hypertension were recruited from cardiology consultant outpatient clinic. Diabetics, pregnant women, patients with renal masses, renal malformation, hydronephrosis, and severely obese patients with body mass index (BMI) of 30 and above were excluded from the study. Written informed consent was obtained and a brief questionnaire was administered. Blood pressure was measured using Welch Allyn adult cuff manual sphygmomanometer and 3M Littmann classic stethoscope and biometric parameters including height and weight were taken with Seca mechanical scale with stadiometer. BMI and body surface area (BSA) were calculated using the formula weight (kg)/height^2 (m^2) for BMI (kg/m^2) and the Dubois and Dubois formula: 0.20247 × height (m) 0.725 × weight (kg) 0.425 for BSA (m^2).

A curvilinear probe with transducer frequency of 3.5–7 MHz of a Sonoace X 6 (Medison Inc., #1003 Daechi-Dong, Seoul, South Korea 2010) ultrasound machine was used. Each individuallaid 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.

For renal size assessment, each individual was asked to lie supine on the couch with the abdomen adequately exposed from upper abdomen to the symphysis pubis. Using the liver on the right and spleen on the left as the acoustic windows, longitudinal, coronal, and transverse scans of the kidneys were obtained in the supine, supine oblique, and prone positions. To obtain renal volume, 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 mid-portion of the kidney in the longitudinal and transverse scans (D1 and D2). These are shown in Figures 1 and 2.

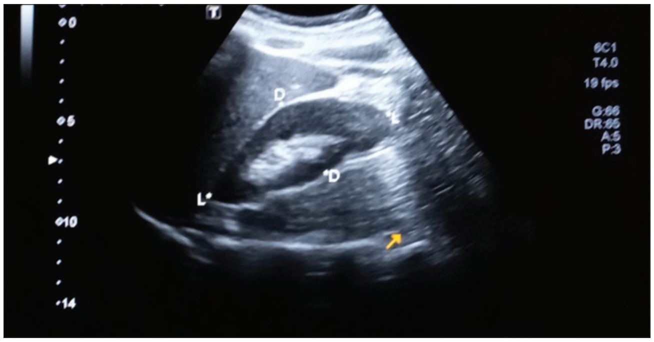

Figure 1: B mode longitudinal ultrasound of the right kidney, Length represents the longest longitudinal diameter between the poles of the kidney and Depth represents the maximum antero-posterior diameter of the kidney measured at the midpole

The kidney volume was obtained using the prolate ellipsoid formula[11] ($L \times W \times D1 + D2/2 \times 0.523$).

Two milliliters of venous blood sample was collected from the antecubital vein under sterile condition using a 5 ml syringe.

EGFR was calculated using these formulae:

Cockcroft– Gault equation:[12]

GFR ml/min = (140-age) (weight in kg)/72 × serum creatinine (mg/mol). Multiply by 0.85 for females.

MDRD equation;[12]

GFR (ml/min/173 m^2) = 186 × serum creatinine$^{-1.154}$ × age$^{-0.203}$ (× 0.742 if female).

All measurements were done by one observer, a senior resident doctor in radiology who has been on training for 3 years, the values were measured three times using the renal protocol for the ultrasound machine and the average value was taken to reduce intra-observer variations.

Data analysis was carried out using IBM SPSS version 17.0 statistics for windows Chicago Illinois, USA. Data comparison (statistical test of significance) was done with Chi-square test for categorical data and *t*-test and analysis of variance for continuous variables. The renal volume was correlated with duration of hypertension from time of clinical diagnosis and eGFR calculated from serum creatinine which represents the renal function. At 95% confidence interval, two-tailed $P \leq 0.05$ was considered statistically significant.

Ethical approval was obtained from the University of Benin Teaching Hospital ethical committee.

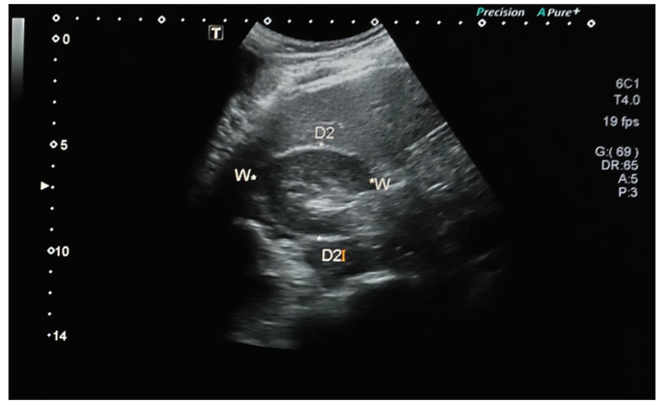

Figure 2: B mode transverse ultrasound of the right kidney at the level of the hilum, Width represents the maximum transverse diameter between the poles of the kidney and D2 represents the maximum antero-posterior diameter of the kidney

RESULTS

One hundred and fifty adult hypertensive patients between the ages of 24 and 86 years participated in this study.

The clinical and laboratory parameters studied showed the mean systolic and diastolic blood pressure of the study population to be 142.1 ± 20.1 mmHg and 83.6 ± 15.3 mmHg, respectively. The mean height and weight of the study group were 1.6 ± 0.6 m and 76.2 ± 15.0 kg, respectively, giving a mean BMI of 28.8 ± 6.3 kg/m^2 while the mean serum creatinine is 0.9 ± 0.03 mg/dl.

The mean renal length for the right and left kidneys were 9.9 ± 0.9 cm and 10.3 ± 0.7 cm, respectively.

The mean renal volume on the right and left were 115.7 ± 29.2 cm^3 and 132.4 ± 40.2 cm^3, respectively. Table 1 shows the mean and range of values for the renal volumes in the different age groups. There is an increase in the mean renal volume up to the 30–39 years age group and a gradual decrease beyond this age group. The lowest mean volume was seen among the 20–29 years age group; 99.7 ± 8.7 cm^3 and 112.1 ± 4.3 cm^3 on the right and left, respectively. The mean renal volume and renal length were apparently higher on the left, the values were also higher in males compared to females but only the values for the right and left renal volumes based on gender differences were statistically significant, $P = 0.001$ and $P = 0.046$, respectively, while $P = 0.700$ and 0.118 for the right and left renal length, respectively, as shown in Table 2.

Table 3 shows correlation of renal length and volume with renal function test. Using the CG formula, the left renal volume as well as the right and left kidney length showed

Table 1: Age range and renal volume distribution in the hypertensives

Age (range)	Mean kidney volume right (cm³)±SD	Range (cm³)	Mean kidney volume left (cm³)±SD	Range (cm³)
20-29	99.7±8.7	98.3-103.7	112.2±4.3	111.8-112.9
30-39	123.3±20.2	20.8-162.2	147.2±28.8	92.8-220.6
40-49	118.7±16.5	63.9-195.7	138.9±25.7	75.3-234.5
50-59	117.4±14.3	57.2-192.1	139.0±27.4	79.0-313.8
60-69	118.5±15.7	68.7-180.3	134.3±22.6	56.1-224.1
>70	116.4±13.1	78.5-218.9	126.9±20.8	47.2-225.7

SD – Standard deviation

statistically significant relationship, ($P = 0.0005$, 0.05, and 0.0001, respectively) while the right renal volume did not show significantly significant relationship, $P = 0.08$. The MDRD formula did not show any statistically significant relationship between the renal parameters and eGFR; $P > 0.05$. Although the P values using CG formula were statistically significant, especially on the left kidney, the correlation coefficient is however very low; $r < 0.3$.

Linear correlation between biophysical parameters and renal sonographic parameters is shown in Table 4. The weight, height, BMI, and BSA show predictive values with $P = 0.001$, 0.008, 0.109, and 0.000, respectively, for the right renal volume and $P = 0.000$, 0.015, 0.000, and 0.000, respectively, for the left renal volume. There is a stronger relationship on the left as compared to the right. Age as a biophysical parameter showed no statistically significant correlation $P = 0.859$ and 0.177 for the right and left renal volumes, respectively.

When renal volume was correlated with duration of hypertension, no statistically significant relationship was established; $P = 0.860$, $r = -0.005$ and $P = 0.947$, $r = -0.003$ on the right and left, respectively.

Figure 3 represents a scatter plot showing multivariate linear regression using age, height, weight, BMI, and BSA as predictors (independent variables) of renal function (dependent variable) in hypertensives, the correlation coefficient $r^2 = 0.3$ indicating a weak predictive value of the biophysical factors when combined together.

Table 2: Renal parameters of the study population according to gender

Parameter	Sex	Mean±SD	*t*-test	*P*
Kidney volume right (cm³)	Male	126.1±27.9	3.4	0.001
	Female	109.9±28.2		
Kidney volume left (cm³)	Male	141.1±40.6	2.0	0.046
	Female	127.5±39.4		
Kidney length right (cm)	Male	10.1±0.8	1.4	0.700
	Female	9.8±1.1		
Kidney length left (cm)	Male	10.5±0.9	1.6	0.118
	Female	10.3±0.8		

SD – Standard deviation

Table 3: Correlation of renal parameters with renal function using Cockcroft and Gault and modification of diet in renal disease equations in hypertensives

	CG		MDRD	
	R	*P*	*R*	*P*
RKV	0.15	0.078	0.08	0.292
LKV	0.23	0.005	0.09	0.211
Right kidney length	0.13	0.05	0.09	0.241
Left kidney length	0.24	0.0001	0.04	0.358

MDRD – Modification of diet in renal disease; CG – Cockcroft and Gault; *R* – Correlation coefficient; RKV – Right kidney volume; LKV – Left kidney volume

Table 4: Linear correlation between biophysical profile and renal parameters in hypertensives

	Age	Weight	Height	BMI	BSA
RKV					
R	0.015	0.280	0.218	0.134	0.291
P	0.859	0.001	0.008	0.109	0.000
LKV					
R	0.111	0.392	0.202	0.307	0.322
P	0.177	0.000	0.015	0.000	0.000

R – Correlation coefficient; RKV – Right kidney volume; LKV – Left kidney volume; BMI – Body mass index; BSA – Body surface area

DISCUSSION

In this study of 150 patients with essential hypertension, there were more females than males. A comprehensive review of hypertension in Nigeria by Ogah *et al.* found higher prevalence in males contrary to the findings of this study.[13] This is probably due to the sampling method in this study coupled with a higher health seeking behavior of females.

The age range of the study population was 24–86 years (mean 62 ± 12.5 years) and more than 50% of the study population were older than 60 years. This is similar to findings in a previous study conducted on patients with essential hypertension by Egberongbe *et al.* in Ile-Ife, Nigeria.[10] This is probably because essential hypertension generally occurs more in the older age group in the population where both studies were conducted.

The mean left renal length and volume were found to be higher than the values for the right kidney and renal dimensions were significantly higher in males compared with females. These findings are similar to those of previous studies by Egberongbe *et al.*,[10] and Sanusi *et al.*[14]

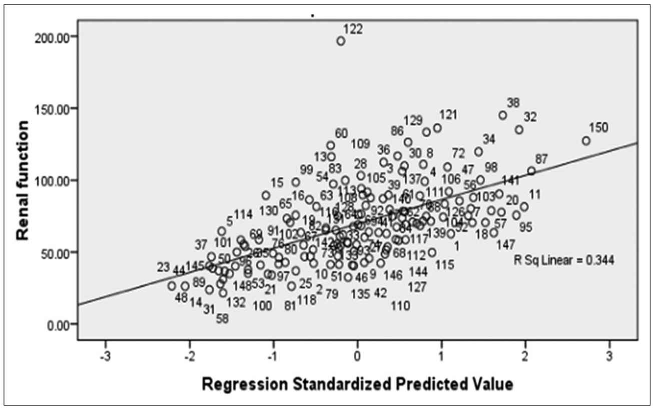

Figure 3: Multivariate linear regression plot using age, height, weight, with body mass index and body surface area as predictors (Independent variables) of renal function (dependent variables) in hypertensives

on patients with essential hypertension and chronic kidney disease, respectively, in Ile-Ife. Emamian *et al*.[9] in Denmark, Okoye *et al*.[15] in Eastern Nigeria, Raza *et al*.[16] in Pakistan, Ohikhokhai *et al*.[17] in Benin-City, Nigeria and Buchholz *et al*.[18] in Karachi, Pakistan all studied normotensive patients and found the relationship between the left and right kidneys and gender variation in the kidney size to be similar to the findings above. This shows that race and gender do not play a significant role among the study populations with regard to kidney size.

There is a gradual increase in renal volume up to the third decade and a gradual decrease as the age increases. This is similar to findings in other studies on normotensives and hypertensives by Egberongbe *et al*.,[10] Sanusi *et al*.,[14] and Buchholz *et al*.,[18] the reduction in size was attributed to a reduction in number of nephrons with advancing age in normotensives and ischemia with resultant reduction in renal parenchymal volume among the hypertensives.[7]

The values for renal volume in the study by Egberongbe *et al*.[10] are similar to the values found in this study, probably due to similarities in ethnic composition of patients in both studies. Odita *et al*.[19] also estimated the kidney length in normal adult Nigerians using excretory urography. Although the left kidney length was higher than the right as seen in this study, their higher values could be attributed to the effect of radiographic magnification and contrast-induced renal enlargement. Shin *et al*.[20] studied renal volume among young Koreans using unenhanced multidetector computed tomography (CT); the mean renal volume in their study was much higher than the values in this study. As seen also with the Odita study,[19] the higher values can be ascribed to the radiographic and contrast-induced renal magnification. Although ultrasound may underestimate the values for renal volume, more accurate imaging modalities such as CT and magnetic resonance imaging are expensive and not always accessible in our setting.

There is a statistically significant relationship between renal volume, renal length, and renal function in this study. This relationship is stronger on the left compared to the right with GFR estimation using CG formula but not with MDRD formula. This is similar to findings in the study by Sanusi *et al*.[14] However, the strong positive correlation between renal length and renal function as reported by Beland *et al*.[7] and between renal volume and renal function was not observed in this study. This study showed weak correlation between renal length and volume with GFR estimation using CG formula, this difference may possibly be because the patients in the above studies had established chronic renal failure.

There was no significant correlation between duration of hypertension and the renal volume in this study. This has also been documented in a previous study in Ile-Ife, Nigeria[10] and this may be due to the fact that estimation of duration of hypertension used for these various studies could not be objectively assessed. The duration in these studies represents the time of clinical diagnosis and it is known that patients with hypertension may be asymptomatic or may not seek proper clinical evaluation in these settings for a significant length of time; the disease may have been ongoing for a long time prior to clinical detection.

Age as a biophysical profile had no effect on the renal volume in this study, there is a statistically significant relationship between the renal volume and BSA, weight, height, and BMI (for the left renal volume) as documented in other studies,[9,18] the strong correlation coefficient was not observed in this study.

CONCLUSION

Ultrasound measured renal volume and length are routinely used for patient monitoring in various disease conditions including hypertension. The values for renal volume and length are higher on the left than the right and higher in males. The decline in renal length and volume with advancing age seen in normal individuals are also noted in hypertensives although this may be accelerated by the disease process. This study has shown that there is no correlation between sonographically derived renal volume/renal length and renal function using CG and MDRD formula among hypertensives and there is no significant relationship between renal function and duration of hypertension. Ultrasound being nonionizing can be used for regular patient monitoring to reduce the rate of hypertension induced renal complications. Renal length, renal volume, and serum creatinine are conventionally used to assess renal status; however, other renal parameters such as cortical thickness and parenchymal volume as well further biochemical tests such as 24 h urine protein and creatinine clearance may be more accurate in assessing the renal function. This study may have been limited by gender bias in favor of females during recruitment of study patients and renal volume measurement based on the ellipsoid formula which may underestimate renal volume.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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