Scientific Research Publishing

Open Journal of Nephrology, 2020, 10, 298-310
https://www.scirp.org/journal/ojneph
ISSN Online: 2164-2869
ISSN Print: 2164-2842

Kidney Volume in Kidney Function Assessment: Determinants and Clinical Correlates in Systemic Hypertension and Chronic Kidney Disease in Southwestern, Nigeria

Uduagbamen PK[1,2*], AdebolaYusuf AO[3], Thompson MU[3], Ajiboye OF[3], Nwogbe CI[1], Oludiran TA[1]

[1]Division of Nephrology and Hypertension, Department of Internal Medicine, Ben Carson (Snr) School of Medicine, Babcock University/Babcock University Teaching Hospital, Ilishan-Remo, Nigeria
[2]Nephrology Unit, Department of Internal Medicine, Federal Medical Centre, Abeokuta, Nigeria
[3]Division of Radiology, Department of Surgery, Babcock University/Babcock University Teaching Hospital, Ilishan-Remo, Nigeria
Email: *petr.uduagbamen@gmail.com

How to cite this paper: Uduagbamen PK, AdebolaYusuf AO, Thompson MU, Ajiboye OF, Nwogbe CI and Oludiran TA (2020) Kidney Volume in Kidney Function Assessment: Determinants and Clinical Correlates in Systemic Hypertension and Chronic Kidney Disease in Southwestern, Nigeria. *Open Journal of Nephrology*, **10**, 298-310.
https://doi.org/10.4236/ojneph.2020.104030

Received: September 8, 2020
Accepted: October 27, 2020
Published: October 30, 2020

Abstract

Background: The kidney volume is a very reliable ultrasound measure, reflecting contributions from all kidney parts. It could be affected by gender, body size and disease conditions. Its use in renal function assessment is based on its correlation with the glomerular filtration rate (GFR). **Objectives:** To assess the determinants and clinical correlates of kidney volume in hypertension and in chronic kidney disease (CKD). **Materials and Methods:** The two-center study was carried out at the Federal Medical Centre, Abeokuta (June-December 2017) and Babcock University Teaching Hospital, Ilishan-Remo (August 2019-January 2020). The kidneys of sixty participants who had hypertension without kidney disease (HWKD) and 58 with CKD were scanned from the front and back and their blood samples were taken for electrolytes and hemoglobin concentration. **Result:** The participants with CKD were significantly older than those with hypertension, $P < 0.001$. The mean kidney volume of hypertensives, 132.4 ± 18.3, was significantly higher than those with CKD, 63.7 ± 5.9, $P < 0.001$. The glomerular filtration rate (GFR) and hemoglobin concentration were significantly higher in hypertensives than in CKD, $P < 0.001$, $P < 0.001$ respectively. The systolic blood pressure (SBP), creatinine and the albumin creatinine ratio (ACR) were significantly higher in CKD than in hypertension, $P < 0.001$, $P < 0.001$ and $P < 0.001$ respectively. **Conclusion:** The mean kidney volume was higher in hypertension and in males. The GFR and hemoglobin levels were significantly

higher in hypertension than in CKD while blood pressure and ACR were significantly higher in CKD than in hypertension. Kidney volume was positively and negatively correlated with GFR and ACR respectively.

Keywords

Kidney Volume, Hemoglobin, Albumin Creatinine Ratio, Hypertension, Correlation

1. Introduction

The tradition of assessing kidney size and functional status using the kidney length is fast eroding. The kidney volume and the cortical thickness are increasingly been incorporated into renal ultrasonography (RUS) due to several factors that undermine the reliability of RUS determined kidney length [1]. The ease of determining the KL compared to the KV and the CT also contributed to its continued use in many centers particularly in resources and personnel scare settings like in most low-income nations like Nigeria [2]. Weish-Rasheid *et al.* found among healthy volunteers, a positive association between kidney length and the body weight [3]. Makusidi and his group found a positive correlation between the glomerular filtration rate and the kidney volume and kidney length in patients with CKD [4]. Korkmaz *et al.* found the renal cortical thickness as a more reliable means of assessing the renal function through RUS compared to the kidney length [5].

The Kidney volume has been reported to be the most reliable parameter for assessing the kidney functional state at ultrasonography [6]. Sanusi *et al.* found a significant positive correlation between the kidney volume and other markers of kidney function assessment among patients with CKD. He and his group found significant interclass agreement between the various parameters of renal function assessment [7]. Buchholz *et al.* found the kidney volume a very reliable RUS parameter for assessing functional status among a healthy population [8]. Jovanovic *et al.* [9] found no correlation between the volume and length of the kidneys in a study where the authors also found no significant kidney size reduction with age as widely reported. An argument in favor of kidney volume is the incorporation of all renal tissue unlike other parameters, such as, cortical thickness (CT) where segmental physiologic or pathologic changes affecting the assessed part may undermine the reliability of the results. Polonia *et al.* reported a progressive yearly decline in renal function by 3.3 ± 8.2 ml/min among Type 2 diabetics [10]. Mclachlan *et al.* in a longitudinal study reported that from middle age, there is a reduction in kidney size of 0.5 cm per decade [11]. The decline in kidney function from middle age can therefore be partly or wholly attributable to the reduction in kidney size. This reduction has been reported not to be uniform as the renal cortex is reported to be more affected compared with the me-

dulla [12]. This further brings to light, the choice and reliability of each RUS measure in conditions with relative cortical sparring such as (diabetes, HIV associated nephropathy) or relative medulla disease (sickle cell nephropathy, obstructive uropathy and toxic nephropathies) or relative pelvicalyceal disease, for instance, hydronephrosis [13].

The gold standard measure for assessing kidney function, the GFR, has an advantage of relevance in acute, subacute and chronic kidney dysfunction as functional alterations are produced in responses to physiologic or pathologic changes and these commonly involve the glomerular filtration [14]. Still, a delayed response is expected when the tubulointerstitial bed is affected causing altered absorptive and secretory function which manifests with urinary changes [15]. Further delays are expected when the responses involve chronic inflammatory changes that lead to fibrosis, thickening, sclerosis, scarring and shortenings, features commonly associated with changes in sizes, texture and structure, that are assessed with RUS. Despite this lag behind in urinary (ACR) and radiologic measures (kidney volume), some reliability is still found when correlation studies are carried out to determine their associations with the GFR [16].

Anemia has been known to be associated with kidney disease and its severity can also be of prognostic value in CKD. Even within this general statement, it is reported that anemia from diseases affecting the tubulointerstitial bed tend to be more severe due to the affectation of the fibroblast cells of the renal peritubularinterstitium, where erythropoietin is produced from [17]. The findings of hyponatremia, hyperkalemia and metabolic acidosis in CKD are also related to the affectation of the Na^+K^+ ATPase, sodium hydrogen exchanger ($NaHE_3$), and the acid secreting Type A intercalated cells of the distal tubules [18]. The defective ion exchange at these transport and exchange levels is seen as the kidney function worsen hence hyponatremia, hypernatremia and metabolic acidosis are common from the third to fourth stage of CKD.

Many studies that assessed kidney volume were either in comparison with other RUS measures or correlations with GFR. Moreover, most of these studies were carried out in the developed world. In our study therefore, we assessed the determinants of kidney volume in hypertension and in chronic kidney disease and determined the correlation between kidney volume and serum (GFR and hemoglobin concentration), and urinary (ACR) measures of kidney function as a way of reducing the knowledge gap.

2. Materials and Method

This was a two-center, hospital based prospective study that lasted for 18 months at the Radiology suites of the Federal Medical Center Abeokuta (January-December 2017) and Babcock University Teaching Hospital (August 2019-January 2020), 118 participants, ≥16 years, who gave written informed consent were consecutively recruited. The participants were made up of 60 hypertensives and 58 with stage 3 or 4 CKD recruited from the Nephrology clinic). Diabetics with or with-

out nephropathy, and those with renal graft, solitary kidney, pelvic tumors, infections, hydronephrosis and obstructive uropathy, renal artery stenosis and missing data were excluded.

Data was taken from a structured interviewer-administered questionnaire and participants' case notes. Sociodemographic data was retrieved from hospital's case files. Participants' height and weight were measured using SECA standiometer (Amazon, United Kingdom) and SECA weighing scale (Amazon, United Kingdom), without shoes, and on light covering. The blood pressure (BP) was taken after 5 minutes rest with a mercury sphygmomanometer (ACCOSON, England). Kidneys were scanned from both front and back after a 3 hour fast. All RUS were done by the same Radiologist.

Kidney volume in cm^3 was calculated by multiplying the length by breath by width in cm [19].

After RUS, blood was taken for creatinine based eGFR and hemoglobin concentration.

Definitions:

Kidney dysfunction using serum-eGFR < 60 ml/min [20].

Kidney dysfunction using urine-ACR > 3.4 mg/mmol [21].

Anemia: Hemoglobin concentration < 13 g/dl [22].

Reduced kidney volume <50 cm^3 [19].

Sample size was calculated from the formula on comparative study using a previous study's prevalence [23]. Categorical variables are presented as proportions and frequencies and compared using Chi square. Continuous variables are presented as mean with standard deviation and compared with student t-test. ANOVA was used to compare three or more variables. Correlation analyses were carried out between kidney volume and the following measures: eGFR, hemoglobin concentration and the urine albumin creatinine ratio.

3. Results

One hundred and eighteen adults participated and had their samples analyzed. The mean age of the participants was 53.3 ± 14.6 years, those with hypertension was 48.4 ± 7.3 and those with CKD was 58.5 ± 6.8, P < 0.001. **Table 1** showed that the sociodemographic, clinical and laboratory characteristics of the participants. The mean BMI of participants with hypertension and those with CKD were 23.5 ± 6.2 and 24.4 ± 3.4 respectively, P = 0.06.

Mean kidney volume of participants with hypertension and with CKD was 132.4 ± 18.3 and 63.7 ± 5.9 respectively, P < 0.001. The radiological findings of the participants are shown in **Table 2**. The mean GFR of participants with hypertension and with CKD were 100.3 ± 22.5 and 46.1 ± 8.4 respectively, P < 0.001. The mean ACR of participants with hypertension and with CKD was 15.0 ± 5.7 and 35.6 ± 8.9 respectively, P < 0.001. The mean hemoglobin concentration of participants with hypertension and with CKD was 14.9 ± 1.2 and 12.2 ± 1.1 respectively, P = 0.001.

Table 3 shows participants' characteristics based on the status of their kidney

Table 1. Sociodemographic, clinical and laboratory characteristics of participants.

Variables		Hypertention Mean ± SD N = 60 (%)	CKD Mean ± SD N = 58 (%)	X^2 t-test	P-value
Gender	Males	38 (63.3)	35 (60.3)	0.8	0.05
	Females	22 (36.7)	23 (39.7)		
Age, years	16.0 - 39.9	9 (15.0)	5 (8.6)	1.6	0.02
	40.0 - 59.9	22 (36.7)	22 (38.0)		
	≥60.0	29 (48.3)	31 (53.4)		
BMI, kg/m^3	<19.5	8 (13.3)	6 (10.3)	1.2	0.04
	19.5 - 24.9	23 (38.3)	24 (41.4)		
	>25.0	29 (48.4)	28 (48.3)		
Mean SBP, mmHg		144.2 ± 7.9	149.3 ± 5.5	3.3	0.002
Mean DBP, mmHg		93.4 ± 2.7	97.6 ± 7.1	1.9	0.04
Mean ACR, mg/mmol		21.1 ± 3.5	38.5 ± 9.5	6.8	<0.001
Mean sodium, mmol/l		142.6 ± 7.4	136.1 ± 3.2	2.4	0.01
Mean potassium, mmol/l		3.7 ± 2.2	4.3 ± 1.8	2.9	0.003
Mean Bicarbonate, mmol/l		24.7 ± 5.8	19.6 ± 2.5	3.3	0.001
Mean chloride, mmol/l		104.4 ± 12.2	99.7 ± 9.7	3.1	0.001
Mean urea, mmol/l		8.7 ± 1.4	11.6 ± 3.5	4.9	<0.001
Uric acid, mmol/l		0.6 ± 0.2	0.9 ± 0.5	3.8	0.001
Mean creatinine, umol/l		102.5 ± 8.8	159.2 ± 11.3	5.7	<0.001
Mean eGFR, ml/min		91.6 ± 3.4	47.1 ± 10.6	7.5	<0.001
Mean Hb conc, g/dl		14.7 ± 3.4	12.9 ± 2.6	5.2	<0.001

CKD—chronic kidney disease, BMI—body mass index, SBP—systolic blood pressure, DBP—diastolic blood pressure, SPO_2—percentage oxygen saturation.

Table 2. Radiological findings of participants.

Variables	Hypertention Mean ± SD N = 60 (%)	CKD Mean ± SD N = 58 (%)	t-test	P-value
Mean kidney length, cm	10.9 ± 3.5	9.1 ± 2.6	5.6	<0.001
Mean kidney breath, cm	4.5 ± 1.4	3.4 ± 1.0	5.9	<0.001
Mean kidney width, cm	2.9 ± 1.2	2.2 ± 1.1	4.2	<0.001
Mean kidney volume, cm^3	132.4 ± 18.3	63.7 ± 5.9	8.4	<0.001

CKD—chronic kidney disease.

volume. The mean age and BMI of hypertensives with reduced kidney volume was less than those with CKD that had reduced kidney volume, $P < 0.001$ and $P = 0.04$ respectively.

The mean systolic and diastolic blood pressure of participants with HWKD that had reduced kidney volume were lower than participants with CKD who had reduced kidney volume, $P < 0.001$ and $P = 0.001$ respectively. The mean serum creatinine and urine ACR of participants with HWKD who had reduced

Table 3. Participants' demographic, clinical and laboratory findings based on kidney volume status.

Variables	Hypertensives KV < 50 cm^3 N = 12 (%) Mean ± SD	CKD KV < 50 cm^3 N = 24 (%) Mean ± SD	X^2 t-test	P-value
Males	5 (41.7)	13 (54.2)	3.4	0.002
Females	7 (58.3)	11 (45.8)		
Mean age, yrs	53.1 ± 12.3	60.3 ± 8.3	4.7	<0.001
Mean BMI, kg/m^3	24.6 ± 5.1	25.9 ± 7.4	1.9	0.04
Mean SBP, mmHg	152.6 ± 2.8	163.6 ± 12.4	5.5	<0.001
Mean DBP, mmHg	99.1 ± 2.3	105.7 ± 7.7	3.2	0.001
Mean creatinine, umol/l	137.2 ± 5.5	176.4 ± 8.4	6.4	<0.001
Mean eGFR, ml/min	63.5 ± 12.8	45.7 ± 8.9	7.1	<0.001
Mean ACR, mg/mmol	28.4 ± 6.2	33.8 ± 14.7	4.0	<0.001
Mean Hb conc, g/dl	12.8 ± 4.2	10.9 ± 5.4	3.7	<0.001

CKD—chronic kidney disease, SBP—systolic blood pressire, DBP—diastolic blood pressure, Hb—hemoglobin concentration, eGFR—estimated glomerular filtration rate, ACR—albumin creatinine ratio, BMI—body mass index.

kidney volume were less compared with participants with CKD who had reduced kidney volume, $P < 0.001$ and $P < 0.001$. The mean eGFR and hemoglobin concentration of participants with HWKD who had reduced kidney volume were higher than in participants with CKD who had reduced kidney volume, $P < 0.001$ and $P < 0.001$ respectively.

Pearson's correlation analysis carried out to ascertain the strength of association between kidney volume and different assessment measures of kidney function in **Table 4**, showed that the positive correlation between kidney volume and GFR was stronger in CKD sufferers (OR—0.11, CI—0.114 - 0.120) than in HWKD (OR—0.098, CI—0.082 - 0.101). The positive correlation between kidney volume and hemoglobin concentration was stronger in hypertensives without kidney disease (OR—0.206, CI—0.198 - 0.245) than in CKD sufferers (OR—0.097, CI—0.095 - 0.098). The negative correlation between kidney volume and urine ACR was stronger in the CKD (OR—0.128, CI—0.119 - 0.129) population than in HWKD (OR—0.056, CI—0.055 - 0.058).

4. Discussion

The kidney volume of hypertensives in our study was higher than those with CKD and the kidney volume was positively correlated with the GFR and the hemoglobin concentration as there was a negative correlation between kidney volume and the urine albumin creatinine ratio. The higher kidney volumes in hypertensives than in CKD mirrors findings by Paquette *et al.* who reported that the mean kidney volume of CKD sufferers was lower than those in health, and those with hypertension [24]. The higher kidney volume could be a pointer

Table 4. Pearson's linear correlation coefficient between kidney volume and eGFR, and ACR, and Hemoglobin concentration between kidney length and cortical thickness.

Variables	r	CI	P	Correlation
KV and glomerular filtration rate				
Participants with hypertension	0.098	0.082 - 0.101	0.55	very weakly positive
Participants with CKD	0.118	0.114 - 0.120	0.39	very weakly positive
KV and hemoglobin concentration				
Participants with hypertension	0.206	0.198 - 0.245	0.07	insignificantly positive
Participants with CKD	0.097	0.095 - 0.098	0.62	very weakly positive
KV and albumin creatinine ratio				
Participants with hypertension	0.056	0.055 - 0.058	0.62	very weakly negative
Participants with CKD	0.128	0.119 - 0.129	0.57	very weakly negative

r—correlation coefficient, CI—confidence interval 95%, KV—kidney volume, GFR—glomerular filtration rate, CKD—chronic kidney disease, ACR—albumin creatinine ratio.

a preserved nephron tissue mass and function. Moreover, hypertension without kidney disease is commonly compensated for by renal tissue hypertrophy with or without hyperplasia. Though these compensatory structural changes could be deleterious on the long run, they present with a "step up" in size and function in the initial stages and this could be detected in RUS. The renal hypertrophy is commonly associated with hyperfiltration and salt wasting [25].

More men than women participated in the study both as hypertensives and with CKD and this agrees with previous findings that found both hypertension and CKD to be commoner in males [26]. The dominance of men in the hypertension and CKD population has partly be attributed to the higher responsiveness to the renin angiotensin aldosterone system (RAAS) pathway. In addition to the greater male responsiveness, Miller *et al.* reported that when RAAS inhibition is commenced, males, after eight weeks showed a depressed response to these drugs [27]. Males that are compliant with their treatment regimen tend to have more poor blood pressure control than treatment compliant women. An implication of this is a faster progression from hypertension to CKD in males than in women. Estrogens as vasodilators in activity also contribute to the lower female prevalence of HTN and CKD [28]. Another reason for the higher prevalence of CKD and faster progression to end stage in males could also be due to the pro-apoptotic and pro-fibrotic activity of androgens in the renal tubules leading to chronic tubulointerstistial nephritis and fibrosis [29].

Hypertensives were younger than those with CKD in our study similar to findings from a previous study [30]. Depending on several factors ranging from genetic to hormonal, environmental and exposures to injurious substances, the length of the lag phase between hypertension and CKD is also dependent on the level of compliance with treatment regimen by hypertensives. Hypertension cause endothelial damage in the kidneys and vascular tissues leading to platelet aggregation, stasis, microthrombi, release of vasoconstricting and pro-inflammatory

cytokines, sluggish flow and atherosclerosis. The resulting chronic hypoperfusion leads to chronic ischemic injury, necrosis with nephron loss, sclerosis and fibrosis. The structural end point is a smaller, more echogenic kidney which can further be indented and calcific (SICK syndrome) found in chronic inflammatory conditions like pyelonephritis, diabetes, reflux disease, analgesic and sickle cell nephropathies [31]. The terminal structural entity therefore, is reduced kidney size and volume in CKD as seen in this study [32].

The higher BMI among participants with CKD than hypertensives in this study reflect the renal function decline typically from the third and fourth stages of CKD that is associated with reduced glomerular filtration, distortion of the glomerular tuft leading to retention of nitrogenous waste and water, and proteinuria. There is interstitial spaces fluid retention (edema) due to reduced oncotic pressure (from hypoalbuminemia) commonly found in CKD sufferers, hence the higher BMI in them, despite the reduced kidney volume [33]. The higher ACR found in the CKD population in this study compared with those with hypertension without kidney disease (HWKD) was also reported by Poudel *et al.* who found a higher ACR in CKD sufferers than in hypertensives without kidney disease [34]. As injury from hypertension continues overtime, the podocytes undergoing surface capping shedding immune complexes into the subepithelial spaces. This leads to foot processes replacement by continuous cytoplasmic bands along the glomerular basement membrane (GBM) with loss of the charge and size selectivity. Podocyte fusion (effacement) causes the loss of albumin, large and/or negatively charged substances into the urine [35].

We found higher levels of serum sodium and bicarbonate with lower potassium, urea and creatinine levels in hypertensives without kidney disease than in CKD as was reported in previous studies [36] [37]. With nephron loss and reduction in renal mass and kidney volume, the secretory and absorptive functions of the renal tubules are depressed coupled with reduced activities of the ion exchangers, transporters and diffusive forces of the tubular apical and basolateral membranes [38]. The higher blood pressure, with salt and water retention in the CKD population, lead to compensatory pressure natriuresis under stimulation by the natriuretic peptides and this partly accounts for the lower sodium found in them as seen in this study [39]. The loss of nephrons could also explain the higher serum potassium in the CKD population from reduced distal tubular (principal cells) exchange between the sodium and potassium and (Type A intercalated cells) exchange between potassium and hydrogen ions [40]. The loss of renal mass and volume with decreasing GFR could explain the decline in nitrogenous waste removal leading to higher blood level as was seen in our study and as previously reported [41] [42].

The higher hemoglobin concentration among HWKD compared to the CKD population found in our study is similar to findings from studies that established links between CKD and anemia [43]. Apart from reduced intake, digestion and assimilation (malnutrition), and increased losses (hemolysis), the reduced nephron mass and volume could cause reduced erythropoietin production from

the peritubular renal interstitium hence higher rates of anemia in the CKD population than in hypertensives without CKD [17]. Due to the pan-renal injury induced by hypertension unlike some diseases with segmental renal tissue affectation, the mass and volume of all anatomical and physiological units of the kidney are commonly reduced in hypertensive kidney disease and this is commonly seen in renal measures using RUS as seen in our study and as reported previously [44].

Females, increasing age, higher BMI, higher blood pressures, lower sodium, bicarbonate and hemoglobin concentration, with elevated nitrogenous waste and urine ACR were more associated with reduced kidney volume in participants. We infer that despite the higher prevalence and severity of hypertension and CKD in males (thereby causing higher losses in kidney volume), the higher prevalence of reduced kidney volume in females in this study could be explained by their lower kidney sizes in health and therefore in disease, as reported by Piras *et al.* [45].

Our study showed in both hypertensives without kidney disease and in CKD, a positive correlation between the kidney volume and 1) the GFR and 2) the hemoglobin concentration. Previous studies have shown a direct relationship between nephron mass (kidney volume) and kidney function in health and in disease [24]. The negative correlation between the kidney volume and urine ACR we found is in agreement with a previous study that found an inverse relationship between kidney function and the degree of proteinuria [34]. The loss of nephron mass and kidney volume is commonly associated with chronic inflammatory changes leading to sclerosis and loss of function of the glomerular tuft with loss of negatively charged heparansulphate which allows a greater albumin loss in the urine [35].

We encountered some limitations in this study, one, creatinine based eGFR was done once hence it was difficult to ascertain conditions that could cause transient reductions or increases in kidney function in participants. RUS, being operator dependent, there could have been mis-representation of structures. It was also difficult to ascertain participants' compliance with the prescribed 3 hour fast. More studies involving a healthy population, and other racial groups are needed to formulate policies that would be widely applicable.

Conclusion: Kidney volume, being the summation of all kidney parts gives a better representation of the amount of renal tissue compared to other RUS measures. The kidney volumes of participants with CKD were less than those with hypertension without kidney disease. The mean kidney volume of females was less in both hypertensives without kidney disease and in CKD despite higher prevalence of both conditions in males. There was a direct relationship between kidney volume and serum sodium, bicarbonate, hemoglobin concentration and the GFR but an inverse relationship with the BMI, blood pressure, serum creatinine, potassium, and urine ACR. Correlation analysis between kidney volume and GFR were stronger in CKD than in hypertension. With hemoglobin concentration, correlation was stronger in hypertension than CKD but with the

ACR, correlation with kidney volume was stronger in CKD than in hypertension without kidney disease.

Acknowledgements

The entire staff of the Radiology Units of the Federal Medical Center, Abeokuta and Babcock University Teaching Hospital, Ilishan-Remo.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Kim, H.C., Yang, D.M., Lee, S.H., *et al*. (2008) Usefulness of Renal Volume Measurements Obtained by a 3-Dimensional Sonographic Transducer with Matrix Electronic Arrays. *Journal of Ultrasound in Medicine*, **27**, 1673-1681. https://doi.org/10.7863/jum.2008.27.12.1673

[2] Emamian, S.A., Nielsen, M.B., Pedersen, J.F., *et al*. (1993) Kidney Dimensions at Sonography: Correlation with Age, Sex, and Habitus in 665 Adult Volunteers. *American Journal of Roentgenology*, **160**, 83-86. https://doi.org/10.2214/ajr.160.1.8416654

[3] El-Reshaid, W. and Abdul-Fattah, H. (2014) Sonographic Assessment of Renal Size in Healthy Adults. *Medical Principles and Practice*, **23**, 432-436. https://doi.org/10.1159/000364876

[4] Makusidi, M.A., Chiijoke, A., Braimoh, K.T., *et al*. (2014) Usefulness of Renal Length and Volume by Ultrasound in Determining Severity of Chronic Kidney Disease. *Saudi Journal of Kidney Diseases and Transplantation*, **25**, 1117-1121. https://doi.org/10.4103/1319-2442.139981

[5] Korkmaz, M., Aras, B., Güneyli, S., *et al*. (2018) Clinical Significance of Renal Cortical Thickness in Patients with Chronic Kidney Disease. *Ultrasonography*, **37**, 50-54. https://doi.org/10.14366/usg.17012

[6] Okur, A., Serin, H.I., Zengin, K., Erkoc, M.F., Tanık, S., Yıldırım, U., *et al*. (2014) Relationship between Kidney Volume and Body Indexes in the Turkish Population Determined Using Ultrasonography. *International Brazilian Journal of Urology*, **40**, 13. https://doi.org/10.1590/S1677-5538.IBJU.2014.06.13

[7] Sanusi, A.A., Arogundade, F.A., Famurewa, O.C., Akintomide, A.O., Soyinka, F.O., *et al*. (2009) Relationship of Ultrasonographically Determined Kidney Volume with Measured GFR, Calculated Creatinine Clearance and Other Parameters in Chronic Kidney Disease (CKD). *Nephrology Dialysis Transplantation*, **24**, 1690-1694. https://doi.org/10.1093/ndt/gfp055

[8] Buchholz, N.P., Abbas, F., Biyabani, S.R., *et al*. (2000) Ultrasonographic Renal Size in Individuals without Known Renal Disease. *Journal of Pakistan Medical Association*, **50**, 12-16.

[9] Jovanovic, D., Branislav, G., Pavlovic, S., *et al*. (2013) Correlation of Kidney Size with Kidney Function and Anthropometric Parameters in Healthy Subjects and Patients with Chronic Kidney Diseases. *Renal Failure*, **35**, 896-900. https://doi.org/10.3109/0886022X.2013.794683

[10] Polonia, J., Azevedo, A., Monte, M., Silva, J.A. and Bertoquini, S. (2017) Annual

Deterioration of Renal Function in Hypertensive Patients with or without Diabetes. *Vascular Health and Risk Management*, **13**, 231. https://doi.org/10.2147/VHRM.S135253

[11] McLachlan, M. and Wasserman, P. (1981) Changes in Sizes and Distensibility of the Aging Kidney. *The British Journal of Radiology*, **54**, 488-491. https://doi.org/10.1259/0007-1285-54-642-488

[12] Su, H.A., Hsieh, H.Y., Lee, C.-T., *et al*. (2019) Reference Ranges for Ultrasonographic Renal Dimensions as Functions of Age and Body Indices: A Retrospective Observational Study in Taiwan. *PLoS ONE*, **14**, e0224785. https://doi.org/10.1371/journal.pone.0224785

[13] Eze, C.U., Eze, C.U. and Adeyomoye, A. (2018) Sonographic Evaluation of Kidney Echogenicity and Morphology among HIV Sero-Positive Adults at Lagos University Teaching Hospital. *Journal of Ultrasound*, **21**, 25-31. https://doi.org/10.1007/s40477-017-0279-9

[14] Levey, A.S., Stevens, L.A., Schmid, C.H., *et al*. (2009) CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration): A New Equation to Estimate Glomerular Filtration Rate. *Annals of Internal Medicine*, **150**, 604-612. https://doi.org/10.7326/0003-4819-150-9-200905050-00006

[15] Lucas, G.N.C., Leitão, A.C.C., Alencar, R.L., Xavier, R.M.F., Daher, E.D.F. and da Silva Jr., G.B. (2019) Pathophysiological Aspect of Nephropathy Caused by Non-Steroidal Anti-Inflammatory Drugs. *Brazilian Journal of Nephrology*, **41**, 124-130. https://doi.org/10.1590/2175-8239-jbn-2018-0107

[16] Menn-Josephy, H., Lee, C.S., Nolin, A., Christov, M., Rybin, D.V., Weinberg, J.M., *et al*. (2016) Renal Interstitial Fibrosis: An Imperfect Predictor of Progression in Some Patient Cohorts. *American Journal of Nephrology*, **44**, 280-299. https://doi.org/10.1159/000449511

[17] Markowitz, G.S. and Perazella, M.A. (2005) Drug-Induced Renal Failure: A Focus on Tubulointerstitial Disease. *Clinica Chimica Acta*, **351**, 31-47. https://doi.org/10.1016/j.cccn.2004.09.005

[18] Ghondup, T. and Qian, Q. (2017) Electrolyte and Acid-Base Disorders in Chronic Kidney Disease and End Stage Kidney Failure. *Blood Purification*, **43**, 179-188. https://doi.org/10.1159/000452725

[19] Egberongbe, A.A., Adetiloye, V.A., Adeyinka, A.O., Afolabi, O.T., Akintomide, A.O. and Ayoola, O.O. (2010) Evaluation of Renal Volume by Ultrasonography in Patients with Essential Hypertensionin Ile-Ife, South Western, Nigeria. *Libyan Journal of Medicine*, **5**, 4848. https://doi.org/10.3402/ljm.v5i0.4848

[20] Uduagbamen, P.K., Salako, B.L., Hamzat, M.A., Kadiri, S. and Arogundade, F.A. (2020) Kidney Function in Frequent Users of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs). *Open Journal of Internal Medicine*, **10**, 69-82. https://doi.org/10.4236/ojim.2020.101007

[21] Weaver, R.G., James, M.T., Ravani, P., Weaver, C.G.W., Lamb, E.J., Tonelli, M., *et al*. (2020) Estimating Urine Albumin-to-Creatinine Ratio from Protein-to-Creatinine Ratio: Development of Equations Using Same-Day Measurements. *Journal of the American Society of Nephrology*, **31**, 591-601. https://doi.org/10.1681/ASN.2019060605

[22] Iseki, K. and Kohagura, K. (2007) Anemia as a Risk Factor for Chronic Kidney Disease. *Kidney International*, **72**, 54-59. https://doi.org/10.1038/sj.ki.5002481

[23] Araoye, M.O. (2003) Sample Size Determination. In: Margaret, O.A., Ed., *Research Methodology with Statistics for Health and Social Sciences*, Nathadex Publishers,

Ilorin, 115-119.

[24] Paquette, K., Fernandes, R.O., Xie, L.F., Cloutier, A., Fallaha, C., Girard-Bock, C., *et al*. (2019) Kidney Size, Renal Function, Ang (Angiotensin) Peptides, and Blood Pressure in Young Adults Born Preterm: The HAPI Study. *Hypertension*, **72**, 918-928. https://doi.org/10.1161/HYPERTENSIONAHA.118.11397

[25] Chagnac, A., Zingerman, B., Rozen-Zvi, B. and Herman-Edelstein, M. (2019) Consequences of Glomerular Hyperfiltration: The Role of Physical Forces in the Pathogenesis of Chronic Kidney Disease in Diabetes and Obesity. *Nephron*, **143**, 38-42. https://doi.org/10.1159/000499486

[26] Alebiosu, C.O., Ayodele, O.O., Abbas, A., Olutoyin, A.I. (2006) Chronic Renal Failure at the OlabisiOnabanjo University Teaching Hospital, Sagamu, Nigeria. *African Health Sciences*, **6**, 132-138.

[27] Miller, J.A., Chernet, D.Z., Duncan, J.A., Lai, V., Burns, K.D., Kennedy, C.R.J., *et al*. (2006) Gender Difference in the Renal Responses to Renin Angiotensin System Blockage. *JASN*, **17**, 2554-2560. https://doi.org/10.1681/ASN.2005101095

[28] Wenner, M.M. and Stachenfeld, N.S. (2012) Blood Pressure and Water Regulation: Understanding Sex Hormone Effects within and between Men and Women. *The Journal of Physiology*, **590**, 5949-5961. https://doi.org/10.1113/jphysiol.2012.236752

[29] Davani-Davari, D., Karimzadeh, I. and Khalili, H. (2019) The Potential Effects of Anabolic-Androgenic Steroids and Growth Hormone as Commonly Used Sport Supplements on the Kidney: A Systematic Review. *BMC Nephrology*, **20**, 198. https://doi.org/10.1186/s12882-019-1384-0

[30] Abad, K., Rivera, F.X. and Owen, J.G. (2018) The Management of Hypertension in Elderly Patients with Chronic Kidney Disease. *Journal of Clinical Outcomes Management*, **25**, 5.

[31] Palit, S. and Kendrick, J. (2014) Vascular Calcification in Chronic Kidney Disease: Role of Disordered Mineral Metabolism. *Current Pharmaceutical Design*, **20**, 5829-5833. https://doi.org/10.2174/1381612820666140212194926

[32] Almén, M.S., Björk, J., Nyman, U., Lindström, V., Jonsson, M., Abrahamson, M., *et al*. (2019) Shrunken Pore Syndrome Is Associated with Increased Levels of Atherosclerosis-Promoting Proteins. *Kidney International Reports*, **4**, 67-79. https://doi.org/10.1016/j.ekir.2018.09.002

[33] Khan, Y.H., Sarriff, A., Adnan, A.S., Khan, A.H. and Mallhi, T.H. (2016) Chronic Kidney Disease, Fluid Overload and Diuretics: A Complicated Triangle. *PLoS ONE*, **11**, e0159335. https://doi.org/10.1371/journal.pone.0159335

[34] Poudel, B., Yadav, B.K., Nepa, A.K., Jha, B. and Raut, K.B. (2012) Prevalence and Association of Microalbuminuria in Essential Hypertensive Patients. *North American Journal of Medicine and Science*, **4**, 331-335. https://doi.org/10.4103/1947-2714.99501

[35] Chin'ombe, N., Msengezi, O. and Matarira, H. (2013) Microalbuminuria in Patients with Chronic Kidney Disease at Parirenyatwa Hospital in Zimbabwe. *The Pan African Medical Journal*, **14**, 39. https://doi.org/10.11604/pamj.2013.14.39.1747

[36] Lin, J., Cheng, Z., Ding, X. and Qian, Q. (2018) Acid-Base and Electrolyte Management in Chronic Kidney Disease and End Stage Renal Disease: Case-Based Discussion. *Blood Purification*, **45**, 179-186. https://doi.org/10.1159/000485155

[37] National Kidney Foundation Guest Editorial (2017) Disturbances in Acid-Base, Potassium, and Sodium Balance in Patients with CKD: New Insights and Novel Therapies. *Advances in Chronic Kidney Disease*, **24**, 272-273. https://doi.org/10.1053/j.ackd.2017.07.001

[38] Oliva-Damaso, N., Oliva-Damaso, E. and Payan, J. (2018) Acute and Chronic Tubulointerstitial Nephritis of Rheumatic Causes. *Rheumatic Disease Clinics of North America*, **44**, 619-633. https://doi.org/10.1016/j.rdc.2018.06.009

[39] Ivy, J.R. and Bailey, M.A. (2014) Pressure Natriuresis and the Renal Control of Arterial Blood Pressure. *The Journal of Physiology*, **592**, 3955-3967. https://doi.org/10.1113/jphysiol.2014.271676

[40] Roy, A., Al-bataineh, M.M. and Pastor-Soler, N.M. (2015) Collecting Duct Intercalated Cell Function and Regulation. *Clinical Journal of the American Society of Nephrology*, **10**, 305-324. https://doi.org/10.2215/CJN.08880914

[41] Vaidya, S.R. and Aeddula, N.R. (2020) Chronic Renal Failure. StatPearls Publishing, Treasure Island.

[42] Sud, M., Tangri, N., Pintilie, M., Levey, A.S. and Naimark, D.M.J. (2016) Progression to Stage 4 Chronic Kidney Disease and Death, Acute Kidney Injury and Hospitalization Risk: A Retrospective Cohort Study. *Nephrology Dialysis Transplantation*, **31**, 1122-1130. https://doi.org/10.1093/ndt/gfv389

[43] Zhou, J., *et al*. (2012) Hemoglobin Targets for Chronic Kidney Disease Patients with Anemia: A Systematic Review and Meta-Analysis. *PLoS ONE*, **7**, e43655. https://doi.org/10.1371/journal.pone.0043655

[44] Nwafor, N.N., Adeyekun, A.A. and Adenike, O.A. (2018) Sonographic Evaluation of Renal Parameters in Individuals with Essential Hypertension and Correlation with Normotensives. *Nigerian Journal of Clinical Practice*, **21**, 578-584. https://doi.org/10.4103/njcp.njcp_57_17

[45] Piras, D., Masala, M., Delitala, A., Urru, S.A.M., Curreli, N., Balaci, N., *et al*. (2020) Kidney Size in Relation to Ageing, Gender, Renal Function, Birthweight and Chronic Kidney Disease Risk Factors in a General Population *Nephrology Dialysis Transplantation*, **35**, 640-647. https://doi.org/10.1093/ndt/gfy270