ESTIMATION OF STANDARD KIDNEY VOLUME IN ADULT NIGERIAN POPULATION: USING 3D RECONSTRUCTION OF ABDOMINAL MULTI DETECTOR COMPUTER TOMOGRAPHY (MDCT) SCAN IMAGES

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ABSTRACT
The kidney volume is an indicator of its size, which depends on the length, breadth and thickness. It can therefore be useful as a quantitative index of value in taking decision during urological management. This study evaluated the kidney volume, length, breadth and thickness among adult Nigerians using MDCT. This research involved retrospective review of abdominal MDCT scan images of 301 patients (male 181, female 120) age (20-65yrs). The data processing includes extra-polating 3D dimension from computer tomography and measuring the maximum length, breadth and thickness of each kidney image. Using clinical prolate ellipsoid formula ($\pi/6$ (kidney index) as kidney volume. Statistical analysis used includes mean, mode, median correlation coefficient and t-test. The kidney volume for male (157.90 cm^3) is larger than female kidney volume (156.60 cm^3). The volume of left kidney (165.70cm^3) is larger than right kidney volume (149.40 cm^3). The left kidney (9.96 cm) is longer than the right kidney (9.86 cm). Correlation coefficient between, the left kidney volume and left kidney length (r = 0.288); breadth (r = 0.565); thickness (r =0.719) while Correlation coefficient between the right kidney volume and right kidney length (r =0.286); breath (r =0.554) and thickness (r = 0.770). Kidney volume, length, breadth and thickness for adult Nigerians were established in this study using MDCT as against previous study estimating volume of kidney using its length only as is in ultrasound, carried out in Eastern Nigeria. These baseline values obtained in this investigation can be used as standard to select appropriate kidney donor and appropriate recipient kidney. The values will also be useful to monitor transplanted kidney in routine follow up, in recipient patient, whenever the need arises for Nigerians.

Keywords: Kidney volume; Kidney transplant; Prolate Ellipsoid formula and MDCT.

INTRODUCTION
Kidney is an organ that varies widely in size due to gender, physical size, ethnicity (Pazvant, *et al*., 2009), and in diseases (Kumar *et al*., 2007). The estimation of renal volume cannot be compromised because it is a clinical and empirical determination of functional state of the kidney (Lalli, 1965 and Poggio, *et al*., 2006). Kidney volume has been recognized as a surrogate biomarker of kidney function (Higashihara, *et al*., 2014).

It also has prognostic value to predict kidney functional determination (Chapman, *et al*., 2012).

It therefore facilitates decision making on the renal management options (Lalli, 1965). Physiologically, the cortex contains 90% of volume of blood while the remaining 10% of renal blood volume in medulla and pelvis (Guyton, 2006). The renal value is therefore function of histomorphometric condition of the kidney (Mounier, *et al*., 2002). Traditionally, kidney length has been considered representing an index of kidney size because of its convenience in measurement.

There are reports of inter-observer variability and poor repeatability in this regard (Ablett *et al.*, 1995). It has also been observed that the indices of the kidney are better represented by the kidney volume than kidney length when considering detection of kidney abnormalities (Shin *et al*., 2009). The prognosis of the kidney transplantation is a function of pre-transplant kidney volume (Poggio *et al*., 2006). There are several ways or methods of estimating the kidney volume, few of them are: Cavalieri principle as carried out in other biological structure (Sahin *et al*., 2003; Pazvant *et al*., 2009); Archimedean principle (Pazvant *et al*., 2009) and elaborate imaging such as magnetic resonance imaging (MRI) (Bakker *et al*., 1999) and multi-detector computed tomography (MDCT) (Shin *et al*., 2009 , Breiman *et al*., 1982). Ultrasound has also been used to estimate kidney sizes especially length and volume (Lee, 1999), but Ultrasound measurement is less reproducible (Bakker *et al*., 1999). MRI and MDCT are the latest development, of more elaborate imaging methods, as they suitable for estimation of organ mass and volume for clinical evaluation.

New 3D reconstruction of CT image and magnetic resonance images are more accurate than 2D ultrasonography (Breiman *et al*., 1982). MDCT provides three dimensional images on the kidney to calculate length, breadth and thickness. MDCT (Fig 1) has synonyms due to its properties and characteristics such as Multi Rows CT, Spiral/Helical CT (Fig 3) and Multi slice spiral CT. The model used for this study was Aquila CXL Toshiba 128 slice (Fig 1). Since there are little or no data about the estimation of organ volume using 3D technique in this part of the world we decided to document the range of various dimensions of kidney length, breadth and thickness (Fig 2.A&B) to calculate kidney index and estimate kidney volume for benefit of Nigerians both at home and abroad when the need arises.

Fig.1: Photograph of MDCT GANTRY MACHINE IN LUTH

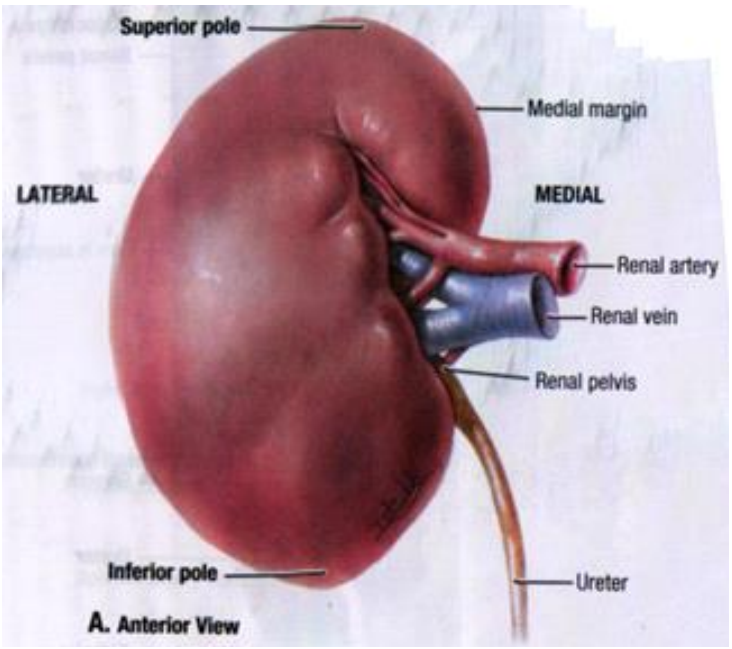

Fig 2A: ANTERIOR VIEW OF THE KIDNEY. (Agur *et al*., 2009)

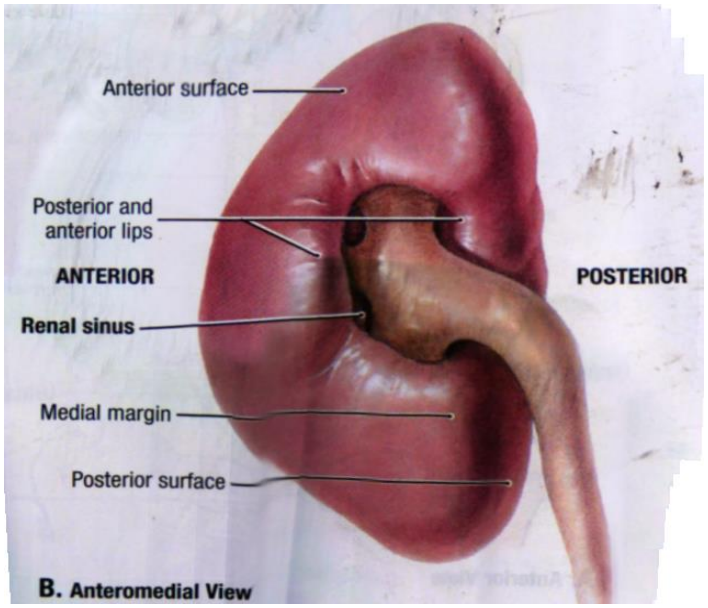

Fig 2B: ANTERIOMEDIA VIEW OF THE KIDNEY (Agur *et al*., 2009)

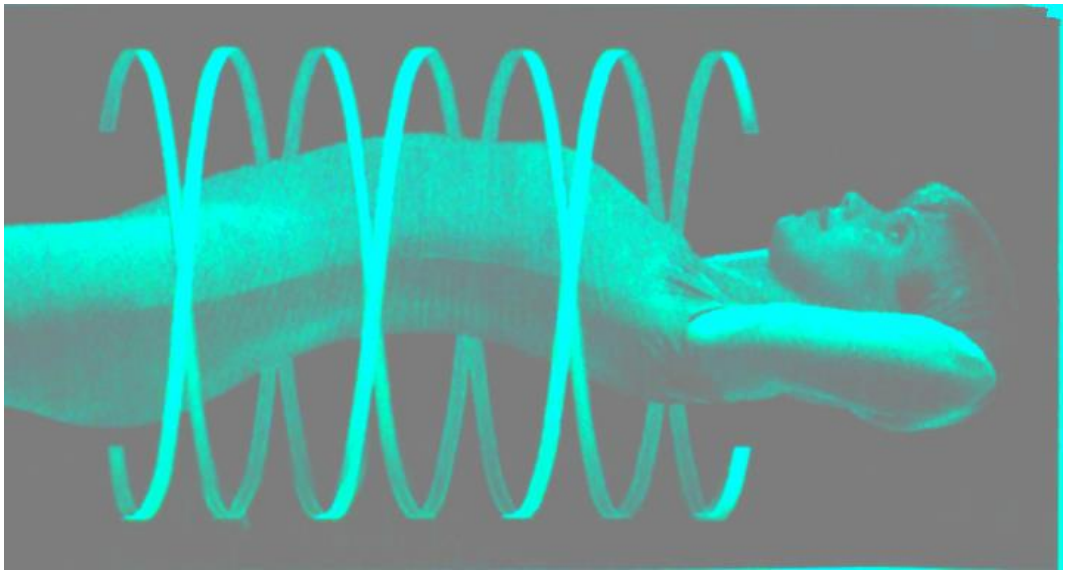

Fig. 3: SPIRAL NATURE OF MDCT (Haaga et al., 2003)

This work is to determine an average normal value for volume of kidney, length, breadth and thickness and their correlation in average adult Nigerian population in comparison with the value of other populations.

MATERIALS AND METHODS

Ethical approval was obtained from Lagos University Teaching Hospital Research and Ethics Committee for this study.

Patient Population

We retrospectively reviewed the abdominal CT scans of 301 Nigerians (male 181 female -120) and ages falling between 20-65 years who had visited the Department of Radio-diagnosis LUTH between July 2013 and November 2014.

The patient population comprised of out-patients and in-patients who required CT examination. The radiologist reports, medical and laboratory reports were also reviewed. These reviews enabled this study to exclude the subjects (patients) with the following criteria: (i) abnormal findings on CT e.g. renal cyst, hydronephrosis, (ii) underlined medical disease like diabetes mellitus or hypertension. Based on these selection criteria, we recruited 301 subjects.

CT and assessment of kidney size

In this retrospective study, axial and cross-sectional images of kidney of the 301 subjects were collected from computer vitrea attached to helical CT scan machine. The model of the machine used was Aquilion CXL Toshiba 128 slice MDCT scanner (Fig 1). The technical parameters of the machine are 250KV potential, 95mA current, 0.5mm slice with 0.35sec rotation time, 72kw x –ray as 150kw system transformer.

The kidney volume was estimated from measurement of maximum length, maximum breadth and maximum thickness on CT images as kidney index. As shown in figures 2. A &B , length is a measure between superior and inferior poles while breadth is a measure between lateral and medial margins at hilum and thickness, as measure between anterior and posterior surfaces of the kidney. The formula ($\pi/6$ (kidney index) used to estimate kidney volume (Bakker, *et al*., 1999, Sommer, *et al*., 2007).

The estimated volume of the kidney was calculated manually by using the standard clinical prolate ellipsoid equation for kidney which is: ($\pi/6$ (kidney index) and is equal to 0.0524 x (max length x max breadth x max thickness).

Statistical analysis

Statistical analysis was performed, using the statistical package SPSS Version 20.0. and the results were considered significant at α level of 0.05.

RESULTS

All the 301 patients in the computer record investigated were from Nigeria, 181 males and 120 females as indicated in table I. The left kidney length (9.96 cm) is longer than the right kidney (9.86cm) but not statistically significant. Likewise, the thickness (5.75cm)

and breadth (5.54 cm) of the left kidney are more than that of right kidney thickness-(5.23cm), and breadth-(5.53cm) but not statistically significant. The value of the left kidney volume (165.66 cm^3), is larger than value of the right kidney volume (149.40 cm^3) but not significantly different. There was no significant difference in male and female value of kidney volume (157.90 cm^3 and 156.60 cm^3 respectively). There was also no significant difference between the right kidney volume (150.20 cm^3) in male and of female right kidney volume (148.00 cm^3).Likewise value for female left kidney volume (165.19 cm^3) is not significantly different from male left kidney volume (165.65 cm^3).

The kidney volume was estimated to be 157.00 cm^3 for both sides and sexes. The estimated 157.50 cm^3 was the kidney volume for male, left and right combined while estimated volume (156.8 $cm^{3)}$ recorded for female. In table 2, kidney volume is correlated with the length, breadth and thickness of the kidney of either sides and for both sexes. Thickness of right kidney has the highest correlation with volume (r = 0.770), followed by breadth (r = 0.554) and length with least value (r = 0.286) . Thickness of left kidney has the highest correlation coefficient (r = 0.719) than breadth (r = 0.564) and length (r =0.288) with kidney volume. Table3. indicated variations in kidney length in accordance with different population values.

Table 1: Biometric analysis of kidney sizes from MDCT

	N	Combine mean ± SD	N	Male mean ± SD	N	Female mean ± SD	P value for t- test
Right kidney							
Length (cm)	301	9.86 ± 0.044	181	9.86 ± 0.7895	120	9.87 ± 0. 726	0.877 not significant
Breath (cm)	301	5.53 ± 0.046	181	5.57 ± 0.792	120	5.47 ± 0. 836	0.28 not significant
Thickness (cm)	301	5.23 ± 0.056	181	5.23 ± 01.19	120	5.22 ± 0.917	0.927 not significant
Volume (cm^3)	301	149.40± 0.0011	181	150.20+0.74	120	148.00± 0.556	0.625 not significant
Left Kidney							
Length (cm)	301	9.96 ± 0.063	181	9.91 ± 1.22	120	10.00 ± 1.07	0.393 not significant
Breath (cm)	301	5.54 ± 0.053	181	5.50 + 0. 82	120	5.57 ± 0.96	0.510 not significant
Thickness (cm)	301	5.75 ± 0.068	181	5.81 ± 1.57	120	5.66 ± 1.22	0.274 not significant
Volume (cm^3)	301	165.70+ 0.0002	181	165.65+ 1.57	120	165.19+ 1.25	0.983 not significant
Average of both Kidneys							
Length (cm)	301	9.89 ± 0.053	181	9.88 + 0. 958	120	9.94+ 0.83	Not significant
Breath (cm)	301	5.53 ± 0.049	181	5.58 + 0. 807	120	5.52+ 0.74	Not significant
Thickness (cm)	301	5.49 ± 0.062	181	5.58 ± 1.88	120	5.40+ 1.22	Not significant
Volume (cm^3)	301	157.54 +0.0001	181	157.90 + 1.45	120	156.60+ 0.74	Not significant

Table 2: Correlation coefficient between kidney volume and length breath and thickness

Combine	Volume of Right kidney (r)	Volume of Left kidney (r)
Length	**0.286**	**0.288**
Breath	**0.554**	**0.565**
Thickness	**0.770**	**0.719**

Table 3: Comparison of renal length reported from different populations

				Renal Length (cm)		
Country	Method	N	Side	Male	Female	All
Nigeria (p resent study)	MDCT	301	R L	9.86 9.91	9.87 10.00	9.86 9.96
Nigeria(Okoye *et al;*2005)	Ultra sound	200	R L	- -	- -	10.33 10.45
India (Prakash *et al* ;2014)	Ultra sound	140	R L	9.67 9.75	9.52 9.67	9.6 9.71
Mexico(Oyuela-*et al.,* 2009)	Ultra sound	153	R L	10.57 10.72	10.29 10.46	10.43 10.58
Pakistan(Buchholz *et al* .,2000)	Autopsies	194	R L	10.6 10.6	10.29 10.46	9.66 9.7
Denmark(Emamian *et al* .,1993)	Ultra sound	665	R L	- -	- -	10.9 10.6
Japan(Tanaka *et al.,* 1989)	Autopsies	5600	R L	11.3 11.5	11.2 11.4	- -
Jamaica(Barton.,2000)	Ultra sound	49	R L	- -	- -	9.7 10.0
Malaysia (Ablett *et al*., 1995)	Ultra sound	205	R L	10.2 10.5	9.8 10.0	- -
South Korea(Kang *et al*., 2007)	Ultra sound	125	R L	- -	- -	10.2 10.5
USA(Brandt *et al.,* 2013)	Ultra sound		R L	- -	- -	10.7 11.1
Iran(Hekmatnia *et al.,* 2004)	Ultra sound	400	R L	11.0 11.3	10.7 10.9	10.9 11.1
(North) India(Sahni *et al.,* 2001)	Autopsies	239	R L	9.95 9.97	9.13 9.21	9.66 9.7

DISCUSSION

The result from this present retrospective study presented the normal kidney volume estimate with MDCT using clinical prolate ellipsoid formula for adult men and women in Nigeria. Length, breadth and thickness of the left and right kidney were taken into

consideration to estimate the volume of the two kidneys per patient. This approach was also used previously to estimate volume of spleen (Mohammad, *et al*., 2014).

Previous studies (Troell *et al*., 1988, Guyton, 2006) indicated in respect of kidney structure, that cortex, medullar are necessarily important to be captured in the measurement of kidney volume. Shin (2009) has also demonstrated measurement of maximum length, breadth and thickness of an organ and is more relevant to volume estimation than to consider kidney length only. Various imaging tools including MDCT (Shin *et al.,* 2009, Asghar *et al*; 2011)have been used to measure kidney or other organs volume in Western and Asia population to replace ultrasonographic evaluation due to its advantage over others. This includes production of multiple slices of image with less period of rays exposure

There is racial variation in normal body parameter including organ size. Hence, it is not proper to extrapolate the normal kidney volume data of MDCT from other populations to Nigerian population.

Previous investigation was on Ultrasonographic study of kidney size in South East of Nigeria (Okoye *et al*., 2005) with outcome of renal length to be 8.5 – 12.9cm with mean of 10.33 $\pm$ 0.7cm and 10.45 $\pm$ 0.63cm for right and left respectively.

Previous study in contrast to this study used only maximum kidney length (coronal section) to estimate kidney volume in Korean men, using 4 slice helical CT scanner machine (Shin *et al.,* 2009). The study estimated the left kidney length (10.90 cm) and right kidney (10.70 cm) and estimated volume for left kidney (207.32 cm^3), right kidney (203.26 cm^3). Comparing this to present estimated kidney, measurement of maximum right kidney length (9.86 cm), maximum breadth (5.53 cm) and maximum thickness (5.22 cm) and for maximum left kidney length(9.96 cm), maximum breadth (5.53 cm) and maximum thickness (5.75 cm) which were used to estimate renal volume of 157.00 cm^3 for every kidney.

Also, it has already been proved that CT slice examination is an objective and reliable method to measure the kidney volume (Kontre and Owen, 1994). MDCT produces more fine slices as in this study (128 slices) which is of advantage to minimize disparity between real size and measure size.

Previous studies have also engaged a new software and method of processing 3-D reconstruction images of MDCT (Cai *et al*., 2007) as in this study, we used manual calculation from prolate formula. Previous research has concluded that kidney volume is more reliable index of kidney size than kidney length hence recommended use of MDCT for clinical field (Shin *et al*., 2009). We therefore justified in this study by using MDCT and not relying on length of kidney only to estimate kidney volume but to use length,

breadth and thickness of the left and right kidneys of male and female adult in Nigerian population.

This study concluded with the standard kidney volume of 157.00 cm^3 and kidney length left (9.96 cm), and right (9.860 cm) for adult Nigerian. In agreement to earlier study (Shin *et al.*, 2009), length of kidney should not be considered alone for pre-transplant kidney. These results provided insight investigation and comparison for atrophic and hypertrophic kidney. The previous study (Prakash *et al.*, 2014) also in the Western literature, indicated that renal values are for Caucasian population and not applicable to other populations. It also confirmed from the previous study that the value of kidney length in other populations differs, as shown in table2: Caucasian (Emamian *et al.*, 1993); Japanese (Tanaka *et al*., 1988); Korean (Kang *et al.*, 2007) populations. The previous studies have reported similarities among the following populations: Pakistan (Buchholz *et al*., 2000); Malaysia (Ablett *et al.*, 1995); Jamaica (Barton *et al*., 2000)and Nigeria (Okoye *et al*., 2005). This study therefore recommends more study on length breadth and thickness of the kidney using MDCT Cavalieri for different populations

CONCLUSION AND RECOMMENDATION

The estimated baseline values obtained are standard for Nigeria for selecting kidney donor, recipient kidney and follow up review of transplanted kidney. There was no significant different in gender and side volume values. This is an indication that any side of kidney can replace any side and irrespective of the gender involved.

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