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Correlation of ultrasonographic renal volume with modified body mass index in Nigerian indigenous dogs

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The aim of this study was to determine the relationship between ultrasonographic kidney volume and modified body mass index through evaluating the kidney architectural appearance, variations between right and left kidney dimensions and correlation between ultrasonographic kidney volumes and modified body mass index in clinically healthy Nigerian indigenous dogs. The ultrasonography was performed to obtain the kidney dimensions in centimeter for the length (bipolar length), width and height of the kidney for both right and left kidneys to compute for the kidney volume in centimeter cube using the formula for the volume of an ellipsoid (L X W X H X 0.523), while the modified body mass index for dogs was obtained by taking the body weight in kilogram of each dog against the squared length of the trunk. The serum creatinine and urea parameters are within normal limits in dogs used for this study. This research revealed normal kidney architecture with hyperechoic renal capsules, hypoechoic renal cortex, anechoic medullary pyramids and hyperechoic renal pelvis. Left kidneys are significantly larger than the right kidneys and there was a weak positive correlation between right (r^2= 0.21) and left (r^2= 0.18) kidney volumes with modified body mass index in clinically healthy in Nigerian indigenous dogs. In conclusion, the left kidney appeared larger than the right kidney and there is a positive but weak relationship between ultrasonographic kidney volume and modified body mass index in healthy Nigerian indigenous dogs.

Keywords: Kidney dimensions, Kidney volume, Modified BMI, Nigerian indigenous dogs, Ultrasonography

Introduction

Canine kidney diseases pose diagnostic challenges due to their varying clinical presentations. Kidneys are located in the retroperitoneal region (Burk & Feneey, 2003) that performs vital functions in the body such as excreting waste products, maintaining homeostasis, blood production and utilization of mineral calcium (Fitzgerald *et al*., 2011). Many kidney diseases are associated with changes in kidney dimensions (Sohn *et al*., 2016), therefore, the knowledge of normal kidney volume is important, as it can be used for the morphological diagnosis of kidney diseases (Barrera *et al*., 2009) and also useful in monitoring of transplanted kidney (Nyland *et al*., 1997). A method introduced by Mareschal *et al*. (2007) which is the ratio of the kidney length to the aortic luminal diameter as a means to access the kidney size, it has a drawback in the measurement of aortic luminal diameter which is greatly affected by diastolic and systolic phases of cardiac cycle. While kidney volume has since been considered as an accurate and reproducible linear ultrasonographic kidney measurement used in kidney diagnosis in dogs (Nyland *et al*., 1989; Barr, 1990; Felkai *et al*., 1992). Some researchers are of the opinion that normal measurement for canine kidney volume should be based on individual breed because of body size disparity among numerous breed of dogs (Lobacz *et al*., 2012) and researches have reported a positive relationship between the ultrasonographic kidney volume and body weight in dogs (Nyland *et al*., 1989; Barr, 1990; Felkai *et al*., 1992; Sampaio & Araujo, 2002), but there were no available information on its relationship with modified body mass index in dogs.

Body mass index is a predominant indicator for the amount of body fat (Pasco *et al*., 2014). Body mass index has been considered as health indicator because overweight and obesity are implicated as consequence of metabolic syndrome (Murguia-Romero *et al*., 2012). In dogs, there is a strong linkage between overweight and obesity with kidney conditions such as chronic kidney disease (Parker and Freeman, 2011; Tvarijonaviciute *et al*., 2013), urolithiasis (Lekcharoensuk *et al*., 2000) and cancer (Glickman *et al*., 1989; German, 2006) as well as kidney cancer in human (Bhaskaran *et al*., 2014). However, some researchers suggested a modified body mass index for dogs due to the facts of being in pronograde posture, which has great difference in body shapes from that of human (Thengchaisri *et al*., 2014). Body mass index is an objective means of accessing the body condition system through size and weight (Adetola *et al*., 2016), unlike body condition score which is a subjective evaluation of the body condition system (Laflamme, 1997) that does not consider different body sizes of dogs.

Nigerian indigenous dogs are a medium size breed of dogs with moderate hair length and mesocephalic cranial index. There is a paucity of information on the relationship between ultrasonographic kidney volume with modified body mass index parameters in Nigerian indigenous dogs which its clinical importance can be related to the morphological diagnosis of kidney diseases (Nyland *et al*., 1989; Barr, 1990; Sampaio & Araujo, 2002; Barrera *et al*., 2009), therefore there is the need to unveil the relationship between the ultrasonographic kidney volume and modified body mass index in Nigerian indigenous dogs. The aim of this study was to determine the relationship between ultrasonographic kidney volume and modified body mass index through evaluating the kidney architectural appearance, variations between right and left kidney dimensions and correlation between ultrasonographic kidney volumes and modified body mass index in clinically healthy Nigerian indigenous dogs.

Materials and Methods

Animal subjects

One hundred and fifteen (115), males (77) and females (38) apparently healthy Nigerian indigenous dogs in Zaria, with ages ranged from 1 to 4.5 years were selected. The research was performed only on dogs considered healthy on the basis of physical examination, body condition score of 3 using 5 points scale (Baldwin *et al*., 2010), normal serum biochemical profile (Creatinine and Urea). While dogs with the history of renal disease, sonographic anomalies of kidneys, neutered and pregnant dogs were excluded from the research. All experimental procedures and protocol were reviewed and approved by the Ethical Committee of the Ahmadu Bello University, Animal Care and Use Committee (ABUCAUC/2017/008) and informed consent was obtained from all the dog owners, prior to the commencement of the study.

Typical features of Nigerian indigenous dog used in this research that serves as the breed identification were average body size, moderate hair length and mesocephalic cranial index (Plate I).

Kidney ultrasonography

The conscious dogs were humanely restrained physically on dorsal recumbency then the ventrum was clipped from the xiphoid process that runs lateral ways along the caudal border of the last rib and extends posteriorly to the umbilical scar to adequately provide scanning space. After clipping of hairs, aquostic gel (Nacal Medical, England) was liberally applied to both the probe's scanning surface and the clipped area on the ventrum. Scanning procedure was carried out using portable digital B-mode scan machine (C5^{TM} Sonostar Technologies Co., Guangzhou, Guangdong, China) using a 5.0 MHz, curvilinear electronic transducer suitable for veterinary use. Sagittal and transverse planes scan of right and left kidneys were carried out. The left kidney was located between L_1-L_3 with its cranial pole having contact with greater curvature of the stomach and the spleen on its dorsomedial aspect, while the caudal pole having contact with small intestines and the descending colon. The right kidney was deeper and cranially located in the para-costal region located between T_{12}-L_1 with its cranial pole having contact with caudate lobe of the liver and right pancreatic lobe ventromedially. To and fro movement of the transducer at these locations aided focusing of the ultrasound impulse on the kidneys in order to be visible on the B-mode monitor. Once there was a clear image of the kidney on the monitor, the freeze button on the keyboard of the ultrasound machine was pressed and distance measurement mode was activated. To obtain the kidney dimensions in centimeter for both right and left kidneys, scanning on sagittal plane was used to obtained the cranial to caudal poles for measurement of the length of the kidney (bipolar length) (Plate II), while on transverse plane, width (Plate III) and height (Plate IV) of the kidney was recorded by measuring from the medial limit to the lateral limit along the hilus of the kidney and measuring the distance from the dorsal limit to the ventral limit of the kidney respectively. The kidney volume in centimeter cube was estimated using the formula for the volume of an ellipsoid which is the product of kidney length, width, height and 0.523 (V = L X W X H X 0.523) (Barrera *et al*., 2009).

Modified body mass index measurement

The dogs were restrained physically on standing position. Modified body mass index was evaluated by taking the body weight with the aid of a sensitive digital weighing scale (Kubei™) in kilogram for each dog as against the length of the trunk (truncal length) obtained by tape measurements in meters then squared (m^2) from the crest of humeral greater tubercle to the level of ischiatic tubercle at the hind limbs (Thengchaisri *et al*., 2014). The truncal length rather than height was used for the modified body mass index calculation, due to dog's pronograde posture, which has a great difference in body shapes scompared to that of humans.

Plate I: A typical features of Nigerian indigenous dog with average body size, moderate hair length and mesocephalic cranial index

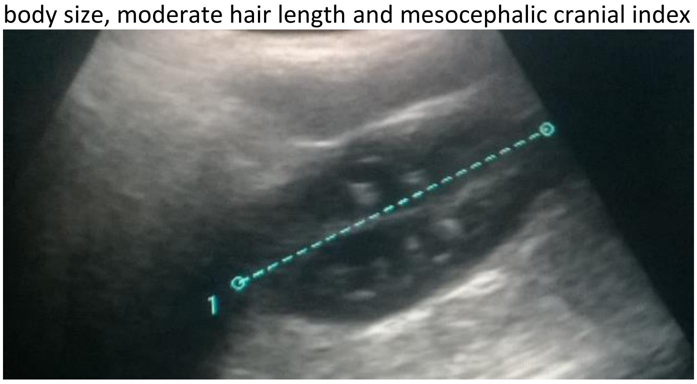

Plate II: Sonographic measurement of kidney length on sagittal plane

Plate III: Sonographic measurement of kidney width on transverse plane

$$\text{MBMI (kg/m}^2) = \frac{\text{weight of animal (kg)}}{\text{Truncal length of animal (m}^2)}$$

Statistical analysis

Data collected were subjected to statistical analysis using Graph Pad Prism® version 5.0 and mean ± SD for each subject was calculated. A paired T-test was conducted to compare data obtained between right and left kidneys and Pearson's correlation coefficient test was used to relate kidney dimensions with modified body mass index. The values of P ≤ 0.05 were considered significant.

Results

Evaluation of biochemical parameters

Mean ± SD of the serum creatinine and urea in Nigerian indigenous dogs are 74.13 ± 24.86 and 4.31 ± 1.23 respectively (Table 1).

Appearance of normal kidneys

On sagittal plane, the shape of the kidneys appeared elongated which are outlined by renal capsules which were represented by a very thin hyperechoic line, immediately after the renal capsule, cortex which is shown to be hypoechoic with smooth echotexture, then medullary pyramids which represent pocket anechoic regions that are surrounded by irregular hyperechoic septa and the centrally located hyperechoic renal pelvis. While on transverse plane, it appeared oval with peripheral hypoechoic and central hyperechoic.

Paired kidney evaluations

Mean ± SD values of the measurement of the right and left kidney volumes are 26.33 ± 10.10 cm^3 and 32.36 ± 11.10 cm^3 respectively for Nigerian indigenous dogs, while the ranges and mean ± SD of the measurement of length, width and height of the right and left kidneys of Nigerian indigenous dogs (Table 2). The left kidney dimensions appeared larger than the right kidney and values for the variation in dimension between the paired kidneys in Nigerian indigenous dogs revealed significant differences ($P < 0.05$) as in kidney length (0.0028), kidney width (0.0065), kidney height (0.0001) and kidney volume (0.0001) (Table 2), so this deduced that left kidneys is statistically larger than the right kidneys in Nigerian indigenous dogs.

Relationship between ultrasonographic kidney volumes with modified body mass index

Ranges and mean ± SD values of the measurement of the ultrasonographic kidney dimensions for Nigerian indigenous dogs (Table 2) and the modified body mass index of Nigerian indigenous dogs ranges from 35.60 Kg/m^2 to 98.14 Kg/m^2 with mean ± SD of 56.56 ± 11.50 Kg/m^2. Correlation between ultrasonographic kidney volumes with modified body mass index in Nigerian indigenous dogs using Pearson's coefficient, showed a weak positive relationship in both right and left kidney volumes as 0.21 and 0.18 respectively (Table 3), which are graphically represented in Figure 1 and 2 respectively.

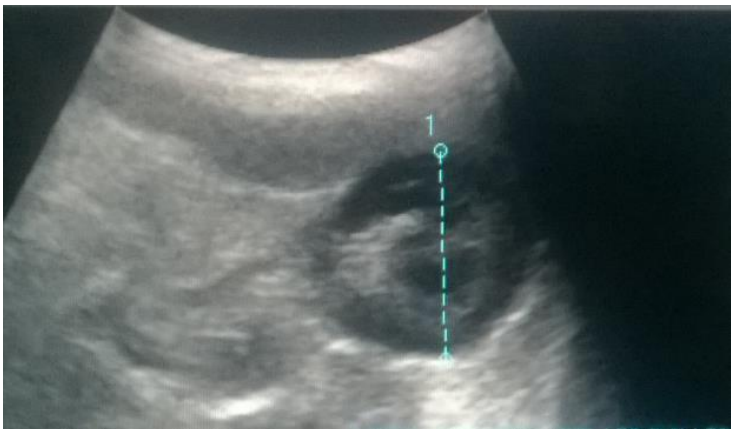

Plate IV: Sonographic measurement of kidney height on transverse plane

Table 1: Evaluation of Biochemical parameters of Nigerian indigenous dogs used in the study

Biochemical parameters	Mean ± SD	Range	Reference values*
Creatinine (umol/l)	74.13 ± 24.86	45.25 – 125.50	40.00 - 130.00
Urea (mmol/l)	4.31 ± 1.23	2.80 – 6.10	2.50 - 7.00

Reference values* (Bush, 1993)

Table 2: Mean right and left kidney dimensions and their comparison in clinically healthy Nigerian indigenous dogs n = 115

	Kidney dimensions				
	Right kidney		Left kidney		
Variables	Range	Mean ± SD	Range	Mean ± SD	Variation (P values)
Kidney length (cm)	3.86 - 7.40	5.54 ± 0.71	4.12 - 7.57	5.81 ± 0.66	0.0028**
Kidney width (cm)	1.86 - 5.00	3.15 ± 0.60	2.04 - 5.42	3.36 ± 0.53	0.0065**
Kidney height (cm)	1.77 - 4.40	2.79 ± 0.49	1.84 - 4.64	3.10 ± 0.56	0.0001***
Kidney volume (cm^3)	9.22 - 63.20	26.33 ± 10.10	13.66 - 70.21	32.36 ± 11.10	0.0001***

** $P \leq 0.01$
*** $P \leq 0.001$

Table 3: Correlation of kidney dimensions with modified body mass index in Nigerian indigenous dogs

Parameters	Right kidney Correlation	Left kidney Correlation
Kidney length (cm)	0.30**	0.37***
Kidney width (cm)	0.083	-0.057
Kidney depth (cm)	0.22**	0.18*
Kidney volume (cm^3)	0.21*	0.18

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

Discussion

The kidney is an intra-abdominal organ usually located in the retroperitoneal space (Burk & Feeney, 2003). Its ultrasonographical image revealed renal cortex with mild echogenicity with finely granular particles, while renal medulla and pelvis are anechoic and irregular hyperechoic appearance respectively and these findings were coincided with the findings done by other researchers (Moarabi *et al*., 2011; Barman & Gaikwad, 2014). The ultrasonographic images of the kidney were obtained using a curvilinear transducer with a frequency of 5.0 MHz, unlike linear transducers that are also suitable for kidney of infants, the convex surface of the curvilinear transducer enabled wide area of impulse coverage and deep tissues penetration and also appropriate for adult subjects like in the case of this study (Saul *et al*., 2011; Dimitrov, 2012; Wieczorek *et al*., 2013; Hansen *et al*., 2016).

The left kidney is significantly large in both male and female Nigerian indigenous dogs. Some studies in Dachshund (Cunha *et al*., 2009) and German shepherd (Kolber & Borelli, 2005) dogs support this finding, while a study reported that right kidney is larger than the left kidney (Mareschal *et al*., 2007) and others reported no differences between right and left kidneys (Sampaio & Araujo,2002; Barella *et al*., 2012; Jeyaraja *et al*., 2015). The variations in this study were due to disparity in body size among various breeds of dogs as explained by Lobacz *et al*. (2012). In human, studies reported the left kidney being larger than the right kidney (Hollinshead, 1971; Raza *et al*., 2011), in explanation for this was suggested by Karim *et al*. (2015) that variation which could be because hepatic tissue may hinder longitudinal development of the right kidney whereas left kidney has liberty for maximum growth without hindrance. Another possible suggestion in human, which could be that the left renal artery being shorter than the right, therefore allow increased blood flow that may cause a slight increase in left kidney volume (Okur *et al*., 2014). Though, puppies above 6 months of age were not evaluated, due to absence of linear transducer and this forms a limitation in the study design, because England (1996) stated that kidneys of puppies at 6 months of age measures proportionately with their body size.

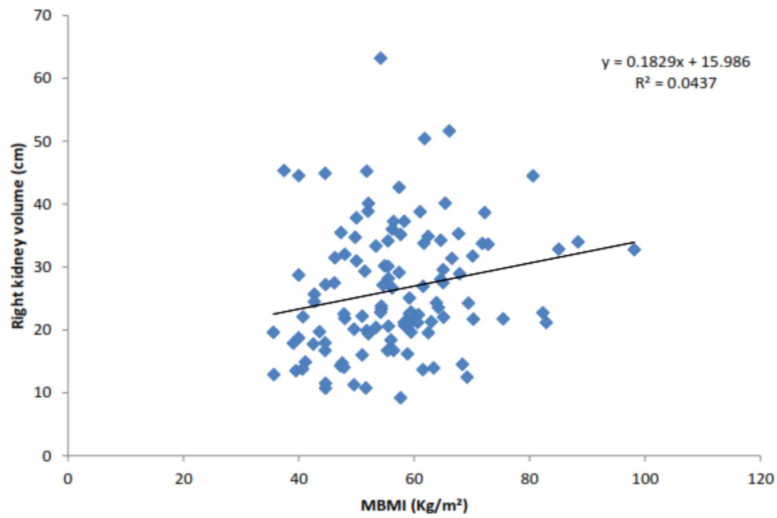

Figure I: Positive linear relationship between modified BMI with right kidney volume

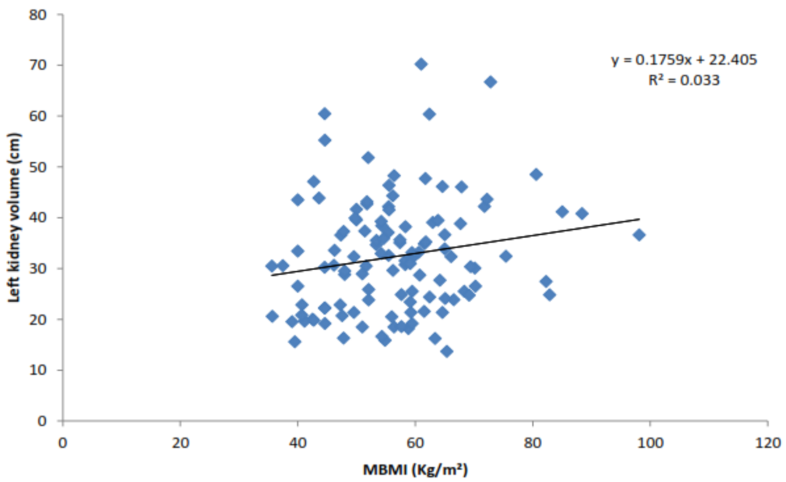

Figure II: Positive linear relationship between modified BMI with left kidney volume

Modified body mass index for dogs is considered in this study because dogs are quadrupeds, so it is preferred to use the truncal length (length of the trunk) of the animal instead of the height as in human, which leads to the establishment of an appropriate morphometric dimension for dogs known as modified body mass index for dogs, as the weight in kilograms per truncal length in meter square (Thengchaisri *et al*., 2014). Even though, some researchers have attempted using the human body mass index for dogs (Koc *et al*., 2009; Adetola *et al*., 2016) but its value increases as the height decrease thereby becoming an inappropriate index for medium and smaller breed of dogs (Adetola *et al*., 2016). There were weak positive correlations between ultrasonographic kidney volume and modified body mass index in Nigerian indigenous dogs. Unfortunately, the correlation between ultrasonographic kidney volume and modified body mass index have not yet been reported in the literature for healthy dogs and to the best of our knowledge, the results obtained in this study is the first to be reported in this species. Several studies in dogs also reported a positive correlation between kidney dimensions and body weight (Nyland *et al*., 1989; Barr, 1990; Felkai *et al*., 1992; Sampaio & Araujo, 2002). However, in human, there were also studies that reported a positive correlation between kidney dimensions and body mass index (Safak *et al*., 2005; Shin *et al*., 2009), while, some studies opposed the findings (Emamian *et al*., 1993; Egberongbe *et al*., 2010). Correlation between the kidney and morphometric dimensions have recently become accepted in the diagnosis of nephropathies (Sampaio & Araujo, 2002; Okur *et al*., 2014). Another limitation to this study was that, dogs with various body condition score were not considered in order to compare its relationships with their ultrasonographical kidney dimensions.

Conclusively, the left kidney appeared larger in dimensions than the right kidney in Nigerian indigenous dogs and correlation between modified body mass index for dogs and ultrasonigraphic kidney volume reveals positive linear relationship with significant correlation with right kidney volume in Nigerian indigenous dogs.

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Conflicts of Interest

The authors declare no conflicts of interest.

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