Morphometric analysis of the kidneys of the adult domesticated African great cane rat *(Thryonomys swinderianus)*

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Summary

The gross anatomy and histomorphometry of the kidney were studied in the adult domesticated African great cane rat (*Thryonomys swinderianus*) also known as the grasscutter. The average weight and age of the cane rats used in the study were 1.93 ± 0.42 kg and 18.80 ± 1.39 months respectively. The mean weights of the left and right kidneys were 3.46 ± 0.19g and 3.57 ± 0.22g respectively, being significantly different ($p<0.05$). The relative kidney weight (left and right) was 0.36%. The mean length of the right kidney was also more than that of the left, being 3.44 ± 0.10 cm and 3.19 ± 0.10 cm respectively, with a significant difference ($p<0.05$). The mean widths of the left and right kidneys were 2.12 ± 0.09 cm and 2.05 ± 0.67 cm respectively. The mean thicknesses of the left and right kidneys were 1.13 ± 0.05 cm and 1.14 ± 0.05 cm respectively. The mean capsular, cortical and medullary thicknesses were 12.50 ± 0.02 µm, 0.26 ± 0.03 cm and 0.85 ± 0.03 cm respectively. The relative medullary thickness, an index of the length of the loop of Henle, was 4.7. The findings of this work provide baseline data that could be relevant in understanding the regional anatomy of the urinary system and the anatomical adaptation for water conservation in the animal.

Key words: Kidney – Cane rat – Relative medullary thickness

Introduction

The grasscutter (*Thryonomys swinderianus*), also known as the African great cane rat (AGCR), is a wild hystricomorphic rodent widely distributed in the African sub-region and is exploited in most areas as a source of animal protein (N.R.C., 1991). The rodent, being the most preferred bush meat in West Africa, including Nigeria, Togo, Benin, Ghana and Cote' d'Ivoire, contributes to both local and export earnings of most West African countries and is therefore hunted aggressively (Asibey and Addo, 2000).

Mammalian kidneys play a dominant role in controlling both the volume and concentration of body fluids. The nephron is the functional unit of the kidney and consists of a glomerulus and well-developed loops of Henle. The morphological and vascular organizations of nephrons enable mammals to produce urine that is significantly more concentrated than their own plasma. Some of these nephrons, "long looped nephrons," are characterized by an extended renal medullary papilla (Bankir and de Rouffignac, 1985), which reflects the great length of the loop of Henle.

Rats in arid zones conserve water and thus survive very well. Their urinary system plays an important role in this water conservation process owing to its ability to concentrate urine (Moffat, 1975). The kidney is that part of the urinary system that is directly responsible for the concentration of the urine, and the loop of Henle has been identified as forming an important part of the concentrating mechanisms of the kidney (Onyeanusi et al., 2009).

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Earlier reports have established a good correlation between the length of the loops and therefore the thickness of the medulla and the ability to concentrate urine in animals (Moffat, 1975; Onyeanusi et al., 2007, 2009).

The study of physiological adaptation and diversity has been a central issue in ecological and evolutionary physiology (Willmer et al., 2000). The environmental tuning of an organism's physiology is often purported to be responsible for allowing an organism to adjust to changing biotic and abiotic conditions through increases in biological performance (Huey and Berrigan, 1996). This is well exemplified by desert-dwelling rodents, for whom maintaining water homeostasis is a significant challenge (Walsberg, 2000). Rodents from arid and semi-arid habitats, where conditions cause the temporal availability of free water to be limited or scarce (Willmer et al., 2000), are faced with the problem of water conservation.

Recent studies on the African great cane rat have focused on management, breeding, haematology, plasma biochemistry and whole blood minerals (Ogunsanmi et al., 2002; Opara et al., 2006). However, there is a dearth of information on the morphometric analysis of the kidneys of the domesticated adult African great cane rat (Thryonomys swinderianus). The present study was therefore designed to investigate the morphometric parameters of the kidneys of the domesticated adult grasscutter with a view to providing basic data that could be relevant for understanding the anatomical adaptation for water conservation through the production of concentrated urine in the animal.

Materials and methods

Experimental Animals

Twenty domesticated adult cane rats were used for the study. They were acquired from a commercial farm in Igbesa, Ogun State, Nigeria. Records about the age and feeding patterns of the animals were also obtained from the farm. The cane rats were kept at the Animal House, Faculty of Veterinary Medicine, University of Ibadan. The cane rats were kept on a daily ration of Guinea corn offal of about 0.2 kg per animal supplemented with raw cassava (*Manihot species*) for 72 hours. They were physically examined and found to be free of any wounds or swelling. The rats were weighed using a Microvar® weighing balance before being anaesthetized and then sacrificed by cervical decapitation.

Biometrical Studies

A mid- ventral abdominal incision was made on each sacrificed animal, after which the peritoneum reflected and the intestine displaced to gain access to the urinary system. The left and right kidneys were then exteriorized. The dimensions of the kidneys were obtained with the use of a metric tape and a vernier caliper. The following dimensions of the left and right kidneys were taken:

Width: Measured from the medial to lateral border.

Length: Measured from the upper to lower pole.

Thickness: Measured from the visceral to the parietal surface.

Histological Procedures

Samples were taken from the kidney and fixed in buffered neutral formaldehyde. These tissues were later processed for histological examinations. Sections of 10 μm thick were stained with Haematoxylin and Eosin. For each parameter (capsular thickness, depths of the cortex and medulla), ten measurements were made per section using a calibrated eye-piece micrometer (Graticules Ltd. Toubridge Kent). The relative medullary thickness (RMT) was then calculated following Sperber (1944):

$$\mathrm{RMT} = \frac{10(\text{medullary thickness})}{(\text{length} \times \text{breadth} \times \text{width})^{1/3}}.$$

Statistical Analysis

All data were expressed as means with the standard errors, and were subjected to statistical analysis using Student's t-test and correlation analysis according to the standard procedure described by Steel and Torrie (1980). Statistical significance was set at $p < 0.05$.

Results

An *in vivo* observation of the kidneys of the domesticated African great cane rat revealed them as being reddish-brown in colour with the right kidney more cranially positioned than the left. They were bean-shaped, smooth and covered with a thin fibro-muscular capsule. Both the left and right kidneys had cranial and caudal surfaces, medial and lateral borders and upper and lower poles. Adipose tissue surrounded the hilus and sides of the kidney. The lateral borders were convex in shape while the medial borders were concave and indented at the hilus. The hilus had renal vessels (entry and exit) with the ureter origi-

Table 1. Biometry of the kidney of the domesticated African great cane rat (*Thryonomys swinderianus*) (n =20).

Mean ± SEM	WTK (g)		LOK (cm)		WDK (cm)		TOK (cm)	
	L	R	L	R	L	R	L	R
	3.47 ± 0.19 ^{a}	3.57 ± 0.22 ^{a}	3.19 ± 0.10 ^{b}	3.44 ± 0.10 ^{b}	2.12 ± 0.09 ^{c}	2.05 ± 0.67 ^{d}	1.13 ± 0.05 ^{e}	1.14 ± 0.05 ^{f}
Correlation Coefficient	0.99		0.95		0.43		0.53	

L: left; R: right; WTK: weight of kidney; LOK: length of kidney; WDK: width of kidney; TOK: thickness of kidney; SEM: standard error of mean. Means with the same superscript within columns are statistically significant ($p<0.05$) while those with different superscript are statistically not significant ($p<0.05$).

Table 2. Mean and S.E.M. values of the micrometrical parameters of the kidney of the domesticated African great cane rat (*Thryonomys swinderianus*) (n =20).

TCP (μm)	TOC (cm)	TOM (cm)	RMC	RMT
12.50 ± 0.02	0.26 ± 0.03	0.85 ± 0.03	3.15 : 1.00	4.7

TCP: thickness of capsule; TOC: thickness of cortex; TOM: thickness of medulla; RMC: ratio of medulla to cortex; RMT: relative medullary thickness.

Table 3. Correlation Coefficients between the weight of the kidney and other renal parameters.

Renal Parameter	Coefficient of Correlation
LOK	0.6917
WDK	0.6406
TOK	0.7327
TCP	0.5312
TOC	0.6513
TOM	0.7015

LOK: length of kidney; WDK: width of kidney; TOK: thickness of kidney; TCP: thickness of capsule; TOC: thickness of cortex; TOM: thickness of medulla.

nating from it. Each kidney lay alongside the vertebral column in the abdominal cavity and at its upper pole was the suprarenal gland. The right kidney was related to the liver while the left was related to the stomach, pancreas, descending colon, spleen and small intestine.

The average weight of the cane rats used for the study was 1.93 ±0.42 kg with an average age of 18.80 ±1.39 months. The mean weights of the left and right kidneys were 3.46 ± 0.19g and 3.57 ± 0.22g respectively (Table 1), being significantly different ($p<0.05$). There was a strong positive correlation ($r = 0.99$) between the weights of the left and right kidneys. The relative kidney weight (both left and right) was 0.36%. Also, the mean length of the right kidney was more than that of the left, being 3.44 ± 0.10 cm and 3.19 ± 0.10 cm respectively, with a significant difference ($p<0.05$). There was a strong positive correlation ($r = 0.95$) between the length of the left and right kidneys. The mean widths of the left and right kidneys were 2.12 ± 0.09 cm and 2.05 ± 0.67 cm respectively. The mean thicknesses of the left and right kidneys were 1.13 ± 0.05 cm and 1.14 ± 0.05 cm respectively. The left and right kidneys did not show any significant difference ($p<0.05$) in terms of width and thickness. There were positive correlations between the weight of the kidney and its width ($r = 0.6406$), on one hand, and its thickness ($r = 0.7327$) on the other (Table 3). The mean capsular, cortical and medullary thicknesses were 12.50 ± 0.02 μm, 0.26 ± 0.03 cm and 0.85 ± 0.03 cm respectively (Table 2). The relative medullary thickness (RMT) was 4.7 (Table 2).

Discussion

The shape and colour of the kidneys of the cane rats observed in this study were similar to those reported for the Wistar rat (Rebel and Stromberg, 1976) and the African giant rat (Onyeanusi et al., 2007, 2009). The anatomical relationships of the left and right kidneys were also similar to previous reports in rodents (Blake, 1977; Diaz and Ojeda, 1999). The 0.36% relative kidney weight obtained in the present study is higher than the 0.25% reported in the African giant rat (Onyeanusi et al., 2007, 2009) but lower than the 0.76 and 0.71% reported in the Wistar rat obtained by Hebel and Stromberg (1976) and Dunns (1967) respectively. The right kidney was heavier than the left one. This finding agrees with those of Dunns (1967), Kozma et al. (1974), Akayevsky (1975) and Onyeanusi et al. (2009). The positive correlations observed between the weight of the kidneys and other dimensions, such as the width and thickness (Table 3), indicated that an increase in size of the kidney would also increase the values of its dimensions.

The relative medullary thickness (RMT) value of 4.7 obtained in the cane rat is similar to that of the African giant rat (4.3), reported by Onyeanusi et al. (2009). It is also similar to those of the dog (4.2) and the cat (4.8) (Schmidt-Nielson and Dell, 1961). RMT values of 6.0, 8.4 and 11 have been reported for the Wistar, Kangaroo and Desert rat, respectively (Schmidt-Nielson and Dell, 1961). Ruckebuch et al. (1991) reported an RMT value of 4.0 for the dog and 4.3 for the cat respectively. This therefore implies that the loop of Henle of the African great cane rat is longer than those of the African giant rat and the dog. The maximum length of the loop of Henle is directly proportional to medullary thickness (Beuchat, 1990). The RMT is an index of the length of the loop of Henle, which acts as a counter current exchanger system and the relative thickness varies directly with the ability to produce hypertonic urine.

Sperber's (1944) work on mammalian kidneys showed a relationship between the length of the renal papilla and the availability of drinking water in the natural habitat. Specifically, mammals from arid and semiarid habitats tended to have exceptionally long loops of Henle, as compared with mammals from mesic habitats. Beuchat (1996) also reported a positive and highly statistically significant relationship between maximum urine osmolality and RMT across 78 species of mammals. The RMT value of 4.7 obtained in the animals used for this study does not suggest any special anatomical adaptation in the urinary system for water economy. However, studies by Tisher (1971) have shown that the rhesus monkey produces concentrated urine in the absence of a well-developed inner medulla and loop of Henle.

The findings from this work provide baseline data concerning the morphometry of the kidney of the cane rat and are consistent with the convergent trends in kidney structure, including a thick medulla relative to kidney size, that have been observed in a variety of lineages of small mammals from diverse habitats (MacMillen and Hinds, 1983). However, maximum loop length alone does not determine variations in urine-concentrating ability. Other important structural characteristics include the arrangement of vascular bundles (the vasa recta) within the medulla, nephron heterogeneity, the presence of extensions of the renal pelvis into the medulla (specialized pelvic fornices), and the degree of confluence of the collecting ducts in the inner medulla (Braun, 1998). Molecular indicators of kidney function, such as vasopressin binding, can also be examined to further determine the ability of cane rat to produce concentrated urine that leads to water conservation in arid environments.

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