VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 70, No. 3, pp. 197–203

ISSN 0015–5659
www.fm.viamedica.pl

The structure of the penis with the associated baculum in the male greater cane rat (*Thryonomys swinderianus*)

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[Received 2 April 2011; Accepted 31 May 2011]

In this study, the structures of penises of eight sexually mature male greater cane rats were examined at both macroscopic and histological levels. Each animal was sacrificed after anaesthesia with ether and then dissected open with the penis exposed from its root. The penises were first grossly examined, measured, and then prepared for histological examination. From this study it was observed that the body size has no allometry with penile size, but the testicular weight correlated with Os penis length in the greater cane rat. Grossly, the penis which was whitish in colour, with a mean length of 5.46 ± 0.36 cm, has no obvious collum penis but a flexura that turns it caudo-ventral and separates the corpus and glans penis. There was the presence of cornified papillae covering parts of the corpus and glans penis as well as a blind sac sacculus urethralis *under the urethra on the glans penis. Histologically, the corpora cavernosa penis were completely separated by a connective tissue septum which sent the trabeculae network into the cavernous tissues and replaced the caverns as it moves from corpus to glans penis. The Os penis formed through endochondral ossification after 42 months of age in this animal. Therefore, from a histological standpoint, the cane rat penis belongs to the intermediate type. In conclusion, these findings provide vital information on the penile anatomy of the greater cane rat, which will serve as a basis for comparing penile morphology among the suborder* hystricomorpha *and expand knowledge of the reproductive biology in this animal.* (Folia Morphol 2011; 70, 3: 197–203)

Key words: penis, baculum, hystricomorphic rodent, reproductive biology

INTRODUCTION

The macro- and micro-anatomical structures of the penis and associated structures of the male reproductive tract have evolved rapidly and divergently in many mammalian orders. Several interpretations have been given and hypotheses advanced to explain the notable variations in the penile and baculum structures within and between mammalian species [22]. These inter-species variations in the penile morphology are particularly remarkable in rodents, which are the widest order of placental mammals and comprise more than half of the mammals currently known [4, 21]. The morphological analysis of the penis is not only of clinical importance [12, 25]

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but can also be extremely useful in reappraisal of the phylogeny as it reveals the many phylogenetic characters in this order [6, 22].

The greater cane rat (*Thryonomys swinderianus)*, popularly known as the Grasscutter, is a wild herbivorous hystricomorphic rodent of African origin [1] that is currently undergoing domestication and captive rearing in the West and Southern African sub-regions. It is vigorously hunted and exploited for food because its meat has an excellent taste, a comparatively high nutritive value [3], and is a meat-of-choice for patients with cardiac problems [19]. Thus a good understanding of the reproductive biology will not only aid the domestication and captive rearing of this animal, it will also enhance increased stock levels and intensification of production practices.

Several investigators have described the anatomy of the penis of both domestic [9, 18] and laboratory animals [7, 8, 11, 15, 20, 23]. However, very little information is available on the anatomy of the penis of wild animals, with no report on that of the greater cane rat. This paper therefore attempts to describe the anatomy of the penis of the greater cane rat (*Thryonomys swinderianus)* with the aim of providing information that is expected to be useful in comparative studies of penile morphology and in testing of phylogenic hypotheses as well as extending knowledge of the reproductive biology in this animal.

MATERIAL AND METHODS

Animals

A total of eight adult male greater cane rats, bred and raised in captivity, were used in the study. All the animals had brownish perineal staining, which was taken as an index of sexual maturity in male cane rats, as reported by Adu and Yeboah [2]. They were maintained on commercial cane feed and elephant grass stems with water given *ad libitum*. The experimental protocol followed the ethical principles in animal research adopted by the Council on Animal Experimentation.

Sample collection, measurements, and processing

The live weight and the linear measurement of the body lengths of each animal were taken. Each animal was then sacrificed after anaesthesia with ether in a closed container and the pelvic cavity was opened up to expose the entire penis from its root. The penises were grossly examined, photographed, and the lengths (from the root to the glans penis) and diameters (corpus) measured. The weights of both testes of each animal were also taken using the weighing balance. For histological examination, the penis was removed from the root, trimmed, and fixed in Bouin's fluid. After being decalcified in 5% nitric acid solution and embedded in paraffin, serial 5 μm sagittal and vertical sections were stained with haematoxylin and eosin (H & E) and van Gieson's Collagen Fibre (vGH) stains. All the slides were examined under an Olympus BX 50 light microscope to evaluate the histological features.

Statistical analysis

All data obtained were expressed as means with standard errors. The data were subjected to correlation analysis to examine the relationship between and within the data using the Microsoft Excel® data analysis tool.

RESULTS

Table 1 showed the mean and standard errors of the body weight and lengths, testicular weight, penile length, penile diameter, and Os penis length while Table 2 showed the relationship between body weights and lengths, the testicular weights, and some penile gross measurements — the penile length, the penile diameter, and the length of the Os penis in the greater cane rats. It was observed that while there was no allometry between the penile size and the body size, a relationship existed between the testicular weight and the penis size (represented by the length and diameter) ($r^2 = 0.57$, $p = 0.05$) as well as between the testicular weights and the length of the Os penis ($r^2 = 0.9$, $p = 0.05$) in this animal.

Table 1. The means and standard errors of some linear measurement of the body, testis, and penile structures in the greater cane rat (*Thryonomys swinderianus* Temmincks)

Parameters	Mean ± standard error
Body weight [g]	2108 ± 331.8
Body length [cm]	40.8 ± 2.59
Testicular weight [g]	1.25 ± 0.47
Penile length [cm]	5.46 ± 0.36
Penile diameter [cm]	0.58 ± 0.08
Os penis length [cm]	1.26 ± 0.25

Table 2. The correlation coefficients between the body weight and length, testicular weight, penile length and diameter, and the length of the Os penis in greater cane rats (*Thryonomys swinderianus* Temmincks)

	Body weight [g]	Body length [cm]	Testicular weight [g]	Penile length [cm]	Penile diameter [cm]	Os penis length [cm]
Body weight [g]	1					
Body length [cm]	0.51	1				
Testicular weight [g]	0.76	0.9	1			
Penile length [cm]	0.01	–0.04	0.57	1		
Penile diameter [cm]	–0.24	0.21	0.57	0.85	1	
Os penis length [cm]	0.55	0.25	0.9	0.7	0.31	1

Macroscopic appearance

The penis of the greater cane rat was attached to the ischiadic arch at the *regio urogenitalis*. This white-coloured organ with a mean length of 5.46 ± ± 0.36 cm was typically composed of a pair of corpora cavernosa penis, a corpus spongiosum penis that housed the penile urethra, and the glans penis, which was incompletely covered by the preputium in the non-erectile state (Fig. 1). The corpus penis was initially directed cranio-ventrally after which it made a prominent flexura (bend) at the point where it joined with the glans penis causing the latter to project caudo-ventrally (Figs. 2, 3). It was observed that there was no collum penis after the glans penis. While the dorsal and lateral surface of the posterior 1/4 of the corpus penis and the anterior part of the glans penis was observed to have cornified papillae, the urethral surface had a prominent raphé preputii (Fig. 3). The mean length of the corpus penis was 4.46 ± 0.45 cm with a mean diameter of 0.58 ± 0.08 cm.

The glans penis in the greater cane rat was observed to be white-coloured and club shaped, and constituted only a minimal portion of the entire penile length with a ratio of 1:5 to the corpus penis (Fig. 3). It had a pointed protrusion at the dorsal surface, which corresponded to the tip of the baculum. The lower part was observed to be rounded forming a blind sac (*sacculus urethralis*) with a median slit below the urethra, which tended to widen in the erectile state thereby increasing the urethral opening (Fig. 3).

The Os penis (Baculum) observed in the cane rat was attached to and continuous with the free end of the corpus cavernosum penis and was fully expressed at the tip of the penis (Fig. 3). This single bone had a broad base with which it was attached to the corpus penis and a narrow shaft that covered the terminal portion of the urethra in the glans penis (Fig. 4). At the urethral surface, the *sulcus urethralis* or the urethral groove was observed to be shallower at the shaft than at the base (Fig. 4). The mean length of the Os penis was 1.26 ± ± 0.25 cm.

Microscopic appearance

It was observed that the tunica albuginea that surrounds the corpora cavernosa penis in the greater cane rat was made up of dense regular connective tissue with smooth muscle cells (Fig. 5). This connective tissue formed a septum which completely divides the corpora cavernosa penis into two compartments and also invades the cavernous tissues with a trabeculae network. It equally surrounded the corpus spongiosum penis, the cavernous tissue that encircled the penile urethra (Fig. 6). The erectile tissues were made up of caverns lined by endothelium and surrounded by dense irregular connective tissues with very few smooth muscles but relatively large cavernous spaces (Fig. 7). It was equally observed that more of the cavernous tissues were replaced by the connective tissue as it moved from the corpus to the glans penis (Fig. 8).

The penile urethra in the cane rat was lined by transitional epithelium, which was transformed into stratified squamous epithelium toward the tip of the glans penis. Penile arteries, diffused lymphatic tissues, and relatively fewer and smaller cavernous spaces were observed in the corpus spongiosum that surrounded the penile urethra (Fig. 9).

The Os penis in this animal was observed to be composed of outer compact bone and inner spongy bone at the posterior part while the distal part that

Figure 1. Non-erectile penis of the greater cane rat (*Thryonomys swinderianus* Temmincks) showing the prepuce (Pc) that incompletely covers the penis (P). Note the scrotal fold (S).

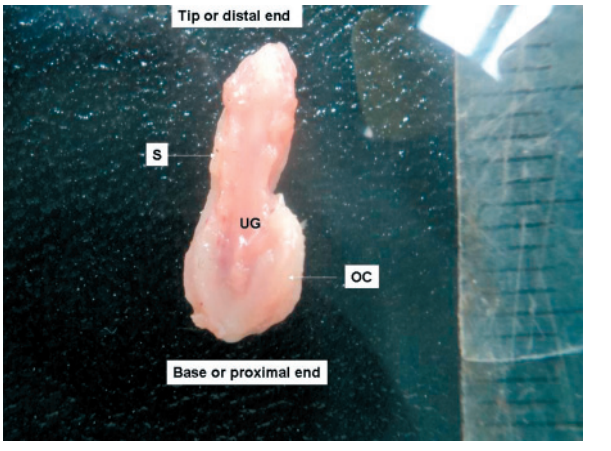

Figure 4. Os penis of the greater cane rat showing the shaft (S) that ends at the tip or distal end of the penis and the base/proximal end which has the ossifying cartilage (OC). Note the urethral groove (UG) that extends through the length of the bone.

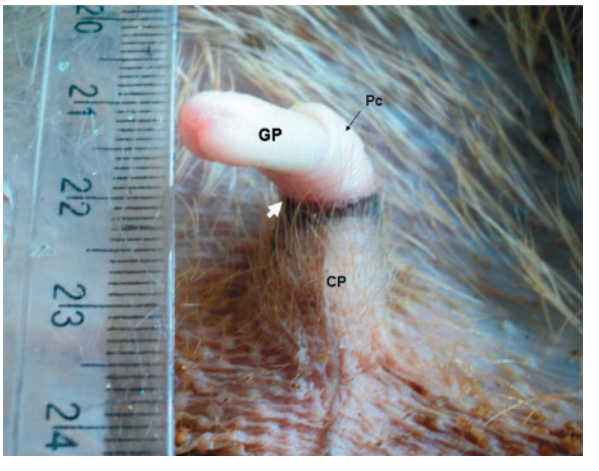

Figure 2. Penis of the greater cane rat with the reflected prepuce (Pc) to expose the glans penis (GP). Note the penile bending/ /flexura (white arrow) and the corpus penis (CP).

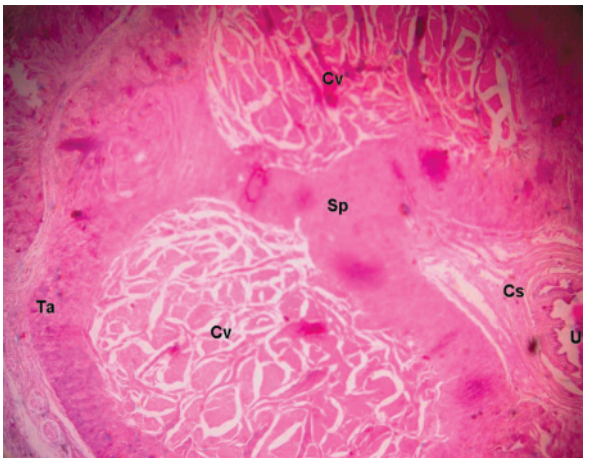

Figure 5. Transverse section of the corpus penis. Note the corpora cavernosa (Cv) completely divided by the septum (Sp) formed by dense connective tissue of the tunica albuginea (Ta). Also note the corpus spongiosum (Cs) that surrounds the urethra (U); H&E × 40.

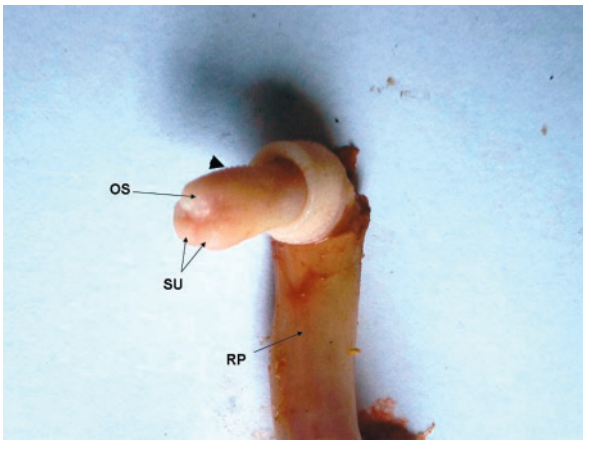

Figure 3. Penis (dissected out) of the cane rat showing the glans penis and the corpus penis. Note the cornified papillae (arrow head), the tip of the Os penis (OS), the *sacculus urethralis* (SU) on the glans penis, and the rapha prepitii (RP) on the corpus penis.

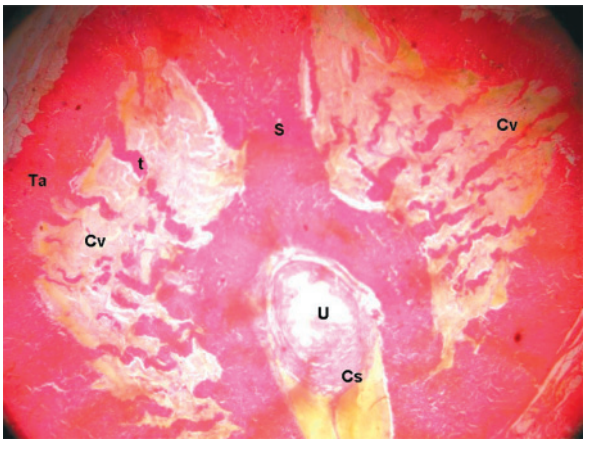

Figure 6. Transverse section of the corpus penis. Note the trabeculae (t) sent into the corpora cavernosa (Cv) from the septum (S) and the tunica albuginea (Ta). Also note the corpus spongiosum (Cs) that surrounds the urethra (U); van Gieson × 40.

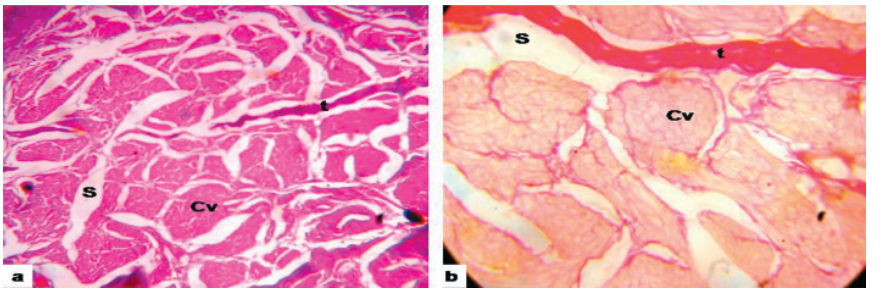

Figure 7. Erectile tissues/caverns. In **A** note the trabeculae (t) sent into the corpora caverns (Cv), and the cavernous space (S) H&E × 100; **B.** van Gieson × 400.

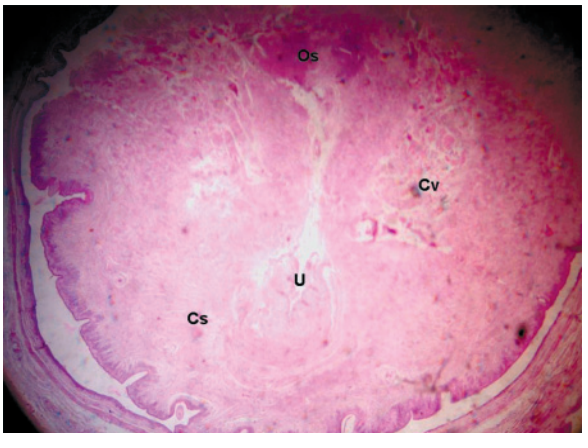

Figure 8. Transverse section of the glans penis. Note the erectile tissues (Cv) being mostly replaced by the corpus spongiosum (Cs) that surround the urethra (U). Also note the Os penis (Os) H&E × 40.

protrudes to the tip of the glans penis is cartilaginous in structure (Fig. 10). While round chondrocytes were observed at the inner portion of the proximal part, hypertrophic chondrocytes were seen close to the bony osteoid of the outer portion suggesting that the outer bone of the proximal part is formed by the ossification of hyaline cartilage (Fig. 10).

DISCUSSION

The penis and its associated structures have provided useful taxonomic characteristics among many groups of mammals while also functioning as a shared outlet for excretion of urine and copulatory ejaculation of semen and spermatozoa. According to Layne [13], the phallus of the few members

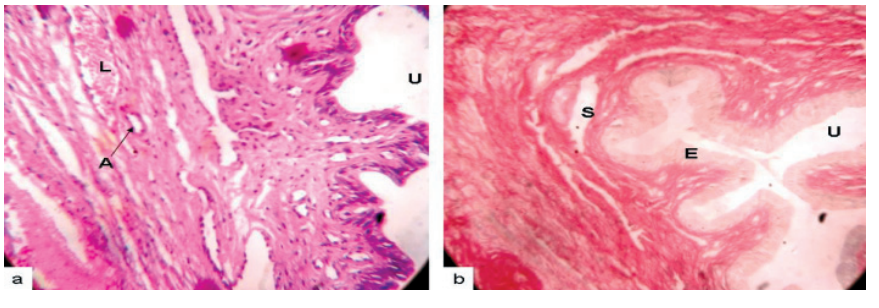

Figure 9. Urethra of the cane rat showing the transitional epithelium (E), penile arteries (A), and lymphatics (L). Note the erectile tissue spaces (S) around the urethral lumen (U); **A.** H&E × 100; **B.** van Gieson × 100.

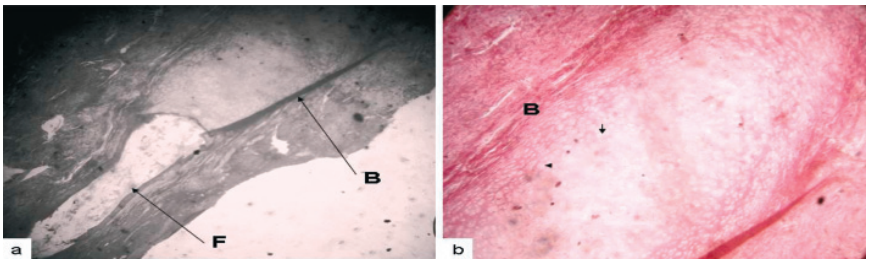

Figure 10. Longitudinal section of the Os penis showing the fibrocartilage (F) at the shaft and the ossifying cartilage (B) at the base. Note the hypertrophied chondrocytes (arrowheads); **A.** H&E (grey scale) × 100; **B.** van Gieson × 400.

of the suborder *hystricomorpha* that have been studied exhibit considerable variability in position, size and shape, armature, and development of the *sacculus urethralis* and baculum. However, the evaluation of the taxonomic significance of these diversities at the species, generic, subfamily and family levels is difficult because the phalluses of relatively few species of the suborder *hystricomorpha* have been studied. The findings in this study provide information on the morphology of the penis of yet another member of *hystricomorpha*, the greater cane rat.

The lack of allometry between body size and penile size observed in the greater cane rat agrees with the observation of Simson et al. [22], who showed that there was no association between the penile size and body size in five genera and six species of *Myoxidae* rodents. In the same vein, the work of Lu et al. [14] reported obvious structural alterations in the penile structure in male adult rats following castration, and that replacement with testosterone could partially restore the impaired structure. Since the testis produces the testosterone, the observed correlation between testicular weight and penile size in the cane rat was expected.

Characteristically, the penis of rodents turns caudo-ventrally after bending from its initial cranio-ventral direction and ends with the glans penis. This finding has been reported in the rat [11], mouse [7, 22], guinea pig and rabbit [20], and porcupine [4]. This study shows that the greater cane rat also demonstrates this interesting peculiarity. However, the evident collum penis that separates the glans and the corpus penis in the rabbit [20] and porcupine [4] is absent in the cane rat.

Layne [13] reported that the unique feature of a typical hystricomorph penis is the presence of a blind sac in the glans penis below the urethra called the *sacculus urethralis*, which becomes everted to form a balloon-like swelling when the penis is erect. Although the cane rat penis was not studied in the erectile state, the observed *sacculus urethralis* affirms this animal as a hystricomorphic rodent. Also, while the glans penis in the cane rat was similar to that of the *Myoxidae* rodent in shape [22], it looks different from that of the porcupine, which has a black colour and can easily be distinguished from the corpus penis [4]. The small cornified papillae which were observed on the corpus and glans penis of the cane rat have also been reported in the cat [18], mouse [16], and porcupine. Since in these species the papillae are considered a secondary sex characteristic, they may also serve the same purpose in the cane rat.

Histologically, the penis of the greater cane rat showed some similarity with that of the dog [24] in that the corpora cavernosa were completely separated by a connective tissue septum. According to Wrobel and Bergmann [24], based on the predominance of erectile tissue (caverns) over the connective tissue and vice versa, penises can be classified into three types, namely: the vascular type, where the caverns predominate; the fibroelastic type, where the connective tissue prevails; and the intermediate type, which is in-between the previous two types. The stallion and man have the vascular type, while the fibroelastic type has been reported in the bull and boar [5]. The intermediate type has been documented in the dog and cat [24]. From this work the penis of the greater cane rat can be classified as the intermediate type. This also agrees with the observations of Atalar and Ceribasi [4], that the penises of carnivores are very similar to those of rodents like the rat, mouse, guinea pig, rabbit, and porcupine.

The observed baculum (Os penis) in the greater cane rat showed a lot of semblance with that of other rodents, particularly the dormouse (Myoxidae), in that it is a single bone with a base and shaft. The urethral groove is of clinical significance because of its possible obstruction by calculi passing through the urethra [10]. While the urethral groove in the dog loses its depth and widens towards the distal end, it does not exhibit any significant change in depth in the fox and mouse [12, 25]. However, the urethral groove in the cane rat differs from that of these animals, and the possible clinical significance of this groove in the cane rat is yet to be determined.

The histology of the Os penis in the cane rat was very similar to that of the rat and mice. The elements of endochondral bone formation from hypertrophied chondrocytes at the proximal part (base) as reported in the mouse and rat by Yildiz et al. [25] was also seen in the cane rat. According to Yilmaz et al. [26], the hyaline cartilage of the proximal end of the Os penis of the adult rat becomes ossified approximately at the 100th day of life. Although the ages of the animals used in this study range between 12 and 42 months, none of their Os penises had a completely ossified base. This means that the growth of the Os penis in the cane rat may continue beyond 42 months since it was equally observed that there is a correlation between length of the Os penis and the testicular weight in this animal. In addition, because it has been reported by Murakami and Mizuno [17] that testosterone influences the chondrogenesis and osteogenesis of the Os penis in the rat,

the strong correlation between testicular weight and Os penis length indicates that these processes are on-going in this animal. The specific age of complete ossification of the Os penis in the cane rat is yet to be determined.

CONCLUSIONS

In conclusion, the present study has provided information on the anatomy of the penis and the baculum in the greater cane rat, which will not only expand the knowledge of the reproductive biology in this animal but also serve as the basis for further research on the variability of the penile morphology among the suborder *hystricomorpha*.

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