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Structure and vascularization of the kidneys of the nutria (*Myocastor coypus*)

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Abstract

Nutria have been raised for fur or meat for many years, the limited number of papers on their kidney anatomical structure prompted us to conduct the present study. The experiment was designed to present and describe the anatomical structure of the kidneys of the nutria (*Myocastor coypus*). It included 6 dead specimens of this species from breeding. The organs in question were initially excised and subjected to more detailed analysis in terms of dimensions, location in the abdominal cavity, but also vascularization. Arteries and veins were injected with red and blue LBS 3060 latex, and we used an electronic caliper to measure individual dimensions. Comparison of the parameters of the two nutria kidneys showed some differences, relative to other rodent species, which are discussed in the discussion.

Running title: Characteristics of the kidneys of the nutria

Keywords: animal anatomy, nutria, kidneys, rodents

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Introduction

Nutria (*Myocastor coypus*) is a large, darkly colored, semi-aquatic rodent. At first glance, it may be misidentified as a beaver (*Castor canadensis*) or a muskrat (*Ondatra zibethicus*). Nutria belong to the family *Myocastoridae*. Nutria has other names, including nutria-rat, South American beaver, Argentine beaver, American beaver and swamp beaver. The nutria population originally ranges south of the equator in temperate South America. Nutria has been introduced to other areas, mainly for fur farming, and its feral populations now inhabit areas in North America, Europe, the Middle East, Africa and Japan [1]. Rodent kidneys have a single renal papilla. The large amount of glomerular filtrate requires a large amount of blood flow through the kidneys, so the renal arteries have a large ratio to the size of the kidneys, and thus about 25% of the blood from one full cardiac output enters the kidneys from the abdominal aorta [2]. An important feature of the generation of osmotic core gradients by countercurrent amplifiers is that the gradient efficiency depends on the length of the loop of Henle. Increasing the length of the loop should result in more concentrated urine. The relative thickness of the medulla accounts for only 59% of the difference in thickening ability between species, suggesting that there are other morphological or physiological factors that significantly affect urine thickening ability [3]. The collecting duct passing through the renal medulla also has the ability to thicken urine according to the action of the countercurrent enhancer [4]. The entire renal cortex is bowl-shaped with upturned edges and surrounds the pyramid-like renal medulla, of which its upper part, the papilla, projects into the renal pelvis. The pelvis is located within the renal sinus, which opens through the renal recess on the medial surface of the kidney [5]. The limited number of studies and scientific records on the anatomy, morphology and vascularization of the kidney in nutria prompted us to conduct the present study. The purpose of this study was to describe the macroscopic structure of the kidney, make accurate measurements, including the vascularization of nutria, and compare the results obtained between selected related animals.

Materials and methods

The study was conducted on specimens in the collection of the Department of Basic and Preclinical Sciences at Nicolaus Copernicus University. Analyzed were 12 kidneys of nutria (*Myocastor coypus*), the animals were from breeding. The organs were measured and preserved, an electronic caliper was used for measurement. Both kidneys were measured in terms of length – at the highest point of the cranial and caudal poles; width – at the widest point of the medial and lateral poles; thickness – between the mural and visceral surfaces, the thickness of the medulla and cortex in longitudinal section was also measured. The position of the kidney in relation to the vertebrae and the lengths of both ureters were also analyzed; they were measured from the renal hilum to the bladder. In order to observe the morphology of the renal arteries, red-stained LBS 3060 latex was injected while the same blue-stained material was injected into the veins; the organs were then preserved in a 10% formalin solution for two weeks in cold storage (3 degrees Celsius), after which the vessels were dissected using surgical instruments. The renal pelvis and renal arteries in two kidneys from a single individual were injected with stained chemically cured DURACRYL® PLUS acrylic (SpofaDental, Jičín); after curing (about 20 minutes), the organs will be subjected to enzymatic maceration, for which Persil powder (Henkel, Düsseldorf) was used at 42 degrees Celsius for two weeks in order to obtain a corrosion-free soft tissue vascular cast. The exact measurements are shown in a table created in Word. On the other hand, photos were taken with a camera (Nikon D3200).

Results

The kidney is surrounded on the outside by a fibrous connective tissue capsule, which is further surrounded by a fatty capsule. The nutria's kidney is smooth unilocular. Into its cavity enter two branches, which are given off by the renal artery, which leaves from the abdominal aorta, while outgoing from it are the renal vein, which runs into the caudal vena cava, and the ureter, which runs into the urinary bladder. In the longitudinal section of the kidney (**Fig. 1,2**), we can see the division into the renal cortex, which is arranged externally, while inside there is the renal medulla, the boundary between the cortex and the medulla is marked by arteries and arch veins. The thickness of the left kidney's medulla was greater compared to that of the cortex, while in the right kidney it was the other way around, with the thickness of the cortex being slightly greater than that of the medulla. The parameters of both kidneys are listed in **table 1**. The left kidney compared to the right kidney was shorter but heavier, it was also slightly wider and thicker. The thickness of the medulla and cortex differed slightly in the two kidneys, with the left kidney being larger than the right kidney. In the abdominal cavity, the right kidney is located more cranially – at the 11/12th thoracic vertebrae, while the left kidney lies at the level of the 13/14th vertebrae. The left ureter was slightly longer than the right ureter (**Fig. 3**), the length of the left ureter was 123.21 mm, while that of the right was 122.64 mm. The left kidney weighed an average of 8.06 g, while the right kidney weighed 7.06 g.

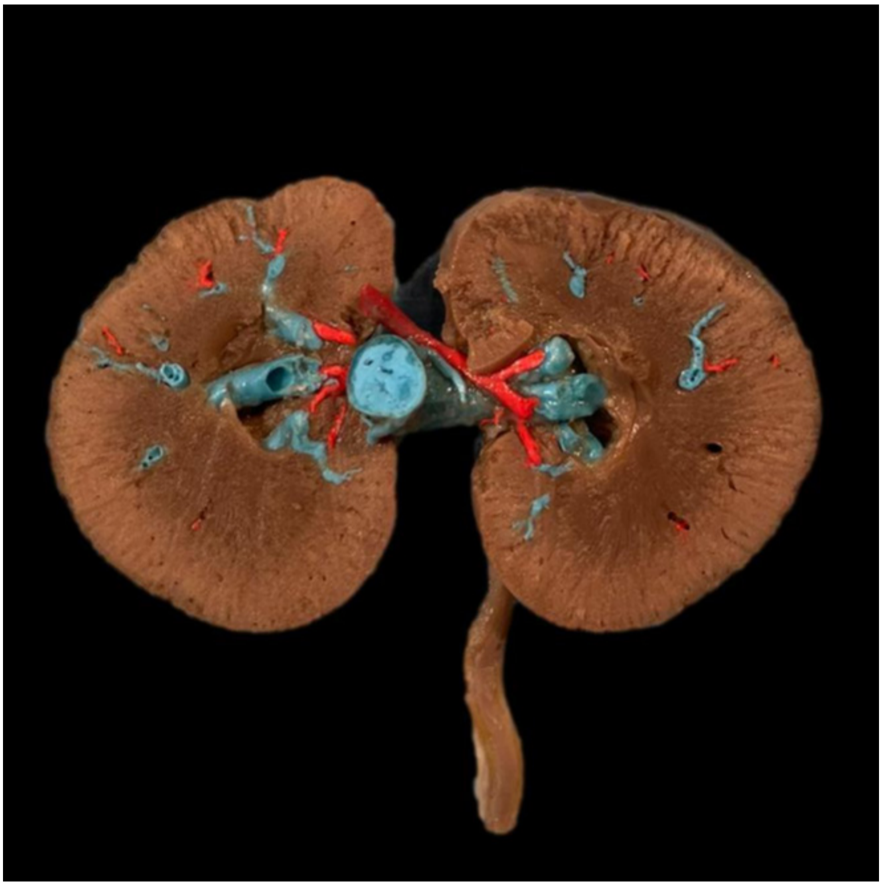

FIGURE 1 Sagittal cross-section of the left kidney of a nutria (*Myocastor coypus*), including latex-injected veins and arteries

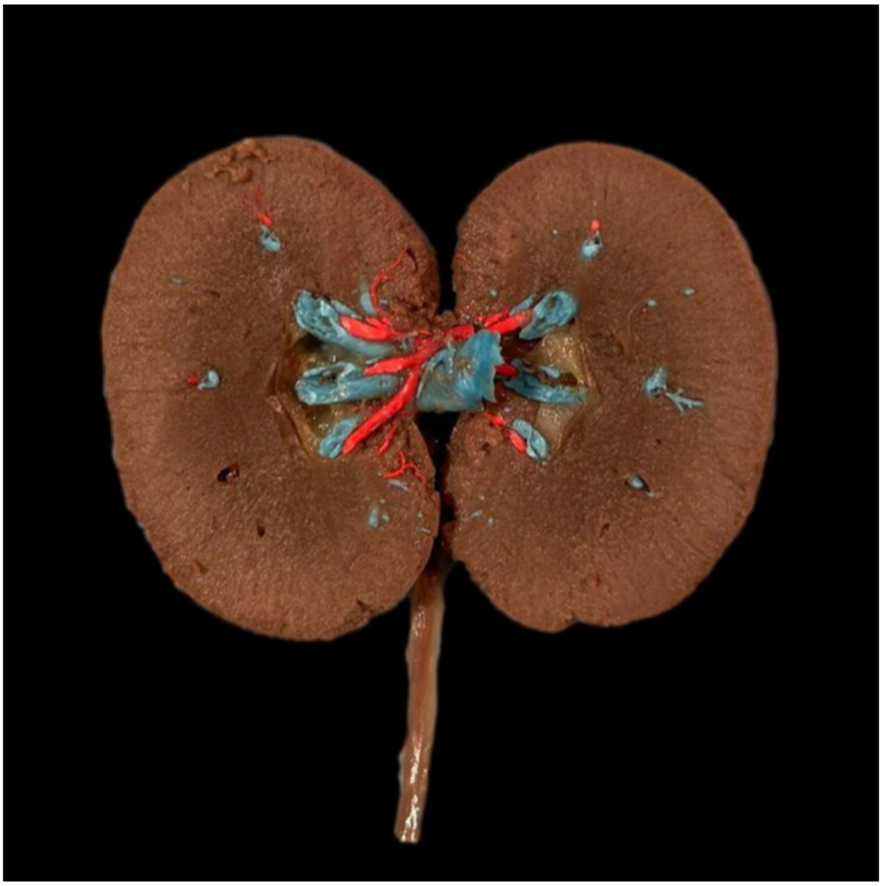

FIGURE 2 The nutria's (*Myocastor coypus*) right kidney in sagittal section, also showing veins and arteries that were injected with latex

TABLE 1 Measurements of the left and right kidneys of nutria (*Myocastor coypus*) – length, width, overall thickness of the organ, thickness of the cortex and medulla, weight

PARAMETERS	LEFT KIDNEY	RIGHT KIDNEY
Length [mm]	30,08 ± 0,79	32,56 ± 1,23
Width [mm]	23,63 ± 5,5	21,19 ± 5,5
Thickness [mm]	13,91 ± 5,31	14,58 ± ٦,٢٣
Core thickness [mm]	6,50 ± 0,87	6,10 ± 1,2
Bark thickness [mm]	6,37 ± 0,87	6,12 ± 0,5
Weight [g]	7,54 ± 0,74	6,71 ± 0,5

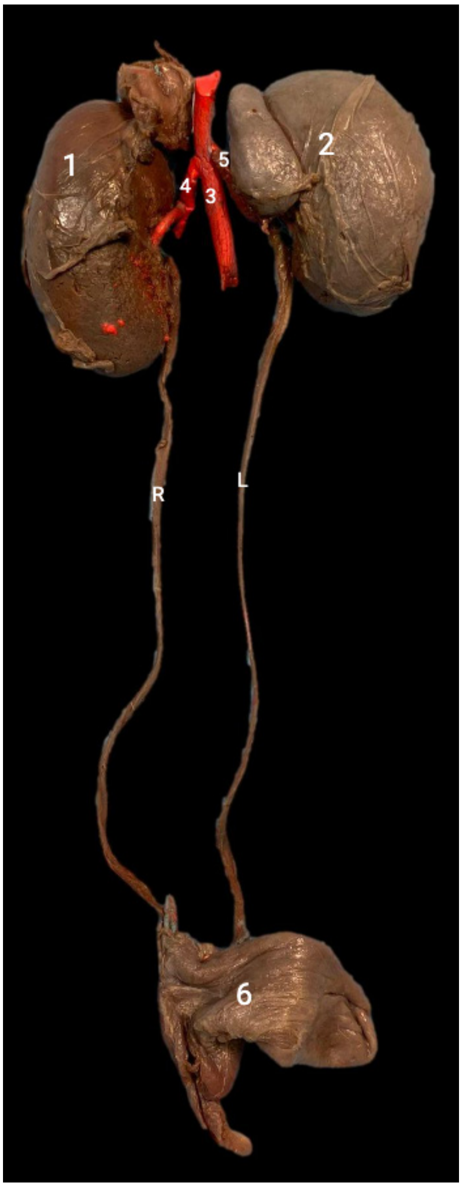

FIGURE 3 The urinary system of nutria (*Myocastor coypus*). 1 – right kidney. 2 – left kidney. 3 – abdominal aorta. 4 – right renal artery. 5 – left renal artery. 6 – urinary bladder. R – right ureter. L – left ureter

Discussion

Each animal species is unique due to the uniqueness of its ecological range, which guarantees variability in the adaptation of homeostatic mechanisms to the influence of environmental factors, including anatomy. There can be subtle differences in structural and functional measurements of organs between different animal species and within the same species [6]. One of the most important functions of the kidneys as organs that enable the body to function properly is the maintenance of proper homeostasis of the body, which is achieved by the uninterrupted filtration of blood from the glomeruli into the renal tubules and the subsequent exchange of water and solutes between the tubules and the perirenal capillaries, resulting in the excretion of excess water, solutes and metabolic products [7]. As reported by some sources, the right kidney relative to the left kidney is located more cranially, in addition, the right renal artery has a more cranial origin from the aorta than the left in all mammals [8]. The kidneys in nutria are located right next to the diaphragm at the height of the 11th or 12th thoracic vertebrae; in nutria, vertebra 10 is the attachment of the diaphragm. Compared to their body dimensions, they have long ureters – the length of the right ureter is 122.64 mm, and the length of the left ureter is equal to 123.21 mm. Both kidneys are vascularized by renal arteries, diverging from the abdominal aorta, which give off two branches before entering the renal hilum. Nutria used to belong to the same family (*Capromyidae*) as another related rodent, the hutia (*Capromys*) native to the West Indies [9]. Now, through review data introduced in 2005 by Wilson and Reeder, nutria have been placed in the family *Myocastoridae* and are their only members. Hutia individuals belonging to the family *Capromyidae*, native to Cuba, have been subgrouped and are divided into three genera (*Capromys, Mesocapromys and Misaterras*), a division accepted by most taxonomists [10]. We measured the weight of the kidneys of 20 different individuals of the hutia species *Mesocapromys melanurus*, with an average weight of 6 g per kidney, and among these individuals, the lowest weight value was 2 g and the highest was 10 g [11]. These weight values show us that the average weight of the kidney of hutia can be similar to nutria (the average weight of nutria kidneys: right and left included in **table 1** is 7.125 g), but there may be individuals whose this value can be significantly higher or lower than the kidney of M. coypus (2 g and 10 g). The length of *M. melanurus* oscillated in 23 individuals at an average value of 16 mm, with the lowest kidney length of one individual being 13 mm and the highest 33 mm. The thickness of the cortex and medulla were also measured in the same individuals, which averaged 2.6 mm for the cortex and 10.4 mm for the medulla [11]. In contrast, Charles A. Woods determined that the relative thickness of the kidney core of the two endemic Haitian hutia species studied was 40 mm [12]. Compared to *Myocastor coypus*, the thickness of the cortex versus the medulla in nutria is more equal, as it takes on values of 6.50 and 6.37 mm (example in **table 1** of the left kidney), while in *M. melanurus* there is a clear advantage in the greater thickness of the medulla versus the thinner cortex. In addition, the renal cortex of *M. coypus* species is much larger, while the renal medulla is much smaller than in *M. melanurus*. Considering the averaged thickness of the medulla of the two endemic hutia species, we can indisputably conclude that this is the smallest value presented among the aforementioned species, so the thickness of the medulla of nutria is clearly more marked than in their island relatives. Taking into account the dimensions of the length of the kidneys of nutria and Cuban hutias, we can note the similarity in the length of the kidney, but not in all individuals of *M. melanurus*. In *M. melanurus*, the individual with the highest value of kidney length was 33 mm, and in *M. coypus* the average length of the left and right kidneys is 31.32 mm, taking a similar measure. It should be noted that not every individual of the hutia of this species may have a similar length to the nutria, as another individual of *M. melanurus* had a kidney length of 13 mm, which is already a much lower value than the kidney dimensions of *M.coypus*. In another related species also Cuban hutia – *Mysateles prehensilis gundlachi*, the average weight of one kidney weighed in 21 individuals was 8.2 g. In contrast, in another species, *Mysateles prehensilis prehensilis*, out of 10 measurements taken of one kidney from different individuals, the statistical weight reached 10 g [11]. Comparing the weight of kidneys in the two separate species of Cuban hutias and nutria, we note the higher weight values of these organs. The nutria, as well as the domestic cat (*Cavia porcellus*), commonly referred to as the guinea pig, belong to the order Rodentia and the same suborder Porcupine (*Hystricomorpha*) [13,14]. Due to the evolutionary convergence and relatedness of the two species, analysis of the characteristics of the kidneys and urinary tract of these animals can provide us with a lot of significant information about possibly existing anatomical differences. A study of ten individuals of Cavia porcellus proves that their kidneys are located in the abdominal cavity slightly lower, that is, differently from the kidneys of nutria [15]. In guinea pigs, the right kidney is located between the 12th thoracic vertebra and the first lumbar vertebra, and the left kidney is located between the 2nd and 4th lumbar vertebrae, while in nutria both kidneys are found between the 11th and 12th thoracic vertebrae. As previously described, the diaphragm in nutria attaches as early as the 10th thoracic vertebra, then in the guinea pig the diaphragm attaches at the height of the 1st lumbar vertebra [16]. This means that despite the differences in the position of the kidneys in relation to specific spinal vertebrae, there is a relationship of topographic position of the right kidney in cavies in close contact with the diaphragm. In addition, we can see that the left kidney in the guinea pig is much lower than its right kidney and they are located in different intercostal spaces. According to Stan, in each individual, the weight of the left kidney of *C. porcellus* was always higher than that of the right kidney. The average weight of the left kidney in all ten individuals was 4.75 g, and that of the right kidney was 3.92 g. The same relationship is fulfilled by the kidneys of nutria, as the left kidneys are also heavier than the right kidneys (**Tab. 1**). Moreover, they differ from the average weight of the collated weights of all guinea pig kidneys by about 2.79 g for left kidneys and by also 2.79 g for right kidneys. A similar relationship in the higher weight measurements of left kidneys from right kidneys has been confirmed in rabbits [17], while this feature is not directly related to membership in the order Rodentia, as studies have confirmed that in the rat the relationship is the opposite, and it is the right kidneys that are heavier than the left [18]. Capybaras (*Hydrochoerus hydrochaeris*) also belonging to the same suborder as nutria, have a higher weight of left kidneys than right ones. With the distinction that they are about incomparably heavier than in *M.coypus*, as the left kidney oscillates at 94.71 and the right at 89.90 g, considering a study conducted on 41 individuals [19]. Another study was conducted, in which the length, width and thickness of kidneys in guinea pigs were measured. On the 20 individuals examined, the average length of the right kidney was shown to oscillate at 23.9 mm, and that of the left kidney was 23.5 mm. The average width of the right kidney was 14.96 mm and that of the left kidney was 13.68 mm, while successively their thicknesses reached the limits of 11.54 mm and 11.41 mm [20]. Consistent with the dimensions of nutria kidneys, guinea pig kidneys are slightly smaller, although we note the same relationship of greater length of the right kidney to the left. In contrast, there is no reasonable relationship between the greater width of the left kidney than the right, as we can see in the case of *M. coypus*. Yousif and Rabee [20] also measured the thickness of the medulla and cortex of the kidneys in healthy specimens of domestic jackdaws. They found that the thickness of the cortex of the right kidney was higher than that of the left kidney (5.914 mm for the right kidney and 5.3 mm for the left kidney) and a higher value for the thickness of the medulla of the right kidney than that of the left kidney (5.28 mm for the right kidney and 4.7 mm for the left kidney). As in nutria, the relationship between the thickness of the cortex and medulla take on similar parameters and the two layers are of similar size. The same cannot be cited for the above-described hutias, in which the core is much thicker than the bark. The dependence of the parameters of core and cortex thickness are closely related to the species and to the environment in which they live. Animals with more efficient renal medullary thickness have more loops of Henle responsible for water absorption and thus urine thickening [21]. Cuban hutia settle in very warm areas with subtropical climates, and consequently these animals need to conserve water and maximize water reabsorption through the loops of Henle. The nutria is found in temperate areas, so the thickness of both the cortex and the medulla is even and neither part of the kidney outweighs the other. Guinea pigs are also characterized in their anatomy by an unbalanced length of the ureters, with the left ureter being the shorter one, and the average length of the left ureter was 9.4 cm, while the right ureter was 10.3, which as much as gives us almost one centimeter difference between the two [20]. The information on the length of the ureters is combined with their location at the height of the vertebrae in question, where the left kidney is much lower in the abdominal cavity than the right kidney, as cited earlier by Stan. In nutria, the anatomical length and structure of the ureters is categorically different and completely opposite, as it is the left ureter that is longer.

Conclusions

The study provided valuable information on the anatomical structure of the kidneys of the nutria, which, although closely related to other rodents, exhibits its own unique characteristics. The kidneys of nutria, like those of other rodents, have a smooth surface and are unilocular. Their position is relatively high in the abdominal cavity, close to the diaphragm, but varies according to the vertebrae of the spine, which is consistent with the general anatomical structure of this species. The differences in kidney structure between different species, such as nutria and hutias, reflect their adaptations to different environments. The kidneys of the Cuban hutia (*Capromyidae*) are characterized by a greater thickness of the medulla compared to the cortex, as a result of their adaptation to warm and dry living conditions, where efficient water absorption is crucial. In contrast, the kidneys of nutria, which inhabit temperate climates, have a more even ratio between cortex and medulla, suggesting a different adaptation mechanism for water management. In addition, differences in ureter length between species, such as the shorter left ureter in guinea pigs compared to the longer left ureter in nutria, also reflect their specific adaptations to the environment. Guinea pigs have a shorter left ureter, which is related to their anatomical location of the kidneys, while nutria present the opposite characteristic. This research shows that although the kidneys of nutria are similar to those of other rodents, the differences in the anatomical structure of these organs in different species are the result of their adaptation to specific environmental conditions. This analysis not only enriches our knowledge of the structure of the kidneys of individual rodents, but also highlights the importance of adaptive differences in animal biology.

Ethical approval

The conducted research is not related to either human or animal use.

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Conflict of interest statement

The authors declare no conflict of interest.

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