Vol 16 No 2, p 227-232

MORPHO-HISTOLOGICAL INVESTIGATION OF KIDNEY OF BACTRIAN CAMEL (*Camelus bactrianus*)

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ABSTRACT

Morphological characteristics of the kidneys in the two-humped camels were investigated using the anatomical and histological methods. The 2 kidneys in the camel contributed about 0.6% of the body weight. The ratio of thickness of the renal medulla to the cortex was 4:1, which indicated that Henle's loops in camel's kidneys were very long. In cortex, there were more juxtamedullary nephrons and mid-cortical nephrons which had longer Henle's loops. Proximal convoluted tubules were far longer than the distal ones. In the outer medullary zone, the vasa recta were grouped obviously into specific vascular bundles which alternated with the bundles of Henle's loops and collecting tubules. The inner medullary zone was thicker than the outer one. Specialised fornices were formed by projecting of either side of the pelvis and extended between renal pyramids to medullary outer zone where second pyramids clearly occurred. The characteristics above showed that kidneys in bactrian camels possessed a strong reabsorption and hence promoting the production of high concentrated urine.

Key words: Bactrian camel, high concentrated urine, histology, kidney, morphology

The two-humped camel has high ability that can endure thirst and produce high concentrated urine. Experiments have demonstrated that the camel is not in danger even it loses body fluid up to the 30% of the total body reserves. There are very few references available regarding the water metabolism in two-humped camel body, and more inferential explanations (Shui, 1990) within the references rather than objective evidences. In recent years, there have been some studies on physiology and biochemistry of water metabolism and its regulatory factors in camel. Because the two-humped camel has higher blood flow through the kidneys and more osmotic pressure which ensures the reabsorption of water and retains alkaline reserves, these are the important functions that could ensure the regulation of the blood acid-base balance in the shortage of water, maintain blood volume, and ensure the normal water metabolism in body (Xiang *et al,* 1997). Antidiuretic hormone and aldosterone were the important factors which regulate the water metabolism and urinary output in two-humped camel (He *et al,* 1999). There is difference between the arterial supply to the two-humped camel's kidney and other animals (Chen and Liu, 2000). In case of water shortage, camel can excrete high concentrated urine to reduce the water loss and can drink salty water which contains fairly high salt concentration (Zhao, 1995). This paper describes morphological and histological features of the two-humped camel's kidney.

Materials and Methods

Ten adult healthy male and female two-humped camels from pasturing area of Inner Mongolia Ala Shan You Qi, one of the aridest areas in China, were used in this study.

All protocols were approved by the Chinese Committee for Animal Use for Research and Education. The individuals were anaesthetised with an intraperitoneal injection of sodium pentobarbital and killed by cervical blood-letting. Their kidneys were weighed and 10 integral kidneys were fixed in the 10% of formaldehyde solution for morphological observations and the relevant data were measured by sliding caliper. Another 10 fresh kidneys were used for histological observations. Many slides were papered from the upper, middle and deeper sections of cortex, and the medulla from the centre of the kidney, and then were fixed in the 10% of formaldehyde solution. The size of these pieces was 8mm×4mm× 1mm. Paraffin sections were then stained with H & E. Olympus microscope was used to

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observe and photograph the slides, and the data were measured by micrometer ruler.

Results

Morphological observations

The left and right kidneys of the two-humped camel appeared fabiform-like, with smooth surface (Fig 1). The average size of left kidney was 19 cm×14 cm×9 cm, and the right one 18 cm×14 cm×8 cm. The total weight of two kidneys was 3.0 kg, accounting for 0.6% of its body weight. In a cross section of the fixed kidney specimen, the boundary between the cortex and the medulla was obvious. The cortical colour was light while the medullary colour was bright. The junction of the cortex and medulla was serrated, and the average thickness of the cortex was 4 times that of the medulla. The medulla was further divided into light colour medulla interna and bright colour medulla externa. The thickness of medulla interna was two times to the medulla externa. The medulla was composed of 11 or 12 renal pyramids. The pyramidal nipples merged mutually to form renal cristae opposite renal pelvis. A distinct secondary renal pyramid was formed in the side-bottom of the adjacent renal pyramid. The bases of these pyramids were towards the cortex while the apices were towards the medulla interna. The secondary renal pyramid in the kidney lateral edge was particularly obvious (Fig 2). The renal pelvis was the intumescent segment of the cranial part of the ureter which was located in the renal sinus. Eliminating the renal parenchyma, about 10 or 11 protuberant mucous folds could be seen. The folds were radiated from the dorso-ventral side of the renal pelvis, and stretched to the medulla externa among the renal pyramids. The correspondent dorso-ventrum of renal pelvis protruded into the boundary of the medulla interna and the medulla externa, connected to each other and formed fornix structure. This is the secondary renal pyramids located at the convex surface of the fornix structure. The renal sinus was filled with adipose tissue, and the ureter, renal artery branches and renal vein tributaries passed through it. The ureter debouched behind the 1/3 of renal pelvis. Before it entered into renal hilus, the renal artery had been divided into two dorsal and ventral branches. The tributaries of the renal vein merged and left away from the renal hilus.

Histological observations

The renal capsule was composed of dense connective tissue. In its deep stratum, lamellar smooth muscle fibres could be seen distinctly. The cortex was composed of cortical labyrinth and medullary rays. The cross-section quantity of the proximal convoluted tubule in cortical labyrinth was more far than the distal convoluted tubule (20:1) (Fig 3). The brush border of the proximal convoluted tubule was well developed. The renal corpuscles were distributed in the central cortex section and cortico-medullary junction, but below the capsule in the range of 1000 to 1500 μm, no renal corpuscles found (Fig 4). The quantity of the juxtamedullary nephrons and the intermediate nephrons was much more than that of the superficial nephrons. In cortex, the density of the renal corpuscle was $115/mm^2$, so it was sparser. There were differences between the size of the renal corpuscles of superficial nephrons and the juxtamedullary ones. The diameter of the former was 200 to 220 μm (external diameter of Bowman's capsule) and 190 to 210 μm (diameter of glomerulus), and the latter was 260 to 280 μm and 250 to 270 μm, respectively. Medullary rays broadened out gradually from the capsule to the cortico-medullary junction, containing the parallel uriniferous tubule and plenty of capillaries. In cortex, the blood capillaries kept tightly close to the renal tubules and the distribution was very rich among them, and it occupied the most of renal interstitium.

The medulla could be differentiated into medulla externa and medulla interna. The vasa rectae in the medulla externa was well grown. Under the cortical labyrinth, it extended and formed wide vasa rectae bundles. The latter were arranged alternatively with the uriniferous tubule bundles of the cortical medullary rays. The width of the vascular bundle was nearly equal to that of the uriniferous tubule bundle. Inside the vascular bundle, the thin segment of the renal tubule was not seen (Fig 5).

The dissepiment of vasa recta was very thin. From the superficial layer of the medulla externa (medulla side of arcuate artery), the change of the simple cuboidal epithelium lining the descending limb into simple squamous epithelium lining the thin segment of the descending limb of Henle's loop was clear (Fig 6).

In a cross section of the medulla interna, collecting ducts, thin segments of the descending limbs, pars rectae as well as many blood capillaries among them could be observed (Fig 7). Sometimes, the small funiculose vessels could also be seen. The wall of the collecting tubule is built of regular simple cuboidal epithelium. Its cell cytoplasm was bright and the boundary was clear. The tubal wall of pars recta

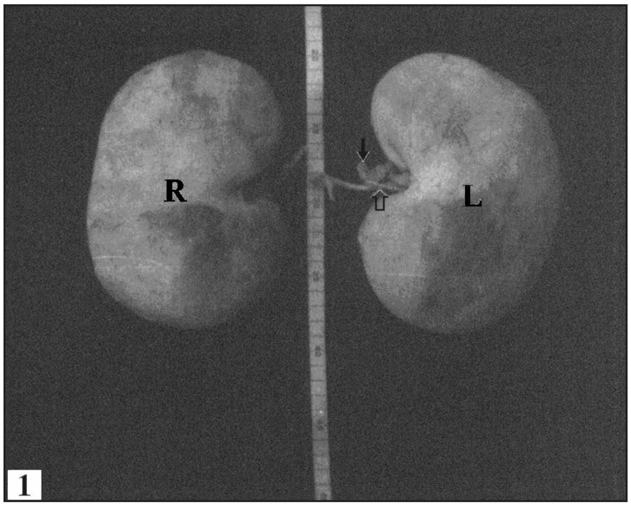

Fig 1. External morphology of the camel kidney. Formalin fixed. Left kidney (L). Right kidney (R). Renal artery (⇧). Renal vein (↓).

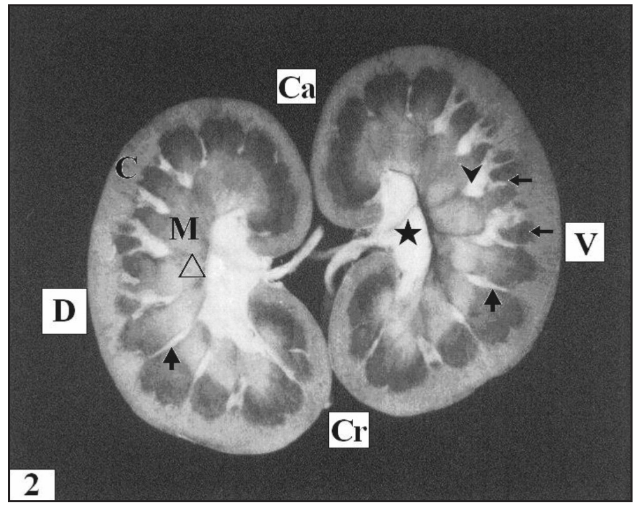

Fig 2. Frontal plane of the kidney. Formalin fixed. Cranial (Cr). Caudal (Ca). Dorsal half (D). Ventral half (V). Cortex (C). Medulla (M). Secondery pyramid (←). Renal pelvic projection (↑). Fornix (▼). Pelvic (△). Renal sinus (★).

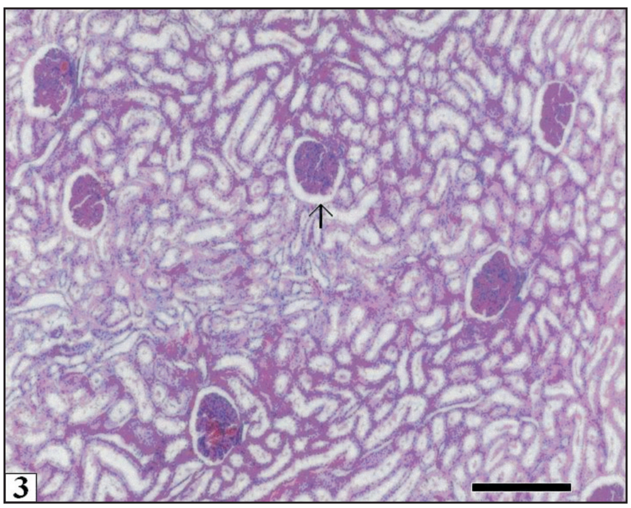

Fig 3. Cortical labyrinth. Corpuscula renis (↑). H&E. Bar=250μm

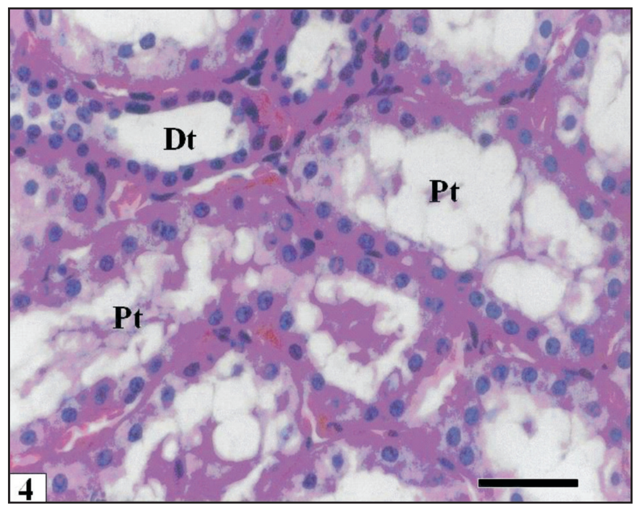

Fig 4. Proximal convoluted tubule (Pt). Distal convoluted tubule (Dt). H&E. Bar=25μm

was formed of low simple cuboidal epithelium, the cytoplasm was addicted to eosin and the boundary was unsharpened.

In the papillary segment of the medulla interna, the interstitial tissue became increasing; the papillary duct was obvious, with epithelium increasing in height and changed into the simple columnar type. The cells were bright and the boundaries were clear. There was much thinner segment of Henle's loop and blood capillaries between papillary ducts (Fig 8).

Discussions

Animals (such as Meriones unguiculata, Macropus, African wild donkey, desert goat and sheep etc.) which inhabit the arid or environments with water shortage for a long time, or were accustomed to drink salty water or eat high salty food, have the ability of excreting high concentrated urine. However, animals (such as Sus scrofa domestica, Wildebeest and bedfordiae etc.) which inhabit the moist climate or the regions with adequate water supply, generally, excrete more diluted urine. These properties must be relevant with the thickness of kidney medulla. The proportion of thickness of the medulla and cortex was 5:1 in Meriones unguiculata, Macropus, African wild donkey, and it was 3:1 in desert goat and sheep, where, the medullary portion was broad. However the proportion of the thickness of medulla and cortex was 1:5 in Sus scrofa domestica and bedfordiae and 1:1 in Wildebeest. The medullas of these animals were relatively narrow (Mbassa, 1988). The proportion of thickness of the medulla and

Fig 5. Cortex. Capsule (★). Cortical labyrinth (✱). H&E. Bar=250µm.

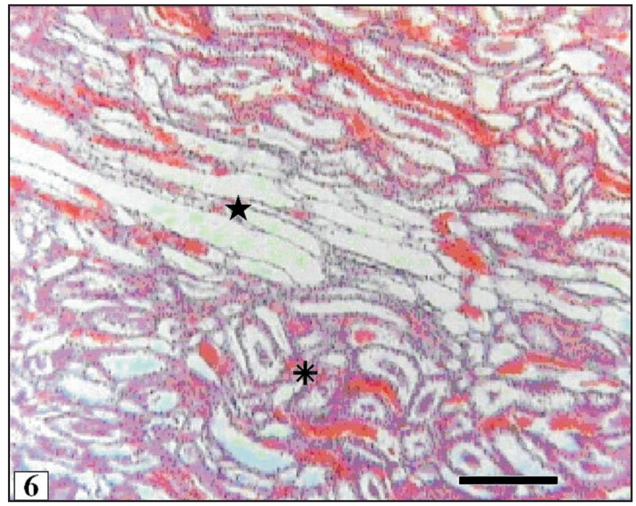

Fig 6. Outer zone of medulla (longitudinal section). Vascular bundle of vasa rectae (★). Uriniferous tubule bundle (✱). H&E. Bar=100µm.

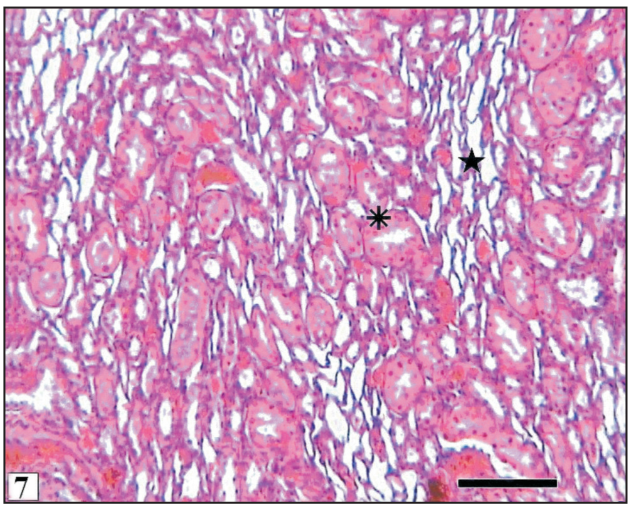

Fig 7. Outer zone of medulla (cross section).Vascular bundle of vasa rectae (★). Uriniferous tubule bundle (✱). H&E. Bar=100µm.

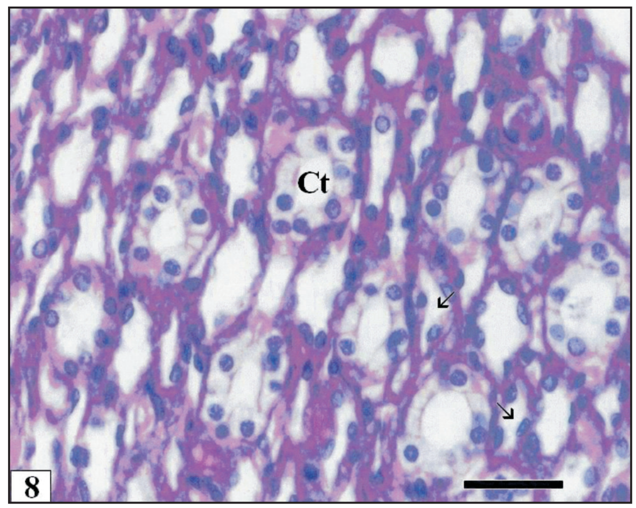

Fig 8. Inner zone of medulla. Thin segment (arrows). Collecting tubule (Ct). H&E. Bar=50µm. These Figures above had been checked.

cortex was directly proportional to the relative length of Henle's loop, the larger the proportion, the longer the Henle's loop; and vice versa. Long Henle's loop was helpful for establishing higher osmotic pressure gradient in the medulla, then forming high urinary concentration, and also it could reduce the loss of water in urine. The proportion of thickness of the medulla to cortex was 4:1 in the two-humped camel. This could be speculated that the Henle's loop was longer in the former. Moreover, this confirms that the medulla of the two-humped camel have morphological basis to form high osmotic pressure gradient.

The distribution of renal corpuscles could not be observed till a distance of 1000 to 1500 µm beneath the renal capsule of two-humped camel in present study. Nephrons in the central and deep cortices were distributed widely, but in the medulla interna and renal papilla we could see plenty of thin segment sections. This indicated that short loop nephrons of the two-humped camel were very few, the majorities were juxtamedullary nephrons and long loop middle nephrons, and its thin segment was long too. Animals which come from the arid region (such as meriones unguiculata and small meriones unguiculata etc.) had more juxtamedullary nephrons and middle nephrons, Henle's loop and its thin segment was longer, and normally they excrete highly concentrated urine (Valtin, 1977).

The surface of proximal convoluted tubule had brush border which increased the absorptive surface area largely. About 70-80% of moisture in the original urine was reabsorbed again here. Beliveau and Bruneter (1984) guessed that animals inhabiting the arid area should have longer proximal convoluted tubule, and it was shorter comparatively in animals inhabiting abundant water source. However, there was no enough morphological evidence to support this view. In the present study, the most of renal tubule sections in the renal cortex were proximal convoluted tubule with well grown brush borders, and distal convoluted tubules were seldom. This demonstrated that proximal convoluted tubule of two-humped camel was long enough, so it has more power than other animals to absorb original urine.

The renal vein of the camel is unique and is different from other domestic animals, it could be related to with high concentrated urine production (Saber, 1987). In the present study, in was observed that the blood supply of two-humped camel kidneys, was abundant, and the relationship between the uriniferous tubules and blood vessels is very close. It might be helpful to promote the movement of substance contained in urine between uriniferous tubule and blood vessel. Stephenson *et al* (1976) emphasised that the uriniferous tubules and blood vessels were integrated functionally, instead of treating them as 2 isolated sections. After exit of the efferent glomerular arterioles of the juxtamedullary nephrons from the renal corpuscle, it formed straight arterioles and descended into the medulla in different depths, and returned into interlobular veins or arcuate veins. Therefore, it would form a lot of "U" shape blood vessel loops in the medulla. In some of animal's kidney which could produce highly concentrated urine, the vasa rectae assembled and formed special blood vessel bundles out of the medulla externa. These blood vessel bundles were arranged alternatively with the uriniferous tubule bundles formed by the straight segments of the Henle's loop and collecting ducts. Kaissling *et al* (1975) believed that the short loop nephron, mixed with thin segment of vasa rectae was a typical structure of small desert animal kidneys. Moreover, they pointed out that macrofauna living in arid environment with few water supply lacks this kind of structure. In the present study, we observed that the arrangement of the vasa rectae in the two-humped camel's kidney was very special, which assembled and formed obvious vascular bundles in the medulla, and arranged alternately with the uriniferous tubule bundles. In the medulla externa, this kind of vascular bundles was particularly broad. Being different from small-sized desert animals, and in contrary to the standpoint of Kaissling *et al* (1975), the distribution of the thin segment could not be seen in the vasa rectae of the two-humped camel's kidney. The alternative arrangement mode of rectiserial Henle's loop and uriniferous tubule was the important factor for reabsorbing the moisture in original urine and exchanging the other substance, and then producing high concentrated urine (Jones and O'Morchoe, 1983).

However; in two-humped camel kidney, the medulla interna was well grown. The renal pelvis gave off mucous prominences from the ventro-dorso and stretched to the medulla externa, and formed distinct secondary pyramid. This demonstrated that the renal pelvis of the two-humped camel belongs to the model-II renal pelvis, and is responsible for the ability of producing high concentrated urine. The appearance of the advanced medulla interna, renal pelvis projections and secondary pyramids was helpful to produce the highest concentration gradient in the medulla, and then concentrated urine in desert rodent (Barret *et al*, 1978).

The kidney weight and its ratio to the body weight were different in different species. The kidney weight of rabbits, pigs, humans, horses and oxen was 18-24g, 400-500g, 300g, 900-1500g and 1200-1400g, respectively. The percentage of the kidney's weight to the body weight was 0.6%-0.7%, 0.5%-0.6%, 0.4%, 0.29%-0.39% and 0.2%, respectively (Tian, 1993 and Cheng, 1994). Generally, the bigger the animal's physique, the smaller the ratio, and vice versa. There was an inverse proportion between the physique and the percentage. However, the physique of the two-humped camel was bigger and its percentage was nearly the biggest (0.6%). It points to the ability of kidney of two-humped camel in handling urine.

Acknowledgement

This research was funded by the grant (No. 39500109) from the National Science Foundation of PR China.

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