Iraqi Journal of Veterinary Sciences, Vol. 37, Supplement III, 2023 (72-79)
Proceedings of the 7th (2nd International) Scientific Conference, College of Veterinary Medicine, University of Al-Qadisiyah

Iraqi Journal of Veterinary Sciences

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Anatomical and histological study of the kidney of the one humped camel

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Article information

Article history:
Received 04 December, 2022
Accepted 06 November, 2023
Available online 01 December, 2023

Keywords:
Kidney
Blood supply
Corrosion cast
Radiology
Glomeruli

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Abstract

This study has been conducted to determine the anatomical and histological structures of the kidneys using different anatomical techniques, including topographical dissection, corrosion casting technique, and radiology, in addition to routine and special stains for histology study. Ten healthy adult kidneys of one-humped camels were chosen for different purposes of this study. Consequently, the camel kidney's anatomical features showed a multilobar kidney type in camel. Externally, kidneys were smooth and bean in shape. In contrast, internal kidneys were divided into main layers: a thin external cortex layer dark in color, which was internally extended and attached into a thick inner medulla layer pale. In addition, the renal medulla was occupied by renal pyramids, renal sinuses, and columns drained to the renal pelvis of the kidney via minor calyces and major calyx and continued with the ureter. Moreover, many measurements of the right and left kidneys were detected, including the different kidney parts. The morphometric averages of the right kidney were higher than the left kidney in most regions, confirming the right kidney's critical role in this animal. Also, the kidneys' right and left renal arteries and vein branches were determined using a corrosion casting technique and a radioactive artery for the renal artery. Results displayed that the renal branched into interlobar, arcuate, and interlobular branches and converted into small units, including arterioles. Histological findings identified typical cortex, medulla, and delicate kidney structures. Additionally, renal corpuscles were recognized, and, importantly, renal space around glomeruli was very thin and narrow. Overall, this study concluded that the type of the camel kidney, depending on the cortex and medulla, is a multilobar kidney type, and there is a significant similarity in the figure and blood supply of the left and right kidneys. Also, camel kidneys' appearance and histology structures are similar to different species in humans, small ruminants, and carnivores, but then again, the renal capsule was very thick. In contrast, the space of renal corpuscles was narrow around the glomeruli, and the renal capsule's glomeruli displayed a large amount of collagen fibers.

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Introduction

Biologically, camels are a member of the Camelidae family, which has different species, including dromedary camels, Bactrian camels, wild Bactrian camels, llamas, alpacas, vicuñas, and guanacos. Many studies have found that the one-humped camel is one of the largest ruminant animals that could resist challenging conditions, for instance, thirsty in the deserts; this confirmed that camels might have had several physiological and anatomical properties of the urinary system (1). So, the tolerance of camels in these problematic conditions might be periodic differentiation of the cortex and medulla. These kidneys in camels would play a key role in preserving biological activity through the production of concentrated urine (1). Usually, the kidney's function is to eliminate and remove wastes and nitrogenous

wastes by filtered cleaning of the blood via removed urea and ammonia. Furthermore, it controls blood pressure and tissue by organizing the body's salts and maintaining its salt balance (2-4). Also, the kidney is considered one of the exocrine glands because it secretes different hormones, such as hormones of the renin-angiotensin system (RAS) and erythropoietin (EPO). Moreover, it secretes humoral factors 1,25 dihydroxy vitamin D3. It produces many vital enzymes, including kallikreins (4). Many studies have described camel kidneys and detected that camel kidneys have similarities to equine, caprine, ovine, rabbit, and canine kidneys (5,6); consequently, the kidneys of camels are externally bean in shape and smooth, and internally multilobar, uni papillary, also the renal papillae are wholly fused to be formed renal papilla or crest, which were drained into a central renal pelvis (7,8). The left and right kidneys of camels are similar in shape and embedded in the sub-lumbar region. Usually, the abdominal aorta is supplied to the right and left kidneys by the renal artery and vein. Still, the renal vein of the right kidney is connected to the inferior vena cava superior to the renal vein of the left kidney in horses and dogs and less in cats and pigs (8). The standard kidney location in mammals is mainly outside the peritoneal cavity, strongly adhesive to lumbar ribs, and surrounded by a substantial amount of fat. The renal artery originates from the abdominal aorta and enters the kidney via the renal hilum (9,10). The kidney's blood vessels are coursed inside the kidneys in different directions and narrowed into tiny penetrated arterioles that constitute tubules of the cortex, the kidney's glomeruli (11). A capsule surrounds these glomeruli (Bowman's capsule), forms the renal corpuscles responsible for the excretion of nitrogenous products, and regulates blood salts through blood filtration (12). This study uses different techniques to find more specific structures and features of camel kidneys.

Materials and methods

Samples and design of study

For this study, ten healthy adult male kidneys of Iraqi camels were studied and collected from the Al Diwaniyah city, Iraq slaughterhouse. Three animals were used for anatomical research, including detecting the topical location of kidneys and their relationship with other tissue (Figures 1). Also, kidneys were extracted from the corpses of camels. Anatomical descriptions and measurements of the kidney were measured and recorded, including weight, color, height, displacement of water, number of renal pyramids, and renal columns. In addition, three camels were used to study the blood pattern of the kidneys using resin (Pyrex Quick Fix, Pyramax Polymers, RURKI 247667 India). So, three camels were used to identify the blood branches for the radiology study.

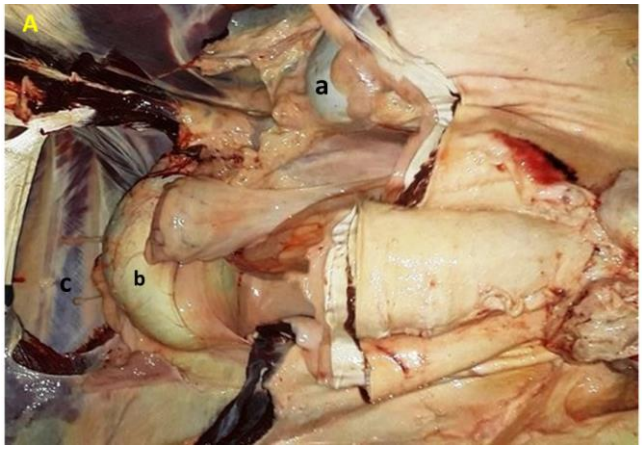

Figure 1: This image illustrates the left and right kidneys after evacuating other tissue. a: right kidney, b: left kidney, and c: rib.

Histological study

Three kidneys (left and right) were used for the histology study. The specimens were taken as soon as possible from cadavers and fixed in 10% formalin, and the solution should be 1:10 of the sample size and left for 48 hours (13-15). After the fixation, the tissue was prepared for histological processing using staining hematoxylin and eosin (16).

Corrosion casting technique

This process was conducted by injecting resin liquid (Pyrex Quick Fix) and using an appropriate plastic cannula (10mm) for the diameter of the renal vein and artery after fixation to prevent the discharge of resin liquid during the injection. 10 ml resin liquid was prepared and pushed by a plastic syringe (100 ml) inside the renal vein and artery, then left overnight at room temperature to polymerize the resin liquid. The next day, the kidneys were incubated with 40% KOH for 4-5 days; after that completion of the casting process, the kidneys were washed with tap water for a day, and then, kidneys were left on the bench of laboratory and air dry. Finally, renal arteries and veins were detected for kidneys and grossly described (17).

Radiological study

Kidneys of camels were washed with warm normal saline and injected into the renal artery to clean it, using a suitable plastic cannula (10mm). Then, 10 mg /ml of the radiopaque contrast media (barium sulfate) (MDL Mfcd00003455 - Sigma-Aldrich, USA) was injected and filled the renal artery of the kidney and directly exposed to digital radiography (DR). Images were snapped from blood supply branches (18).

Results

Anatomical study of the right and left kidneys of one-humped camels was smooth and bean in shape, red to brown color, and surrounded by connective tissue, which consisted of a network of fibrous tissue; it was less transparent. Internally, the kidney capsule comprised two tablet layers attached firmly to each other except at the hill's region. After removing the pill, the Kidney has two surfaces, dorsal and ventral surface., and two borders, lateral and medial edges. Also, the left kidney was similar to the right kidney in shape, but it was less elongated than the right kidney (Figure 2). The right kidney was extended between lumbar vertebrae 2 to 4 lumbar vertebrae. In comparison, the left kidney is located below the three transverse vertebrae of the lumbar vertebrae 5,6,7. Still, it was unstable depending on the volume and size of the food saturation ratio in the rumen (Figure 1).

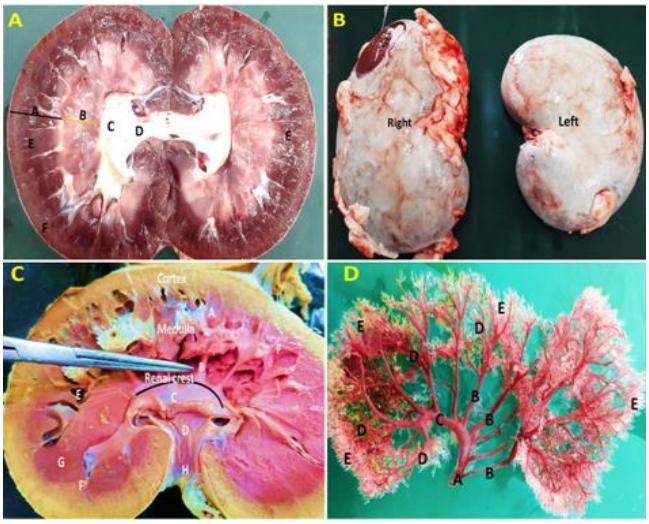

Figure 2: These figures display the camel's kidney's external and internal structures and renal artery. Image A shows the kidney's inner surface and main structures involved with the cortex, medulla, and renal crest. A: cortex, B: Minor calyx, C: Major calyx, D: Renal pelvis, E: Renal column, F: Medullary rays. Image B shows the right (A) and left (B) camel's kidney. Image C shows the internal surface of the kidney and the main structures involved with the cortex, medulla, and renal crest after fixation formalin 10%. A: Pyramid, B: Minor calyx, C: Major calyx, D: Renal pelvis, E: Sinus of kidney, F: Renal column, H: Entrance of ureter, and G: Renal column. Image D shows the renal artery tree and branches. A: Renal artery, B: interlobar artery, C: Arcuate artery, D: interlobular artery, E: tiny capillaries and arterioles.

The anterior pole was rounded end and corresponded to the parietal lobe of the liver, while the posterior pole was flat and located in the dorsal abdominal area. Also, the medial border was curved and formed the kidney's hilus, representing the entrance of blood vessels, nerves, and ureters. The renal vein and artery supplied each kidney; subsequently, the renal artery branched into the aorta. The renal artery course was divided into 2-3 branches before entering the renal pelvis. The renal artery corresponded with the renal vein (Figures 2 and 3), but the renal vein drained to the caudal vena cava. Also, the renal artery was distributed between lobes and branched into an interlobar street and arcuate artery.

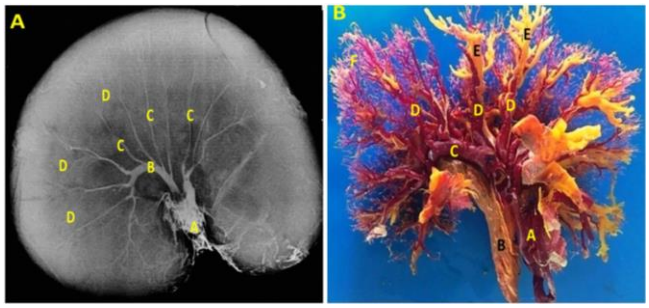

Figure 3: Image A shows the renal artery tree and branches. A: Renal artery, B: interlobar artery, C: Arcuate artery, D: interlobular artery. Image B shows the renal artery tree and branches. A: Renal artery, C: Arcuate artery, C: interlobar artery, D: interlobular artery. Image B shows the renal and vein artery tree and branches. A: Renal artery, B: Renal vein, C: Arcuate artery, D: interlobar artery, E: interlobular vein, F: tiny capillaries and venules.

Inside, the kidney displayed two main layers: cortex and medulla. The cortex was the outer layer of the kidney, which was soft, granular in appearance, and had a brown color, while the renal medulla was the inner layer of the kidney and appeared cone parts in shape were renal pyramids. The renal pyramid bases were toward the cortex, drained into the renal pelvis sinus, and formed the renal papillae (Figure 3).

This study detected the mean measurements of the right and left kidney, including the weight, length, volume, length of the medial border, length of the lateral wall, the thickness of the cortex, the thickness of the medulla, renal pelvis,13 and 12 average numbers of the renal pyramid and renal column: 1555± 120gm, 1450± 113gm, 51.033±0.7cm, 46.033±0.5cm, 4.79±0.188ml, 46.033±0.5cm, 15.13±1.2 cm, 10.11±0.8 cm, 60.11±3.6 cm, 50.05±2.1 cm, 18.07±1.6 mm, 15.11±0.6 mm, 50.14±1.2 mm, 33.11±1.2 mm, 30.11±1.1 mm, and 20.11±1.3 mm (Table 1).

Additionally, the fibrous capsule surrounded the kidney with adipose tissue, and blood vessels passed and penetrated the capsule toward the hilus of the kidney and branched inside the medulla and cortex of the kidney. Also, the ureter coursed with the blood supply via tablet and connected to the renal pelvis. As well, the average thickness of the cortex was 18.07±1.6 cm in the right kidney, while the left was

15.11±0.6 cm. The cortex was delicate and extended into the pyramidal part of the medulla; the renal medulla was filled by the main renal pyramids, 12 pyramids in number and cone in shape, and separated by 13 columns in number between pyramids (Figure 2).

The base of each pyramid was based on the renal cortex, and the top of the pyramid ended with the renal papilla, which constituted the minor calyx and drained into the significant calyx. These major calyces were extended with the renal pelvis, which continued with the ureter. All renal papillae joined together to form the renal crest of the kidney (Figure 2).

Table 1: Morphometric dimensions of right and left kidneys in adult camels

Parameters of the kidney	Right Kidney	Left Kidney
Weight (g)	1555±120	1450±113
Length (cm)	51.033±0.7	46.033±0.5
Displacement of water (ml)	4.79±0.188	3.70±0.175
Length of medial border (cm)	15.13±1.2	10.11±0.8
Length of lateral border (cm)	60.11±3.6	50.05±2.1
Thickness of cortex (mm)	18.07±1.6	15.11±0.6
Thickness of medulla (mm)	50.14±1.2	33.11±1.2
Thickness of renal pelvis (mm)	30.11±1.1	20.11±1.3
Number of a renal pyramid	12	12
Number of renal columns	13	13

Radiology study and corrosion casting technique of angiology of blood vessels

The radiopaque contrast media and corrosion casing process after resin injection for renal artery were clarified and illustrated the branches and tree of it inside layers of the kidney. The result showed the renal artery, which branched into the interlobar lane, continued as arcuate arteries, and moved into interlobular streets. These interlobular arteries were narrowed more and converted into arterioles and capillaries. Besides, the kidneys' right and left renal arteries displayed that the renal artery was divided into dorsal and ventral branches, so the dorsal branch was continually given a shorter anterior branch and a more extended posterior branch. In contrast, the ventral branch was directly branched into interlobar branch arteries. However, the number of interlobar streets slightly differed between the left and right kidneys, and more numbers in the right kidney. Furthermore, the renal vein was companied by the renal artery throughout the parenchyma of the kidney and given branches with all renal, vein, and artery branches as interlobar arteries, arcuate arteries, interlobular arteries, and terminated with very tiny vessels venules (Figures 2 and 3).

Histologically, results displayed that the kidney of a camel surrounded by a thick renal capsule, which consisted of predominantly dense connective tissue rich in collagen fibers and less reticular fibers, spindle fibroblasts capillaries, venules, and adipose tissue were very clear in this layer (Figure 4 and 5). Renal parenchyma revealed two main layers, including cortex and medulla layers; the cortex was rich in renal corpuscles, which formed nephrons of the kidney and distributed among medulla rays extending from the medulla layer toward the cortex layer. Also, distal and proximal convoluted tubules collecting duct were interspersed with cortex, which was lined by simple cuboidal epithelium and some regions with simple low columnar epithelium in collecting duct, and papillary ducts in particular toward minor calyces (Figure 5).

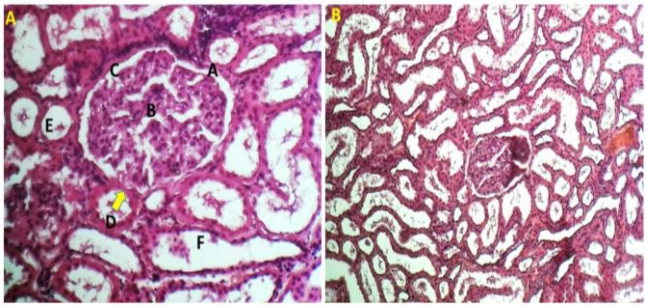

Figure 4: figures B and A showed renal corpuscle in cortex. A: Bowman's capsule, B: glomerular part, C: Renal space, D: Juxtaglomerular cells, E: Proximal convoluted tubule, and F: Distal convoluted tubule. Magnificent: A: 400x, and B: 100x

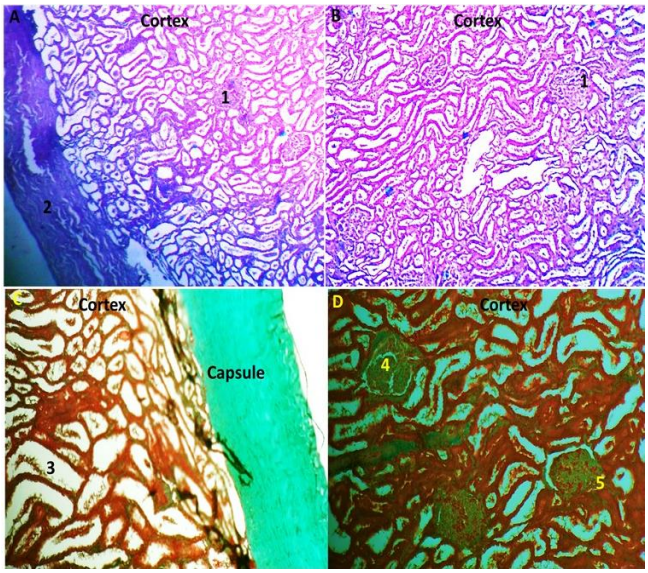

Figure 5: Images B and A showed renal corpuscle in cortex stained with H&E. 1: Bowman's capsule, 2: Renal corpuscle. Magnificent: A: 40x, and B: 100x. Images C and D showed renal corpuscle in cortex stained with PAS. 3: Distal convoluted tubule, 4: Glomerular part, 5: Juxtaglomerular cells. Magnificent: C: and D: 40x.

Renal corpuscles are semi-circled in shape and have different sizes, large and small. Bowman's capsule surrounded these kidney units, mainly consisting of many collagen fibers, and the glomeruli of renal corpuscles were in the middle, circled by capsular space. Additionally, most renal corpuscles displayed that capsular space is fragile, and juxtaglomerular cells were evident in the vascular pole. Majorly, the medulla layer exhibited many collecting ducts that ended with renal papilla throughout it toward calyces and renal pelvis, in addition to the blood supply and fatty tissue (Figures 4 and 5).

Discussion

This study found the location of the camel's kidneys were between the right and left kidney, which was similar to detections of other researchers' findings in camels, bovine, and small ruminants (19). Still, a topographical study noticed that the right kidney extended from lumbar vertebrae 2 to 4 lumbar vertebrae (20,21). The left kidney was movable and unstable depending on the status condition of the rumen. On the other hand, it was located between three transverse vertebrae of the lumbar vertebrae 5,6 and 7 (22). this result was confirmed in camels, bovine, and small ruminants, but it was different in location according to species (23,24). As a result, the location of the kidney was different between species according to weight and size in the animals.

Furthermore, the external appearance of the Kidney of one-humped camels was surrounded by capsules rich in adipose tissue, smooth and bean in shape, confirmed in other camels and other domestic animals and dogs (25,26). However, the right kidney was more longitudinal and more significant than the left kidney, which was agreed with Al-Sobayil (27). Still, it was different in small ruminants (28,29) and not lobulated, unlike bovine (30,31).

The range of the weight of the kidney and its bodyweight ratio were found to be different between humans and some species; consequently, it was measured in rabbits, pigs, humans, horses, and oxen and approximately was 18-24g, 400-500g, 300g, 900-1500g, and 1200-1400g, respectively (32-34), these weights have been confirmed that camels' kidneys are massive compare to ratio of body which were about 1450 to 1555 g in our finding. Our result distinguished that the cortex was very thin compared to the medulla, and medullary rays, renal columns, and pyramids extended from the medulla toward the cortex, and slim capsules were firmly adhesive to the cortex, so these structures were detected in humans, small ruminants, and carnivores (35-38).

Also, the medulla presented many pyramids, renal columns, and sinuses. These pyramids were drained into minor calyces, which extended with major calyx and renal pelvis toward the ureter, which agreed with previous studies in humans, camels, small ruminants, and dogs (39-41). However, this result was different in bovine (42). The blood supply of camels' kidneys was very similar to other findings in humans, camels, other species of small ruminants, and dogs (7,43-46) because our study distinguished the same features of the renal artery and vein. Subsequently, the renal artery was accompanied by a renal vein divided into arcuate, interlobar, interlobular, arterioles, and capillaries.

Histological results recognized that a thick capsule surrounded the cortex, mainly comprised of collagen fibers, so this capsule was fragile in humans, camels, small ruminants, and dogs (1,7,8). Renal corpuscles occupied the cortex and contained glomeruli surrounded by renal space and bowman's capsule. Also, juxtaglomerular cells were identified in arterioles in the vascular pole of renal corpuscles, similar to humans, camels, small ruminants, and dogs. Still, renal space was exceedingly narrow in camel kidneys (1,7,8,47,48).

Interestingly, this result showed that glomeruli were very rich with collaged coiled with arterioles of glomerular unit of renal corpuscles; this frame of collagen of glomeruli might be related to the efficiency of camel's kidney and regulated metabolism and ions balance for camel. Additionally, proximal and distal convoluted tubules were recognized in the cortex lined by simple cuboidal epithelium and collecting duct lined by simple low columnar epithelium based on a basement membrane of collagen fibers. The same structures were identified in humans and other species (49-51).

These results did not record any essential differences in renal veins and arteries compared with humans and other species (46). However, the size of the kidney in camels, the thick capsule, and the narrow renal space were particular with camels' kidneys; these different structures might be about kidney function and outcomes of salty water or highly salty food throughout the kidney. Also, the proportion of the thickness and long distance of the medulla to the cortex was 4:1 in the two-humped camel.

Conclusion

This study focused on the angiology supply of camel's kidneys using different techniques and detected the renal vein and artery tree and anatomical features of Iraqi one-humped camel's kidney; the study concluded that camel's kidney has significant similarity with other domestic animals. However, in this study, many differences have been recorded in camel's kidney, including the large size of the kidney, thick capsule, renal space of renal corpuscles, and feature of collagen in glomeruli, which may be interpreted as tolerated challenging conditions of camels and feeding on salty hard plant.

Acknowledgment

The authors would like to acknowledge the Department of Anatomy, Histology, and Embryology, College of Veterinary Medicine, University of Al-Qadisiyah for supporting this research.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the current study.

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دراسة تشريحية ونسيجية لكلية الجمل ذو السنام الواحد

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الخلاصة

أجريت هذه الدراسة لتحديد التركيب التشريحي والنسيجي للكلى باستخدام تقنيات تشريحية مختلفة، بما في ذلك التشريح الطبوغرافي، وتقنية الريزين، والأشعة، بالإضافة إلى الصبغات الروتينية والخاصة لدراسة الأنسجة. تم اختيار عشر كلى بالغة سليمة من الإبل ذات السنام الواحد لأغراض مختلفة من هذه الدراسة. ونتيجة لذلك، أظهرت السمات التشريحية لكلية الجمل وجود كلية متعددة الفصوص في الجمل. ظاهريًا، كانت الكلى ناعمة وشكلها حبة الفول. في المقابل، تم تقسيم الكلى الداخلية إلى طبقات رئيسية: طبقة قشرة خارجية رقيقة داكنة اللون، والتي كانت ممتدة داخليًا وملتصقة بطبقة النخاع الداخلي السميكة الشاحبة. بالإضافة إلى ذلك، كان النخاع الكلوي مشغولاً بالأهرامات الكلوية والجيوب الكلوية والأعمدة التي يتم تصريفها إلى الحوض الكلوي للكلية عبر الكؤوس الصغيرة والكأس الكبرى وتستمر مع الحالب. علاوة على ذلك، تم إجراء العديد من القياسات للكلية اليمنى واليسرى، بما في ذلك أجزاء الكلى المختلفة. وكانت المتوسطات المورفومترية للكلية اليمنى أعلى من الكلية اليسرى في معظم المناطق، مما يؤكد الدور الحاسم للكلية اليمنى في هذا الحيوان. كما تم تحديد الشرايين الكلوية اليمنى واليسرى وفروع الوريد باستخدام تقنية الريزين والشريان المشع للشريان الكلوي. أظهرت النتائج أن الكلية تتفرع إلى فروع بين الفصوص، ومقوسة، وبين الفصيصات وتتحول إلى وحدات صغيرة، بما في ذلك الشرايين. حددت النتائج النسيجية القشرة النموذجية والنخاع وهياكل الكلى الحساسة. بالإضافة إلى ذلك، تم التعرف على الكريات الكلوية، والأهم من ذلك، أن المساحة الكلوية حول الكبيبات كانت رقيقة وضيقة للغاية. بشكل عام، خلصت هذه الدراسة إلى أن نوع كلية الجمل، اعتمادًا على القشرة والنخاع، هو نوع كلية متعدد الفصوص، وهناك تشابه كبير في الشكل والإمداد الدموي للكلية اليسرى واليمنى. كما أن مظهر كلى الإبل وبنيتها النسيجية تشبه الأنواع المختلفة لدى البشر، والحيوانات المجترة الصغيرة، والحيوانات آكلة اللحوم، ولكن مرة أخرى، كانت المحفظة الكلوية سميكة جدًا. في المقابل، كانت مساحة الكريات الكلوية ضيقة حول الكبيبات، وأظهرت كبيبات الكبسولة الكلوية كمية كبيرة من ألياف الكولاجين.