Anatomical and histological study of kidney, ureter and urinary bladder in male guinea pig (*Cavia porcellus*)

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Summary

A total of 20 healthy adult male guinea pigs were used in this study to investigate the anatomical, histological and morphometrical characteristics of the kidneys, ureter and urinary bladder. The gross anatomical study showed that the right kidney had a bean shape with reddish pink color whereas the left kidney had a heart shape. The renal cortex appeared darker than medulla with reddish brown color, while the medulla was pale in color. The mean thickness of cortex was more than that of medulla in both left and right kidneys and the ratio of cortex to medulla was 1.06: 1 in both kidneys. The mean length of right ureter was 10.3±0.62 cm while the mean length of left ureter was shorter. The filled urinary bladder appeared as a pear-shaped hollow sac situated in the pelvic cavity and only the rounded cranial part of bladder was expanded. Four histological regions of renal tubules were found in kidney. The Proximal convolutes tubule is first longest and coiled segment of renal tubules which originate from urinary pole of renal corpuscles and measured about 25.421±0.3µm in diameter and lined with simple cuboidal epithelial cells. The Nephron loop (Loop of Henle) was consisted of the descending and ascending thin limbs, the descending thin limb was measured 13.591±0.1µm diameter, whereas the thick ascending limb was measured (19.987±0.5µm) in diameter. Distal convolutes tubule was shorter than the proximal tubule and measured about 21.139±0.5µm diameter. The collecting duct was measured about (31.759±0.2µm) diameter. It was lined with simple cuboidal or columnar epithelium. The cross section of Ureter was possessed a star shape lumen and its wall consist from four tunics (mucosa, lamina propria submucosa, muscularis and serosa). It was lined by transitional epithelium. The histological structure of Urinary Bladder was resembles the ureter, the lamina propria contain few mucous glands.

Keywords: Anatomical, Histological, Kidney, Ureter, Quinea pig.

Introduction

The domestic guinea pig is a descendant of the wild cavy (*Cavia aperea*) which is a common rodent in South America(1). Various mammals (dog, cat, swine, rat and guinea-pig) are used for studying structure and function of the urinary system, quite often, results that were found in one species are directly transferred to the human (2). Continuity and excretion, are the main functions of the lower urinary system, depend strictly on the anatomy of the pelvis, despite the fact that individual anatomical structures can be comparable, but a great considerations for humans must be supposed compared to animals(3).

Previous studies on the guinea pig have focused on management, breeding and whole blood minerals (4 and 5). However, there are few informations on the morphometric analysis of the kidneys and lower urinary organs of the domesticated adult guinea pig

Materials and Methods

Twenty healthy adult male guinea pigs weighing 500-800 gm were obtained from local market (Alghazal market) in Baghdad city used in the present study. Animals were divided randomly into two groups; Ten 10 guinea pigs set for anatomical study and Ten 10 animals for histological and histochemical study.

The animals were weighed alive using a digital balance and the animals were sacrificed at regular intervals after anesthetize by intramuscular injection of a mixture of ketamine and xylazine at dose ketamine 80-100 mg/kg of body weight and xylazine 10-12.5 mg/kg (6). After wards, abdominal cavity was opened and intestine displaced to get

access to the urinary system to explore the shape, position and relationship of kidneys and urinary tract. The relation of kidneys, ureter and urinary bladder to adjacent organs were studied in situ. Length, width, weight, thickness and ratio of cortex to medulla of left and right kidneys were measured using a ruler and a vernier calliper. The organs were weighed using a digital balance. Length and diameter of ureter were measured using a ruler. The organs were photographed by using a digital camera (Sony-cybershot-7.2 MPX-China).

The guinea pig kidneys, ureters and urinary bladder were dissected and freed from the surrounding connective tissues , then excised and a representative samples were taken from these organs . They were immediately immersed in saline solution (0.9% NaCl) for removal of blood. Specimens of 1cm³ were taken from right and left kidneys, ureters and urinary bladder. All samples were immersed in Neutral buffered formalin 10% for 72 hrs. The samples were processed by routine histological possessing method and a paraffin sections (5 – 6 µm) were obtained by using rotary microtome and mounted and affixed to histological slides (7). Hematoxyline and Eosin, Masson's Trichrome, PAS and Alcian blue ph 2.5 were used in this study (8). Renal corpuscle diameter/µm, Proximal tubules diameter/µm, Distal tubules diameter/µm, Ascending and descending limbs of loop of Henle diameters/ µm and Collecting duct diameter/ µm were measured by using the color USB 2.0 digital tube camera (Scope Image 9.0- China) which was provided with image processing software.

Computer package (Sigma plot V12.0/ SYSTAT software) was used to conduct the histomrphometrical analysis. Data were presented as means ± SE (standard error) and were analyzed using Duncan's test with significant level at $P < 0.05$ (9).

Results and Discussion

Gross anatomical study: The urinary system of guinea pig constitute from two Kidneys, two ureters, urinary bladder urethra. The kidneys were retroperitoneal in position and located in the posterior part of abdominal cavity on each side of the vertebral column. ,the right kidney appeared bean shaped organ with reddish pink color whereas the left kidney had a heart shape (Fig.1). The present results are consistence with earlier reported results (10 and11) in all mammals and in desert rodent(12) but disagree with they recorded that the right and left kidneys of the investigated gaint rat were bean shaped(13).

The right kidney situated slightly cranial to the left kidney ,the upper pole of the right kidney make impression on the caudal lobe of the liver. this result come in agreement with previous finding (14) who stated that the right kidney was rostral and cranionmedially to the left kidney in guinea pig. The difference of the kidneys position on each side of the vertebral column may be due to variation in rate of growth of different organs in the abdominal and pelvic cavities during various developmental stages (15 and 16), in laboratory animal while disagreed with other (17) who determined position of the kidneys in rabbits correspond on the lumbar vertebrae also other (18) stated that disposal of the kidneys dependent or the level of artery vessel, because not use artery vessel marker for the determine disposal of the kidneys .

The kidneys were covered by fibrous capsule with adipose tissue (Fig.2). Each kidney had two surfaces (dorsal and ventral), two borders (medial and lateral) and cranial and dorsal pole. The lateral border was convex in shape while the medial border was concave have apparent indented area (the hilus) where the ureter, renal artery and vein enter or leave the kidney (Fig.3). The adrenal glands were closely attached to the cranial pole of each kidney.

There was a difference in the gross measurements of right and left kidneys of guinea pig and the right kidney records higher measurements than the left one but most of the morphometric measurements were not significant statistically. The mean weight of right and left kidney (4.5±0.3 and 4.1±0.4 gram respectively). The mean length, width and thickness of right kidney was (23.9± 0.5mm),(14.96±0.2mm), (11.54±0.3mm respectively) (Table, 1), while the mean length, width and thickness of left kidney was (23.5±0.33) mm, (13.68±0.7) mm,(11.41±0.8) mm respectively (Table,1). According to

variation in color, two anatomical distinct regions were detected in kidney, the outer cortex and inner medulla. The renal cortex appeared darker than medulla with reddish brown color while the medulla was pale brown in color. The mean thickness of cortex was higher than that of medulla in both left and right kidneys, the mean thickness of cortex and medulla of right kidney (5.914±0.4 mm), (5.28±0.6 mm) respectively (Table, 2) while the mean width of cortex and medulla of left kidney(5.3±0.9 mm),(4.7±0.5 mm respectively) (Table, 2). The ratio of cortex to medulla was 1.06: 1 in both kidney. This result was in agreement with other (12), in true desert rodents while disagreement with other (19) who mentioned that the cortex and medulla are arranged into more pyramidal shape called renal pyramids and the apex of the each pyramid that is called renal papilla.

A single white color ureter leaves each kidney via the hilus and runs caudally on either side of the midline in the dorsal of the abdomen (abdominal part of ureter). Each one is a thin-walled muscular tube suspended by a fold of mesentery which (the pelvic part of ureter) enter the urinary bladder from its craniodorsal aspect (Fig. 3). The mean length of right ureter was 10.3±0.62 cm while the mean length of left one was shorter 9.7± 0.45 cm .

The filled urinary bladder appeared as a pear-shaped hollow sac situated in the pelvic cavity and only the rounded cranial part of bladder was expanded in the midline of caudal abdomen. It's rounded end points cranially and the narrow end (the 'neck') points caudally and runs into the urethra (Fig. 3)

Histological Results: The sections of the kidney revealed four distinct regions: Renal capsule, renal cortex, the middle renal medulla and the inner renal pelvis (Fig.4)،

Renal capsule: The kidney was enclosed by a thin layer of connective tissue capsule which composed of thin bundles of smooth muscle fibers and collagen bundles. Thickness of capsule was varied, the greatest thickness was recorded near the hilum (7.3±0.2 µm) while it measured about (4.7±0.13 µm) at the convex (Fig.5).

The renal cortex and medulla were forming the most of renal parenchyma. The renal cortex was darkly stained with H&E stain due to heavily vascularization. At special regions throughout the renal cortex that named renal columns which were passed a cross the renal medulla toward the renal pelvis (Fig.4). The renal columns surrounded by blood vessels which are branching of the renal artery those travel to the outer portion of the cortex. The apex of pyramid tapers into a slender structure which borders on a cup-shaped tube called a renal papilla. The renal cortex and medulla of each kidney contained many nephron (Fig.5 and 6). Each nephron was which consisted of two main components. The renal corpuscle and the renal tubules.

Renal corpuscle were globe-shaped structures had long epithelial tubular part named "renal tubule". It was measured about ((61.871±0.2µm) in diameter. The most of renal corpuscle structures were composed the bulk of the renal cortex, while most of their tubules were downing into the renal medulla. The renal corpuscle composed of two parts: the glomerulus and Bowman's capsule (Fig.7). The glomerulus was consisting of tuft of capillaries renal corpuscle .

Bowman's capsule was surrounding the glomerulus and consisted of double-layered; an outer parietal and inner visceral layers. The parietal layer was extended of the renal tubule and consisting of simple squamous epithelium. The visceral layer was consisted of epithelial cells which engulf around the capillary tuft of glomerulus forming visceral podocytes. Between the parietal and visceral layers there was a space called the Bowman space which was continued with the origin of the renal tubule (Fig.7). The renal corpuscle had two poles; urinary and vascular pole, the urinary pole was located at the origin of the proximal convoluted tubules while the vascular pole was at the efferent and afferent arterioles enter into and exit out of renal corpuscles .

The renal tubules were looped parts which had four regions: The proximal convoluted tubule, the nephron loop, the distal convoluted tubule and the collecting tubules.

Proximal convolutes tubule: The first longest and coiled segment of renal tubule which originating from urinary pole of renal corpuscles. It was measured about (25.421±0.3 µm) in diameter. It composed of much cortex

region and consisted of a highly tortuous region. It was consisted of simple cuboidal epithelial cells. The epithelial cells had large rounded centrally located nuclei and the apical surfaces of these cells were showing brush border which lead to clear narrowing luminal space (Fig.8). These results were disagreed with other finiding (21), they reported that the proximal convoluted tubules are lined with columnar epithelial but in agreement with that proximal tubule is more narrow than the distal convoluted tubule.Nephron loop (Loop of Henle) : The nephron loop was the part of nephrotic renal tubule that dipped into the medulla. It was consisted of the following segments:

The descending thin limb: It was passing from renal cortex toward the renal medulla and back toward the renal cortex as the ascending thin limb. It was measured about (13.591±0.1 µm) in diameter.

The thick ascending limb: It was continuation of the ascending thin limb so, it was located within renal medulla and composed of simple cuboidal epithelium, it was measured (19.987±0.5 µm) in diameter (Fig.9). These results were in agreement with those of (22) in albino rat and (14) in guinea pig.

Distal convolutes tubule: It was the last segment of the renal tubule and measured about ((21.139±0.5µm) in diameter). This segment of the tubule was also convoluted and similar the proximal tubule, the distal tubule was composed of simple cuboidal epithelium has wider lumen and lacks a brush border (Fig.8)

The collecting ducts were tubular structure that measured about (31.759±0.2µm) in diameter. It was located within renal cortex and medulla so, it composed of cortical collecting duct and the medullary collecting duct which form collecting system. It was lined with simple cuboidal or columnar epithelium (Fig 9). Ureter: It was possessed a star shaped lumen and composed of tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa proximally and tunica adventitia distally. Tunica mucosa of ureter was line with transitional epithelium which rested on the propria of fibrous connective tissue and showed no muscularis mucosa. Tunica Submucosa was continued with lamina propria. Tunica muscularis was composed of thick inner circular layer and thin outer longitudinal layers of smooth muscle. Tunica adventitia/ serosa was fibro elastic connective tissue (Fig.10). Urinary Bladder had a histological structure resembles the ureter, except that it was much larger structure. Tunica mucosa of the bladder was thrown into folds which lined by transitional epithelium and the propria submucosa was merged due to absence of muscularis mucosa .The tunica muscularis is composed of three identified layers (inner longitudinal, middle circular and outer longitudinal (Fig.11).

Histochemical Results **:**Carbohydrate histochemical results revealed that the proximal convoluted tubule were showed positive reaction for PAS stain indicating presence of neutral glycoprotein while the distal convoluted tubules and collecting tubules were negative for PAS stain (Fig. 12), the renal medulla revealed that the collecting tubules and all segments of loop of henle were negative for PAS stain. On the other hand the result of Alcian blue were showed positive Alcian blue stain in the colleting tubules and distal convoluted tubules indicating presence of acidic glycoprotein (Fig.13). The results of ureter and urinary bladder were similar and both organs have given negative reaction for PAS stain and positive for Alcian blue stain and it give and indicator for acidic glycoprotein The basement membrane of proximal and distal tubules as well as loop of henle give a positive reaction to the PAS and Alcian blue stains. The glomerular basement membrane give a positive reaction to PAS stain and weak reaction with alcian blue. These results were in consistence with many researchers (23) they recorded a considerable amount of carbohydrates in the cytoplasm of kidney cells of control rats, by PAS-technique, which gave a red or magenta color.

Table, 1: Length, width, thickness (mm) and weight (gram) of the right and left kidneys of male guinea pig.

	Length mm	Width Mm	Thickness mm	Weight gram
Right kidney	23.9± 0.5	14.96±0.2 [a]	11.54±0.3	4.5±0.3
Left kidney	23.5±0.33	13.68±0.7 [b]	11.41±0.8	4.1±0.4

Different letters mean there is a significant difference at p<0.05.

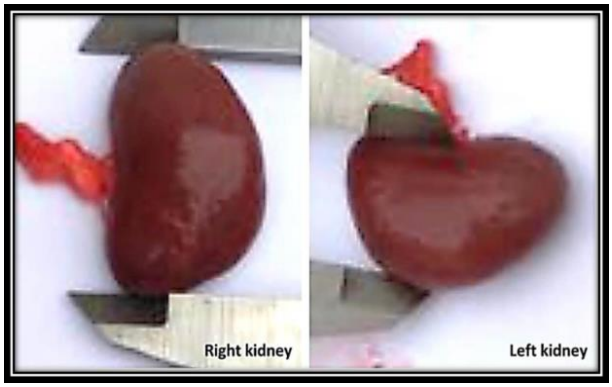
Table, 2: Thickness (mm) of cortex and medulla of the right and left kidneys of male guinea pig.

	Cortex	medulla
Right kidney	5.914±0.4	5.28±0.6a
Left kidney	5.3±0.9	4.7±0.5b

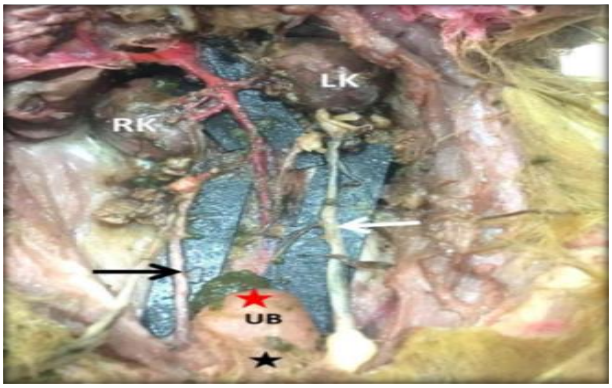
Different letters mean significant difference at p<p0.05.

Table, 3: Diameter of renal structures in guniea pig / micrometer.

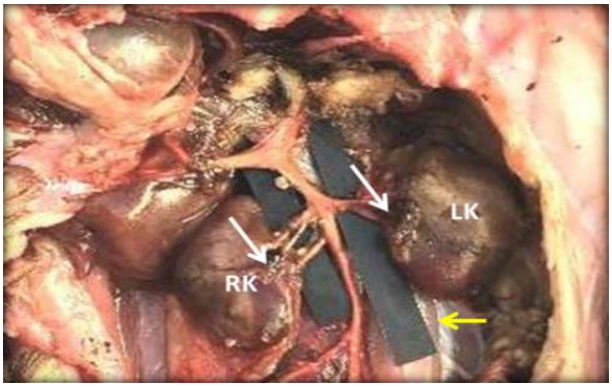
Renal corpuscle *µm*	Proximal convolutes tubule *µm*	Descending thin limb of henle loop *µm*	Thick ascending limb of henle loop *µm*	Distal convolutes tubule *µm*	Collecting duct *µm*
61.871 ± 0.2	25.421± 0.3	13.591±0.1	19.987±0.5	21.139±0.5	31.759±0.2



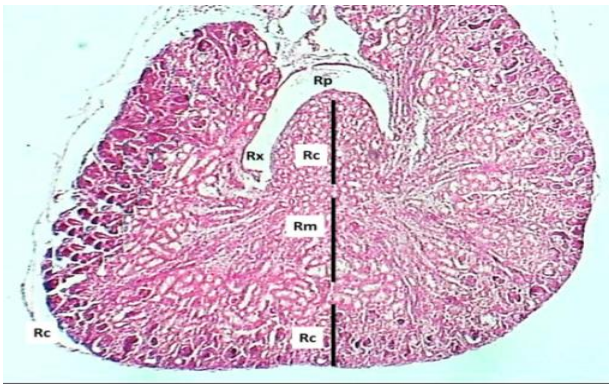
Figure, 1: photograph shows the right and left kidneys of male guinea pig. The right kidney had been shape while left one had heart shape.



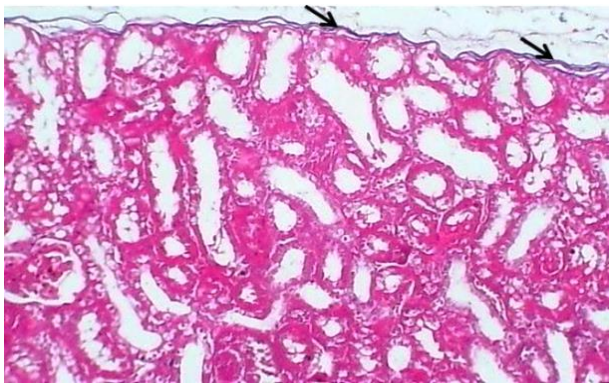
Figure, 3: photograph shows the right kidney (RK) and left kidney (LK) of male guinea pig. Note the left ureter (white arrows) and right ureter (black arrow), bladder (red star).



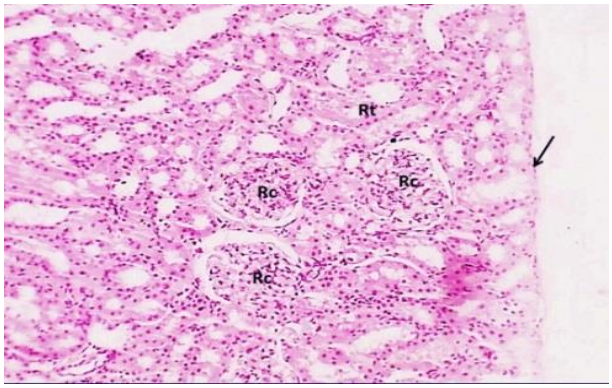
Figure, 2: photograph shows the right kidney (RK) and left kidney (LK) of male guinea pig. Note the hilus (white arrows) and left ureter (yellow arrow).



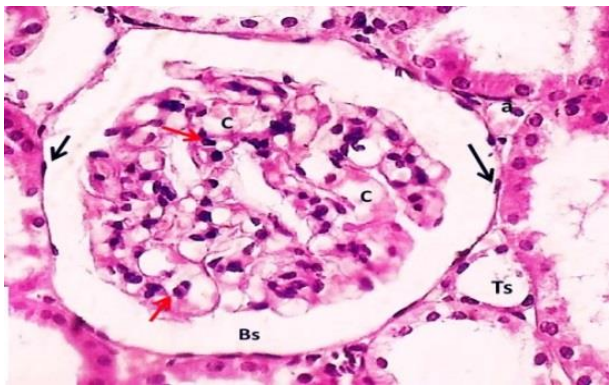
Figure, 4: Histological sagittal section of whole kidney shows: renal capsule (Rc), renal cortex (Rc), renal medulla (Rm), renal column (Rc), renal pelvis (Rp) and renal calyx (Rx). H&E stain. 40x.



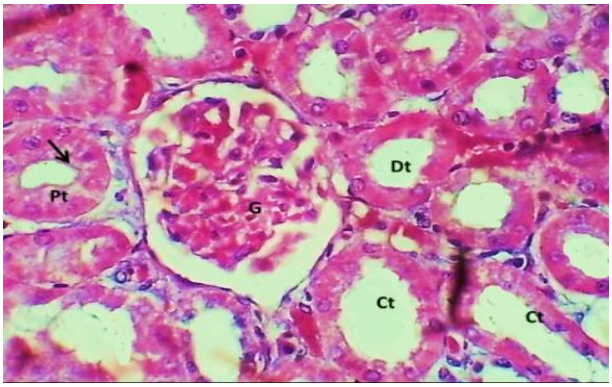
Figure, 5: Histological section of kidney shows: renal capsule (Arrows). Masson trichrom stain. 100x.



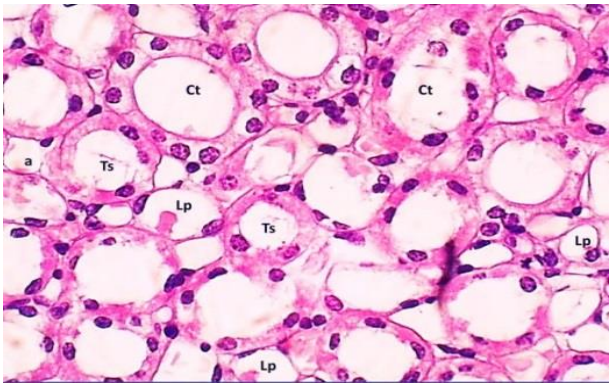
Figure, 6: Histological section of renal cortex shows; renal corpuscles (Rc) renal tubules (Rt). H&E stain.100x.



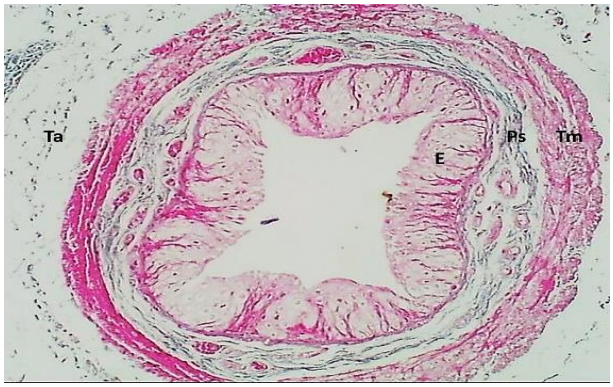
Figure, 7: Histological section of nephron (glomerulus) shows: Capillaries (C), squamous epithelium of parietal layer (Black arrows), visceral layer forming podocytes (Red arrow), bowman space (Bs) and thin segment of loop of henle (Ts). H&E stain. 400x.



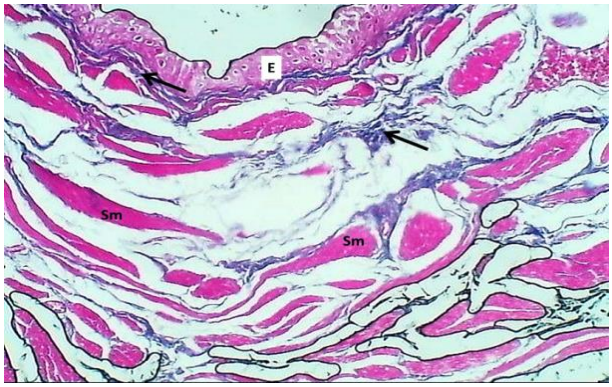
Figure, 8: Histological section of renal cortex shows glomerulus (G) proximal tubule (Pt) and brush border (arrow), distal tubule (Dt) collecting duct (Ct). H&E stain. 400x.



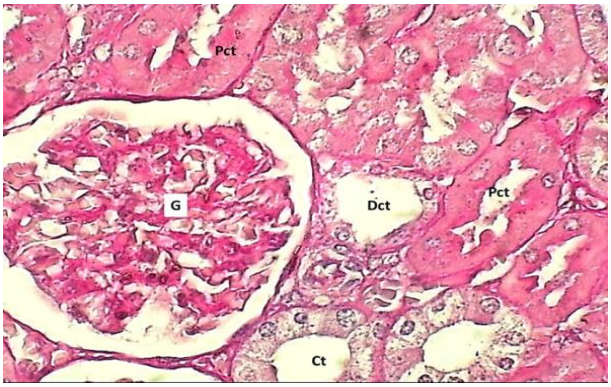
Figure, 9: Histological section of renal medulla shows: Collecting tubules (Ct), thick segments (Ts), thin segments (LP) of loop of henle and blood vessels (a). H&E stain. 400x.



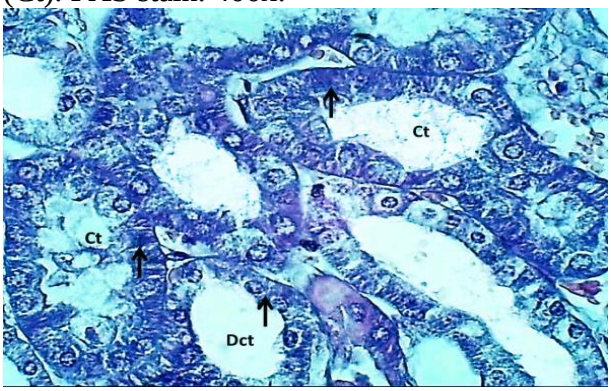
Figure, 10: Histological section of ureter shows: epithelium (E), propria submucosa (Ps), tunica muscularis (Tm) and tunica adventitia (Ta). H&E stain. 100x.



Figure, 11: Histological section of urinary bladder shows: epithelium (E), collagen bundles (arrows) and smooth muscle fibers (Sm), Masson trichrom stain. 100x.



Figure, 12: Histological section of renal cortex shows: glomerulus (G), PAS positive reaction in proximal convoluted tubules (Pct), distal convoluted tubules (Dct) and colleting tubules (Ct). PAS stain. 400x.



Figure, 13: Histological section of renal cortex shows: positive Alcian blue reaction (arrows) in distal convoluted tubules (Dct) and colleting tubules (Ct). Alcian blue stain. 400x.

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دراسة تشريحية ونسجية للكلية والحالب والمثانة في ذكور خنازير غينيا(*Cavia porcellus*)

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الخلاصة

استخدمت في هذه الدراسة عشرون من ذكور خنازير غينيا البالغين وذلك لمعرفة الخصائص التشريحية والنسجية والقياسات الشكليائية للكلية والحالب والمثانة البولية في ذكور خنازير غينيا. اظهرت الدراسة التشريحية أن الكلية اليمنى لديها شكل حبة الفاصولياء ذات لون احمر فاتح في حين أن الكلية اليسرى لديها شكل القلب و تقع الكلية اليمنى اماميا للكلية اليسرى . ظهر اختلاف في القياسات بين الكليتين اليمنى واليسرى، وسجلت الكلية اليمنى قياسات أعلى من قياسات الكلية اليسرى ، لكن لم يكن هناك فرق معنوي إحصائيا في معظم القياسات بين الكليتين اليمنى واليسرى. ظهرت القشرة الكلوية أكثر قتامة من النخاع مع اللون البني المحمر في حين أن النخاع كان لونه بني فاتح. كان متوسط سمك القشرة أعلى من النخاع في الكليتين اليمنى واليسرى وكانت نسبة القشرة إلى النخاع 1.06: 1 في كلتا الكليتين. كان متوسط طول الحالب الأيمن 10.3 ± 0.62 سم بينما كان متوسط طول الحالب الايسر أقصر. ظهر الحالب بشكل انبوب ابيض اللون يمتد من سرة الكلية ويخترق المثانة البولية من جانبها الامامي الظهري. ظهرت المثانة البولية الممتلئة على شكل كيس مجوف على شكل كمثرى يقع في تجويف الحوض. تم تمييز أربعة مناطق من النبيبات الكلوية. ظهر النبيب الكلوي كجزء ملفوف من النبيبات الكلوية التي تنشأ من القطب البولي للجسيمات الكلوية وهو ذو قطر (25.421 ± µm0.3) ويبطن بخلايا مكعبة بسيطة تمتلك حافة الفرشاة وان تجويف النبيبات الدانية كان ضيقا. تألفت عروة هينلي من النبيبات الرقيقة النازلة والصاعدة. اظهرت النتائج ان النبيب الرقيق النازل ذو قطر (13.591 ± µm0.1) في حين أن النبيب السميك الصاعد ذو قطر (19.987 ± µm0.5). كانت النبيبات القاصية الكلوية بمعدل قطر ((21.139 ± µm0.5). ظهرت النبيبات الكلوية القاصية في كل من القشرة والنخاع وكانت مبطنة بظهارة مكعبة بسيطة ذات تجويف واسع وتفتقر إلى حافة الفرشاة. كانت النبيبات الجامعة أطول من الأنابيب الكلوية ويبلغ قطرها حوالي (31.759 ± µm0.2) ، وكانت مبطنة بظهارة بسيطة مكعبة الشكل أو عمودية. اظهرت المقاطع العرضية للحالب انه ذو شكل نجمي ومبطن بالظهارة الانتقالية وتالف جداره من الغلالات الاربعة الرئيسية لأي عضو انبوبي كما ظهرت المثانة بتركيب نسيجي مشابه للحالب الا انها لا تمتلك الشكل النجمي وتحتوي على غدد مخاطية في المنطقة اللبادية من الغلالة المخاطية.

الكلمات المفتاحية: تشريحية، نسجية، الكلية، الحالب، خنزير غينيا.