



MORPHO - HISTOLOGICAL STUDY ON THE DEVELOPMENT OF KIDNEY AND URETER IN HATCHING AND ADULTHOOD RACING PIGEON (*COLUMBA LIVIA DOMESTICA*)

Ramzi Abdul-Gahaffor Abood AL-Ajeely & Fadhil S. Mohammed.

College of Veterinary Medicine Dept. of Anatomy and Histology, University of Baghdad, Iraq.

ABSTRACT

In one day –old squab pigeon have revealed that the kidneys were flattened retroperitoneal, very fragile organs embedded in ventral surface of synsacrum bone and each kidney was incompletely divided into three lobes, the caudal lobe was the largest and wider than the others. In mature pigeon the kidney was still in position and completely divided into three lobes. In casting adult pigeon, each lobe owns a ureteral radical independent from the other lobes, the independent radical form a radiate which were uniting with each other's and draining in main ureter. Each kidney vascularized by cranial, middle and caudal renal artery and cranial and caudal renal portal vein then drain by cranial and caudal efferent veins the later with renal portal veins formed the left and right common iliac vein. However the renal portal vein entering the kidney served as the capillaries surrounding the tubules but does not enter the glomeruli. The kidney of squab covered by thin capsule and in mature appeared very thin. Squab and mature pigeon both had uniform parenchyma and there was no any demarcation between the cortex and medulla, both structure interment with each other. Although, it was recognized two types of nephrons, the reptilian type or cortical type which was more numerous and lacked a loop of Henle. The mammalian type or medullary type was less numerous and had a loop of Henle. The ureter is generally lined by a pseudostratified columnar epithelium. Moreover, there is intraepithelial acinar gland stained intensively with PAS stain.

KEYWORDS: Kidney, Racing Pigeon, Ureter.

INTRODUCTION

The pigeon for many centuries is one of the avian species more used for human nutrition (Eleonora *et al.*, 2008), have been domesticated for thousands of years, the predecessors of modern day racing pigeons released at unfamiliar locations return to their home lofts in most cases, carry messages, "pigeon posts" have been established all over the world. However, during the development of the kidney in the avian embryo, the pronephros, mesonephros and metanephros appear in sequence in a manner similar to that seen in the mammalian and reptilian embryos. The mesonephros is the functional kidney for fish and amphibians while the metanephros is the functional kidney of reptiles, birds, & mammals (Casotti *et al.*, 2000, Hiruma and Nakamura, 2003, Fletcher and Weber, 2007). The role of bird kidneys, like the kidneys of other vertebrates, is for filtration, excretion or secretion, and absorption. Kidneys also play an important role in conserving water and reabsorbing needed substances (Ritchison, 2008). This study was designed to give a large scale and clear investigation of sequential developmental changes which happened after hatching to be compared with the morphological structure which exposed in mature birds.

MATERIALS AND METHODS

The Experimental Animals

Two groups of mature healthy pigeons belong to the order *Columbiforms* of genus *Columba*, species *Columba livia* and sub species *Columba livia domestica* (AL-Louse, 1960, Chiasson, 1984) were collected from a local commercial market of birds in Baquba city. The first

group consists of twelve mature healthy pigeons, six male and six female. These birds were put in special bird's cages for copulatory and fed granular diet, water was provided ad libitum. From these groups, ten squab pigeons were collected on the first day of hatching, six of them were used for morphological and the others for histological observation. The second group consists of thirty mature healthy pigeons regardless of their sex, male or female. These birds were fed as previously over a period of two weeks before use, confirming that all studied birds were free of any clinical abnormality or lesions, twenty five of them were used for the morphological indices and the others for the histological observation. Body weight of six squab pigeon and ten mature pigeons were recorded just prior to be euthanized, with ketamine 25mg/kg B.W and xylazine 5mg/kg B.W injected through the alar vein of mature pigeon (Bohle and Christensen, 1985, Durrani *et al.*, 2008) and intraperitoneal for squab pigeon (Casotti *et al.*, 2000) with insulin syringe. Weight, width and length of kidney were recorded immediately after obtaining the kidneys from the sacrificed pigeon.

Blood supply

Six mature pigeons, four of them for arterial blood supplies and the others for renal portal circulation, were anesthetized with ketamine and xylazine, the anesthetized birds were given some time to complete bleeding through a pinhole opened in the left ventricle of the heart until bird die. The birds were injected a mixture consists of latex and carmine red stain which was injected into the aorta another different color which was injected into the right atrium for two birds pass through caudal vena cava to portal vein.

After injection, the whole bird body was left in 10% formalin for 48 hours for polymerization.

Cast form of blood vessels

Six mature pigeon, four of them for arterial blood supplies and the two for renal portal circulation, were anaesthetized and killed by bleeding as previously mentioned, followed by an auto-polymerisable prepared acrylic resin, self-curing repair powder and liquid containing Methyl methacrylate monomer, 4-dimethylaminotoluene. The resin was injected through the left ventricle to descending aorta of birds and through the right atrium to demonstrate the portal vein. The specimens were left at room temperature at least two days to ensure full hardening of the resin. After solidification, the specimens were transferred to the maceration kept separately in large jar containing 500 ml of 40% potassium hydroxide for 72 hours to digest the tissue (Casotti and Braun, 1995).

Cast form of kidney

Three mature pigeons were anaesthetized and killed by bleeding as previously mentioned. The resin was injected by manual using style syringe (5 ml) with the cannula 23 gage inserted into ureter to distribute the resin into uretral branches and medullary cones.

Histological study

The experimental birds were killed by a high dose of ketamine and xylazine. The sample were collected and fixed 10% neutral buffered formalin. The specimens were washed by tap water for 4 -6 hours and transferred to the different graded alcohol, than through xylol, finally Embedding in paraffine wax, Blocking, Cutting and Staining. The sections were stained with the different stain. and examined by using a light microscope with a digital camera.

RESULTS AND DISCUSSION

Morphological Results

The kidney in a day-old squab pigeon appeared flattened retro-peritoneal organs embedded in ventral surface of synsacrum bone, occupied the renal fossae of ilium and their color was pink to red pink, it was very fragile (Fig.1 and 2). This supported by many researchers (King and McLelland, 1984, Shively, 1984 and Welle, 2001). However, Romanoff (1960) indcribed the gross appearance of the kidney at the time of hatching in one day-old chicks. Support this result. Each kidney revealed three distinct incomplete attached lobes, the caudal lobe was the largest and wider than the other two lobes. The result of the present study is a newly data duo to lack in literature dealing with pigeons, supporting this in other birds (King, 1975, Steiner and Davis, 1981 and Ritchie *et al.* 1994). In addition, McLelland (1990), Bellair and Osmond (2005) illustrated that the kidney of chick at hatching have three elongated lobes.

The adult kidney is still in its position but the cranial lobe is more bulging than the others and the synsacrum bone completely hide the other lobes with its complete ossification (Fig.4). Welle (2001) showed that the avian kidney radiographically occupied the dorsal body cavity caudal to the acetabula which lie in pockets of the bone on the ventral surface of synsacrum where the cranial division

bulges out ventrally, moreover this parallel with other authors (Hodges, 1974 King and McLelland, 1984). The color of kidney in adult pigeon appeared variable from brownish red to dark red (Fig. 4 and 5). McLelland (1990) discussed that the color of kidney in canary varies from pink to brownish this according to the amount of blood they contain. Each kidney consists of completely attached three lobes, a large caudal lobe, a small middle (Fig.4 and 5). McLelland (1990) found in *non-passerine* birds the kidney can be externally divided into cranial, middle and caudal divisions. King (1975) in chicken found that each kidney is divided into, rounded cranial, more slender middle expanded and irregularly shaped caudal division, but in adult pigeon is similar to what was described by Braun and Dantzer (1972) in *desert quail*; Casotti and Braun (2000) in *sparrows*. External iliac artery pass through line of demarcation between the cranial and middle lobe while the Ischiadic artery passing the constrict line between the middle and caudal lobe (Fig.4). This is with the line of results by Chiasson (1984) in pigeon; Wideman *et al.*, (2005) in the domestic fowl; Yokota *et al.* (2005) in *amniotes*. The left kidney is heavier than the right one may be due to higher flow of the blood in the left kidney by the left external iliac vein. This is supporting the work of Shideman (1981) in chicken. However, table (3) showed the correlation between different kidneys' traits (weight, length and width) in squab pigeons. These results showed a high significant level in ($p \leq 0.01$) between weight of the left and the right kidneys with the body weight, although there was a correlation between the length of the left and the right kidneys with the body weight on a significant level ($p \leq 0.05$). On the other hand, in table (4) it was observed that there was an absence of the correlation between kidney traits in mature racing which did not show any significant correlation except between length of the left kidney and length of the right one. Data of the present study suggested that each lobe acts as an independent function until the animals become mature (Fig. 6 and 7). However Boykin and Braun (1993) in chickens and *desert quail*, discussed that the anatomical arrangement of medullary cones do not permit the output from one medullary cone to another medulla, thus all the medullary cones function as parallel units. However, the biometric analysis of kidney system of racing pigeon in this study revealed a newly data, which are presented in tables (3 and 4). In which a correlation was made between body weight and kidney traits. Like works are supported by Islam *et al.* (2004) in chicken.

Many radicals interfering with renal parenchyma, the latter exhibited numerous cones which appeared draining their continent into each ureteral radical (Fig.6). Each lobe has its own radiated radicals independent from the other lobe, the radical collecting forms the main ureter after uniting with each other (Fig.6 and 7). The result of casting does not mention previously in this species of birds except that of Radu (1979) who used latex following only the ramification of the blood supply of fowl, turkey, duck and geese. Kurihara and Yasuda (1975a) using resin and neoprene cast to describe the blood vessels of the kidney of fowl.

TABLE 1: Measurements of the weight, length and width of the kidney traits in squab pigeons (n= 6)

Traits	Mean \pm S.D	Min.	Max.
Body weight of squab pigeon (gm)	13.833 \pm 0.86	12.99	15.00
Left Kidney weight (gm)	0.1365 \pm 0.01	0.13	0.15
Right Kidney weight (gm)	0.1322 \pm 0.01	0.12	0.15
Length of left Kidney (cm)	1.083 \pm 0.12	0.90	1.20
Width of left Kidney (cm)	0.416 \pm 0.08	0.30	0.50
Length of right Kidney (cm)	1.016 \pm 0.08	0.90	1.10
Width of right Kidney (cm)	0.383 \pm 0.05	0.30	0.40

TABLE 2: Measurements of the weight, length and width of the kidney traits in mature racing pigeons (n=10)

Traits	Mean \pm S.D	Min.	Max.
Body weight of racing pigeon (gm)	307.43 \pm 48.34	230.27	402.02
Left Kidney weight (gm)	1.21 \pm 0.29	0.90	1.086
Right Kidney weight (gm)	1.09 \pm 0.15	0.85	1.29
Length of left Kidney (cm)	2.68 \pm 0.22	2.60	3.30
Width of left Kidney (cm)	1.14 \pm 0.11	1.00	1.30
Length of right Kidney (cm)	2.81 \pm 0.19	2.60	3.29
Width of right Kidney (cm)	1.11 \pm 0.06	1.00	1.20

TABLE 3: Pearson correlations (r) between Kidney traits (weight , length , width) in squab pigeons .

Traits	B. W. (gm)	L.K.W. (gm)	R.K.W. (gm)	L.L.K. (cm)	L.W.K. (cm)	R.L.K. (cm)	R.W.K (cm)
Body Weight of squab pigeons (B.W.) (gm)	1.0	0.986**	0.981**	0.860*	0.860*	0.860*	0.479
Left Kidney Weight (L. K. W.) (gm)	---	1.0	0.996**	0.793	0.825*	0.825*	0.463
Right Kidney Weight (R. K. W.) (gm)	---	---	1.0	0.816*	0.847*	0.847*	0.531
Left Length Kidney (L. L. K.) (cm)	---	---	---	1.0	0.947**	0.947**	0.768*
Left Width Kidney (W. L. K.) (cm)	---	---	---	---	1.0	0.999**	0.750*
Right Length kidney (L. R. K.) (cm)	---	---	---	---	---	1.0	0.759*
Right Width Kidney (W. R. K.) (cm)	---	---	---	---	---	---	1.0

* Significant correlation (r) at $p \leq 0.05$
** significant correlation (r) at $p \leq 0.01$

TABLE 4 : Pearson correlations (r) between Kidney traits (weight , length , width) in mature racing pigeons

Traits	B. W. (gm)	L. K. W. (gm)	R. K. W. (gm)	L. L. K. (cm)	L. W. K. (cm)	R. L. K. (cm)	R. W. K. (cm)
Body Weight of mature pigeons (B.W.) (gm)	1.0	0.505	0.428	0.269	-0.030	0.96	-0.269
Left Kidney Weight (L. K. W.) (gm)	---	1.0	0.868*	-0.07	0.28	-0.09	0.224
Right Kidney Weight (R. K. W.) (gm)	---	---	1.0	0.235	0.334	0.173	0.532
Left Length kidney (L. L. K.) (cm)	---	---	---	1.0	0.457	0.950**	0.487
Left Width Kidney (W. L. K.) (cm)	---	---	---	---	1.0	0.368	0.412
Right Length Kidney (L. R. K.) (cm)	---	---	---	---	---	1.0	0.656*
Right Width Kidney (W. R. K.) (cm)	---	---	---	---	---	---	1.0

* Significant correlation (r) at $p \leq 0.05$
** significant correlation (r) at $p \leq 0.01$

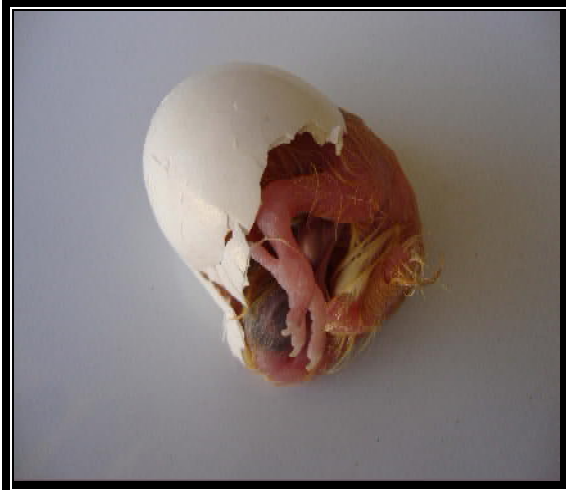


Figure 1: Photograph of squab pigeon during hatching time

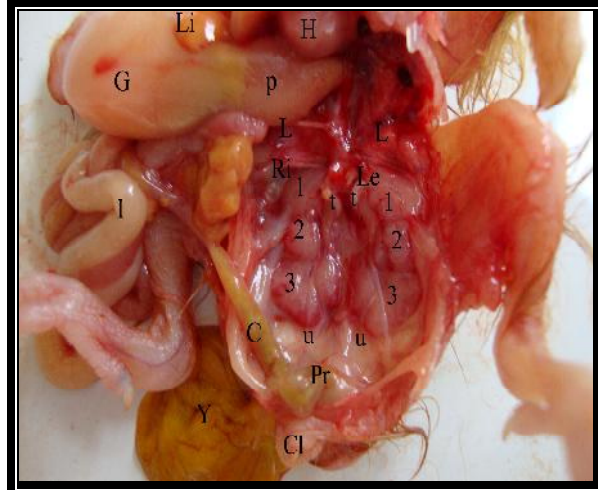


Figure 2: Photograph illustrates anatomical position, shape and color kidney of one-day old squab pigeon (ventral view). a- Left kidney 1. Cranial lobe 2. Middle lobe 3. Caudal lobe b- Right kidney 1. Cranial lobe 2. Middle lobe 3. Caudal lobe c- Left test d- Right test e- Left ureter f- Right ureter g- Left lung h- Right lung i- Heart j- Proventriculus k- Gizzard l- Intestine m- Rectum n- Proctodeum o- Yolk sac p - Cloaca vent.



Figure 3: Photograph of healthy mature racing pigeon.

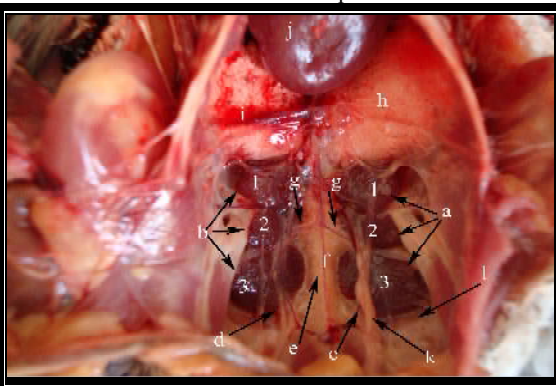


Figure 4: Photograph illustrates anatomical position, shape and color kidney of mature racing pigeon (ventral view). a- Left kidney b- Right kidney c- Left ureter d- Right ureter e- Splanchnic f- Aorta g- Left and Right Ischiadic artery h- Left lung i- Right lung j- Heart k- Oviduct l- Renal fossae

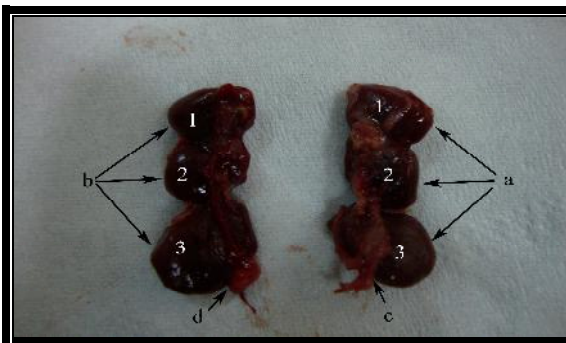


Figure 5: Photograph illustrates lobation kidney of mature racing pigeon (visceral surface). a- Left kidney 1. Cranial lobe 2. Middle lobe 3. Caudal lobe b- Right kidney 1. Cranial lobe 2. Middle lobe 3. Caudal lobe c- Left ureter d- Right ureter

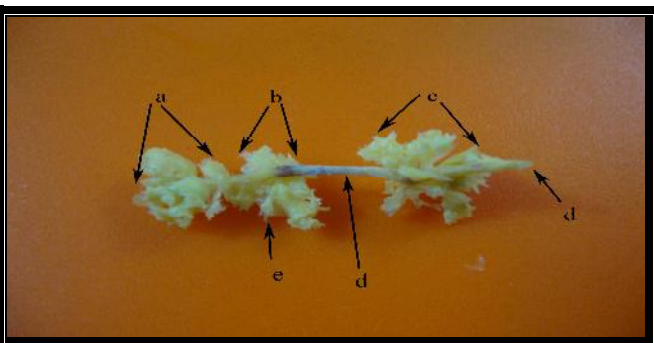


Figure 6: Photograph illustrates cast of kidney of mature racing pigeon showing. a- Cranial lobe b- Middle lobe c- Caudal lobe d- Ureter e- Ureteral radicals

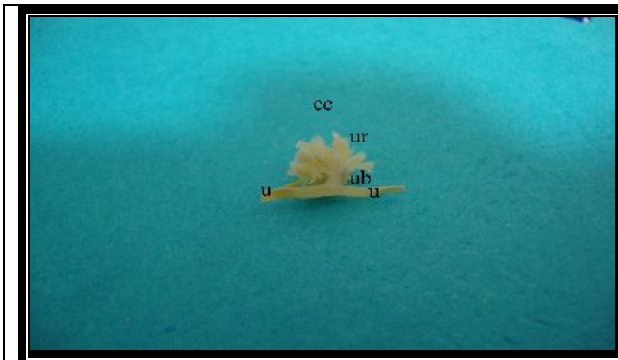


Figure 7: Photograph illustrates the cast of cc. caudal lobe of kidney. u- Ureter ur- Ureteral radicals ub- Ureteral branch

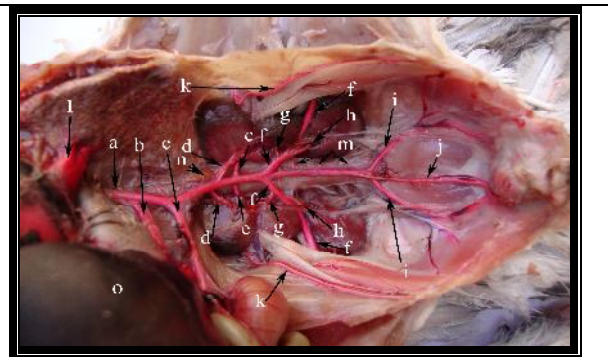


Figure 8: Photograph illustrates arterial blood supply of the kidney of mature racing pigeon were latex injection and preserved in formalin. a- Aorta b- Celiac artery c- Cranial mesenteric artery d- Cranial renal artery e- External iliac artery f- Ischiadic artery g- Middle renal artery h- Caudal renal artery i- Internal iliac artery j- Median caudal artery k- Pubic artery l- Pulmonary artery m- Intervertebral artery n- Adrenal gland o- Liver

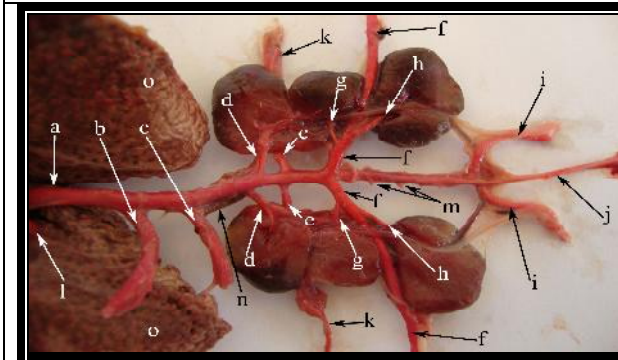


Figure 9: Photograph illustrates arterial blood supply of the kidney of mature racing pigeon were latex injected and preserved in formalin. a- Aorta b- Celiac artery c- Cranial mesenteric artery d- Cranial renal artery e- External iliac artery f- Ischiadic artery g- Middle renal artery h- Caudal renal artery i- Internal iliac artery j- Median caudal artery k- Pubic artery l- Pulmonary artery m- Intervertebral artery n- Adrenal gland o- Left and Right lung

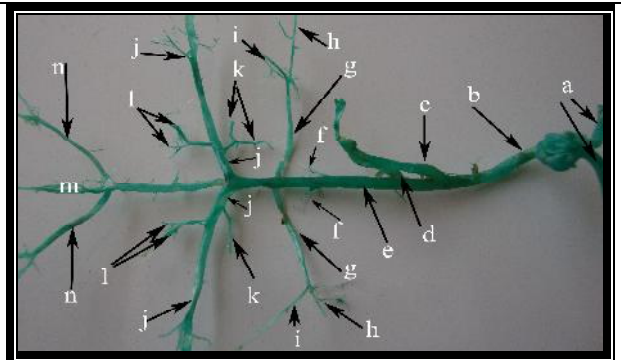


Figure 10: Photograph illustrates blood supply cast of kidney macerated of mature racing pigeon. a.Brachiocephalic trunk b.Aortic arch c.Celiac artery d.Cranial mesenteric artery e.Aorta f.Cranial renal artery g.External iliac artery h.Femoral artery i.Pubic artery j.Ischiadic artery k.Middle renal artery l.Caudal renal artery m.Median caudal artery n.Internal iliac artery

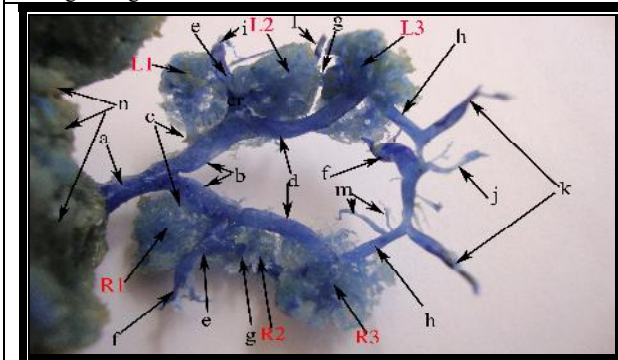


Figure 11: Photograph illustrate cast of renal portal vein macerated in mature racing pigeon. a.Caudal vena cava b. Common iliac vein c. Cranial renal vein d.Caudal renal vein e. External iliac vein f.Caudal mesenteric vein g.Cranial renal portal vein h.Caudal renal portal vein i.Femoral vein j.Median caudal vein k.Internal iliac vein l.Ischiadic vein m.Intervertebral vein n.Liver L1- Cranial lobe of left kidney L2- Middle lobe of left kidney L3- Caudal lobe of left kidney R1- Cranial lobe of right kidney R2- Middle lobe of right kidney, R3- Caudal lobe of right kidney

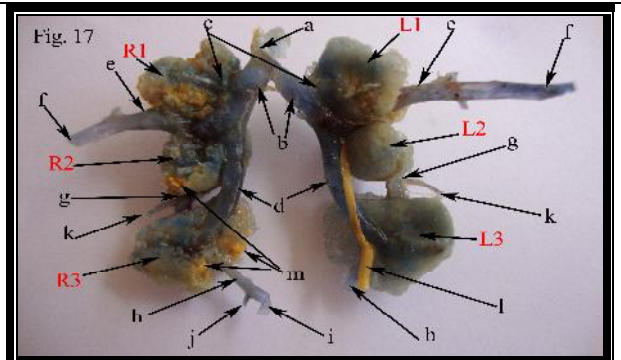


Figure 12: Photograph illustrates cast of renal portal vein macerated in mature racing pigeon. a- Caudal vena cava b- Common iliac vein c- Cranial renal vein d- Caudal renal vein e- External iliac vein f- Femoral vein g- Cranial portal vein h- Caudal portal vein i- Median caudal vein j- Internal iliac vein k- Ischiadic vein l- Ureter m- Ureteral ridicules L1- Cranial lobe of left kidney L2- Middle lobe of left kidney L3- Caudal lobe of left kidney R1- Cranial lobe of right kidney R2- middle lobe of right kidney R3- Caudal lobe of right kidney

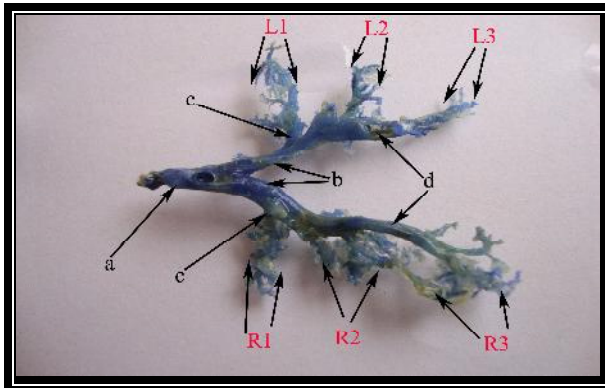


Figure 13: Photograph illustrate cast of efferent renal vein macerated in mature racing pigeon. a.Caudal vena cava b. Common iliac vein c.Cranial renal vein d.Caudal renal vein L1- Efferent venules of left cranial lobe L2- Efferent venules of left middle lobe L3- Efferent venules of left caudal lobe R1-Efferent venules of right cranial lobe R2- Efferent venules of right middle lobe R3- Efferent venules of right caudal lobe

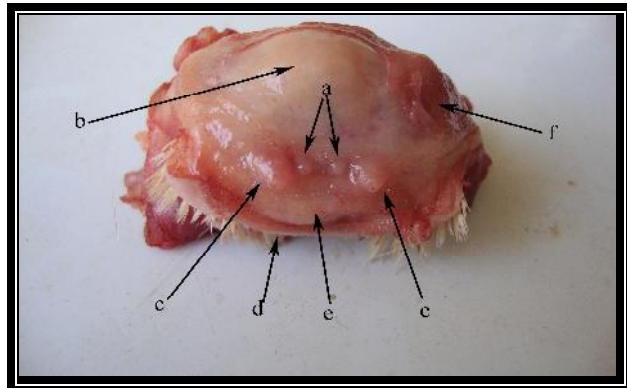


Figure 14: Photograph illustrates opening of ureter in cloaca a- Renal papillae b- Coprodeum c- Phallic body d- Cloacal vent e- Urodeum f- Proctodeum

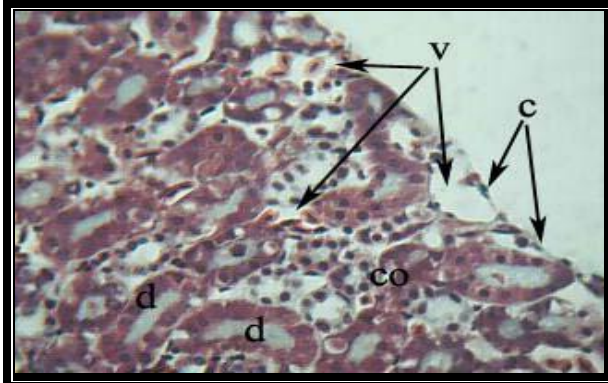


Figure 15: Photomicroscope illustrates the kidney of mature racing pigeon surrounded by very thin capsule. (M.T stain, X 40) c- Capsule co- Collecting tubules d- Distal convoluted tubules v- Venules

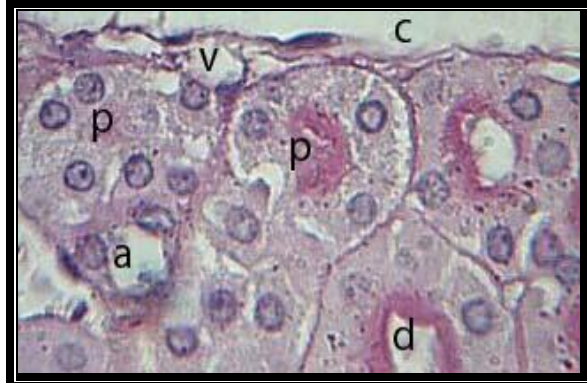


Figure 16: Photomicroscope illustrates the kidney of mature racing pigeon surrounded by very thin capsule. (PAS stain, X 100) c- Capsule d- Distal convoluted tubules p- Proximal convoluted tubules a- Arteriole v- veiniole

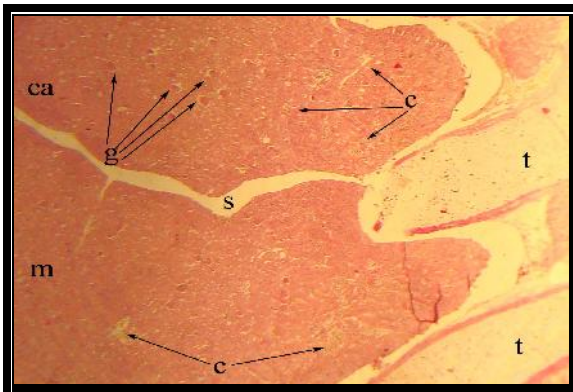


Figure 17: Photomicroscope illustrates the lobe of kidney of squab ramified with central vein. (V.G. Stain, X 40) ca. caudal lobe m. middle lobe s. space between lobe c. central vein t. transverse process of lumbar vertebra g. glomeruli

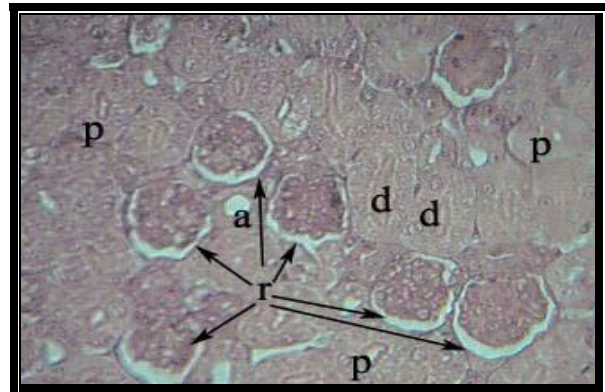


Figure 18: Photomicroscope illustrates numerous reptilian glomeruli of squab kidney. (V.G stain, X 40) r- Reptilian glomeruli p- Proximal convoluted tubule d- Distal convoluted tubule a- Arteriole

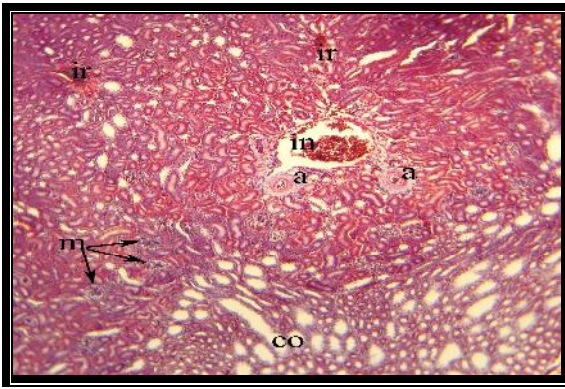


Figure19: Photomicroscope illustrates the kidney of mature racing pigeon ramified with central vein (intralobular vein) and there is no line of demarcation between cortex and medulla. (M.T stain, X 10) in- Intralobular vein ir- Interlobular vein m- Mammalian glomeruli co- Collecting ducts a- Arterioles

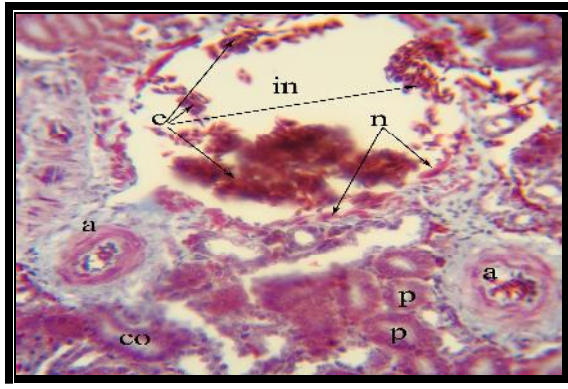


Figure 20: Photomicroscope of high power of (fig. 26) illustrates the intralobular vein. (M.T stain, X 40) in- Intralobular vein a- Arterioles co- Collecting tubule e- Erythrocytes n- Nucleus of endothelial cells of vein p- Proximal convoluted tubule

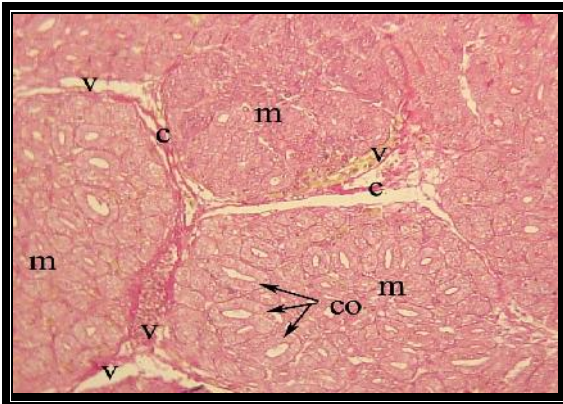


Figure 21: Photomicroscope illustrates the medullary area in kidney squab contained bundles homologize of tubules. (V.G stain, X 10) m- Medullary area c- Connective tissue surrounded the bundles of tubules v- Veinioles co- Collecting duct

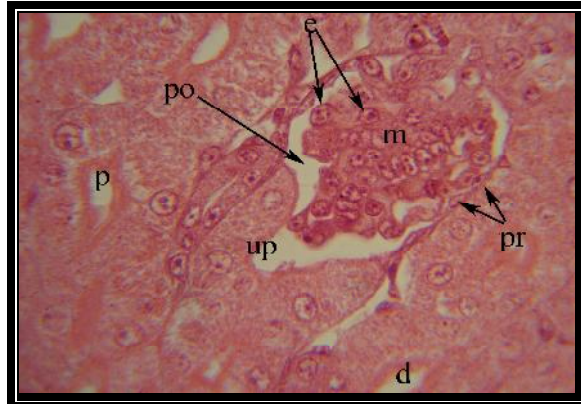


Figure 22: Photomicroscope illustrates the reptilian glomeruli of kidney squab contained wide Bowman's space. (V.G stain, X 100) e- Erythrocyte po- Bowman's space up- Urinary pole in proximal convoluted tubules p- Proximal convoluted tubule pr- parietal layer of Bowman's space d- distal convolute tube

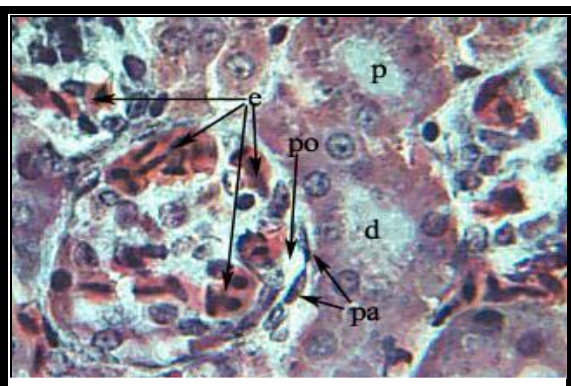


Figure 23: Photomicroscope illustrates the reptilian glomeruli of kidney mature racing pigeon contained narrow Bowman's space. (M.T stain, X 100) e- Erythrocytes p- Proximal convoluted tubule d- Distal convoluted tubule po- Bowman's space pa- Parietal layer of Bowman's capsule

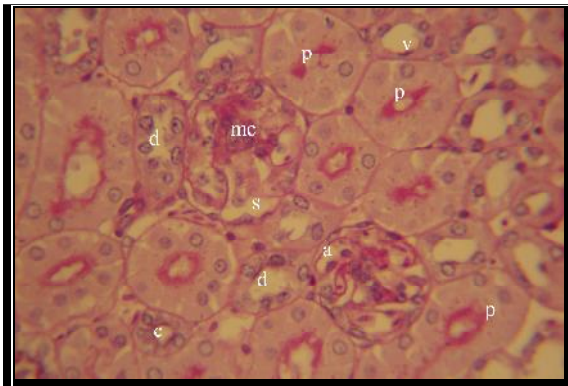


Figure 24: Photomicroscope illustrates the mammalian glomeruli of kidney mature racing pigeon. (PAS stain, X 100) mc- Mammalian glomeruli contain mesangial cell p- Proximal convoluted tubule d- Distal convoluted tubule s- Bowman's space c- Thin Henle's loop th- Thick Henle's loop a- Arteriole v- Veiniole

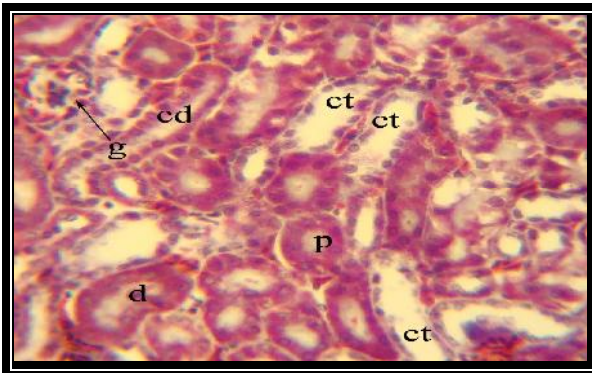


Figure 25: Photomicroscope illustrates the tubules in kidney of mature racing pigeon. (M.T stain, X 40) cd- Collecting duct ct- Collecting tubule g- Glomeruli p- Proximal convoluted tubule d- Distal convoluted tubules

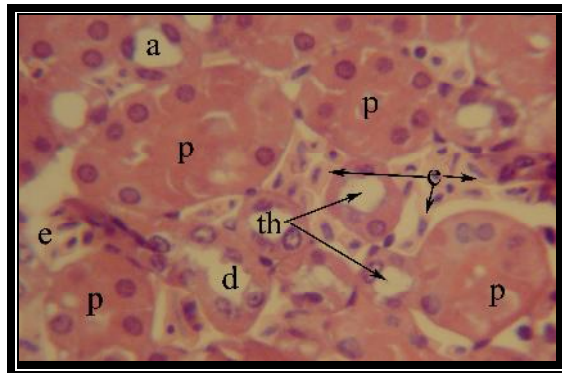


Figure 26: Photomicroscope illustrates the tubules in kidney of mature racing pigeon. (H & E stain, X 100) p- Proximal convoluted tubule th- Thick limb of Henle's loop e- Erythrocytes d- Distal convoluted tubule a- Arteriole

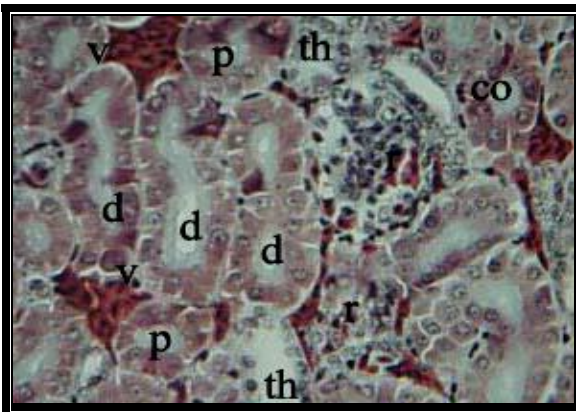


Figure 27: Photomicroscope illustrates the tubules in kidney of mature racing pigeon. (M.T stain, X 40) p- Proximal convoluted tubule d- Distal convoluted tubule th- Thick limb of Henle's loop tn- Thin limb of Henle's loop v- Venules g- Glomeruli co- Collecting duct

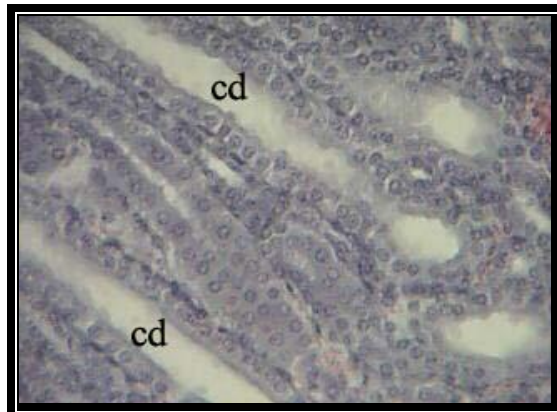


Figure 28: Photomicroscope illustrates duct in kidney of mature racing pigeon. (H & E stain, X 40) cd- Collecting ducts

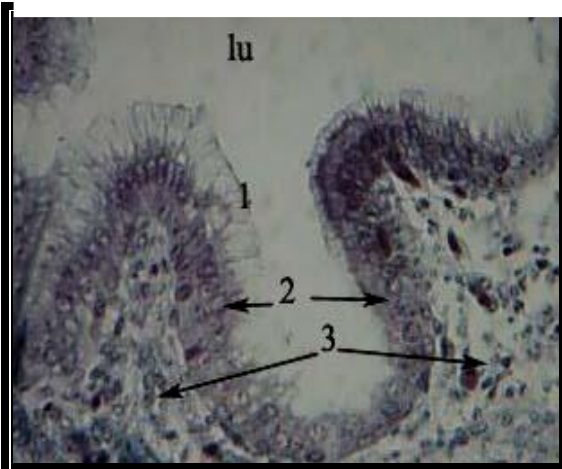


Figure 29: Photomicroscope illustrates ureter in kidney of one day squab racing pigeon. (M.T stain, X 40) lu- Lumen of ureter 1- Microvilli of ureteral mucosa 2- Pseudostratified columnar epithelium 3- Lamia propria

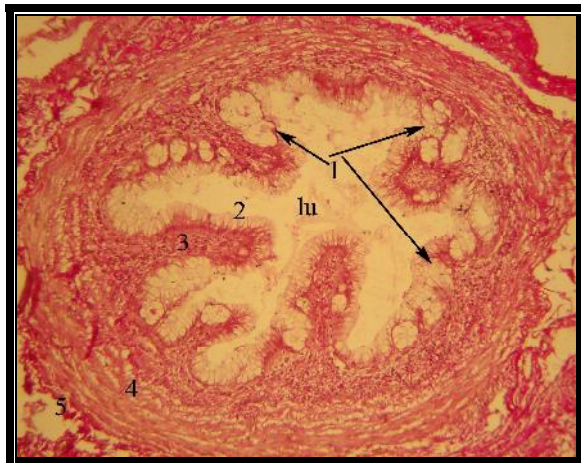


Figure 30: Photomicroscope illustrates ureter in kidney of mature racing pigeon. (V.G stain, X 10) lu- Lumen of ureter 1- Intraepithelial acinar gland 2- Mucosal epithelium 3- Lamia propria 4- muscularis 5- serosa

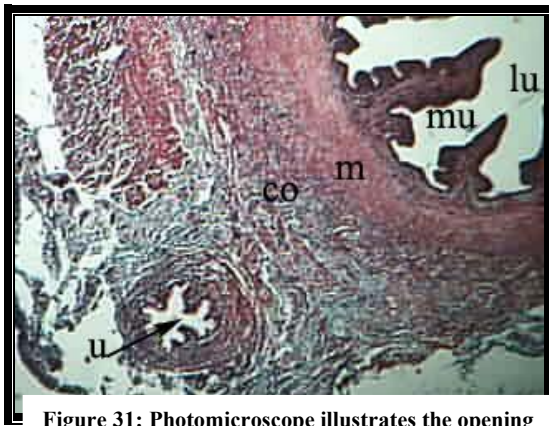


Figure 31: Photomicroscope illustrates the opening of ureter in cloaca of mature racing pigeon. (M.T stain, X 4) u- Ureter opening co- Connective tissue m- Muscular mu- Mucosal fold of rectum lu- lumen of rectum

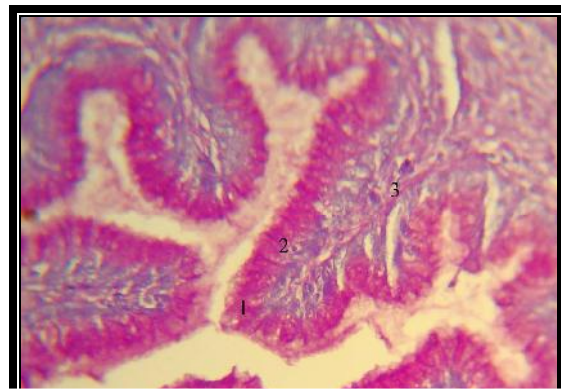


Figure 32: Photomicroscope illustrates ureter in kidney of mature racing pigeon appeared PAS positive. (PAS stain, X 10) 1- Microvilli of ureteral mucosa appeared PAS positive 2- Pseudostratified columnar epithelium 3- Lamina propria

Arterial supply

Both techniques for the latex and corrosive cast in situated and in macerated illustrating the architecture phenomena of the three dimensional distribution of the vascular arteries and veins. However, the cranial lobe of each kidney is vascularized by cranial renal artery arising from the abdominal aorta while the Ischiadic artery branches from the descending aorta passes laterally between the middle and caudal lobes of the kidney give branches the middle renal artery to supply the middle lobe of the kidney then caudal renal artery which appeared as a branch from the Ischiadic artery to nourish the caudal lobe of the kidney (Fig. 8, 9 and 10).

Sturkie (1976) and Robert and Wideman (1991) in fowl that the kidney supplied by cranial renal artery branching directly from the descending aorta to nutrient the cranial lobe, while middle and caudal renal arteries branching from Ischiadic artery supply their respective kidney division. Moreover, Radu (1974) radiographically found that the caudal renal artery originated directly or indirectly as a common trunk from the Ischiadic artery in fowl, turkey, duck and geese the territorial distributions of the renal arteries are similar in all four species. Whittow (2000) mentioned that *ardea cinerea* has one pair of renal arteries branches from the femoral arteries instead of the Ischiadic artery.

Renal portal vein

Using latex and cast technique the common iliac right and left veins are formed by the cranial renal vein which draining from the cranial lobe the caudal renal vein arise from caudal lobe and receives branches from the middle lobe and combined with renal portal and external iliac veins. The right and left common iliac join to form the caudal vena cava, the external iliac veins join the renal portal vein before entering the common iliac vein between the cranial and middle lobes of the kidney (Fig.11 and 12). The present study determine the architecture of the racing pigeon kidney with that the information would lead to a better understanding of the function of the countercurrent multiplier system within the avian pigeon kidney especially using a newly technique erosion casting by resin and latex. Data of this study are supported by

chiasson (1984) in pigeon that the right and the left common iliac vein are formed by the renal veins of cranial, middle and caudal lobes of the kidney where these veins combined with the renal portal and external iliac veins then the right and left common iliac join to the caudal vena cava. Although, except Kurihara and Yasuda (1975b) in fowl, mentioned that the middle and caudal renal portal vein anastomosis with the external iliac vein and Ischiadic vein. This modeling work explains the different hypothesis which gives a key for the role of portal circulation by Burrows *et al.* (1983) in *Rhode island red roosters*, were suggested that during episodes the sympathetic discharge is high in fight or flight situation, the blood should shunt directly to the central circulation when the valve open or relax. Moreover, Robbeins and Prashad (1981) in laying hen, notice that during active shell formation renal plasma increased whereas glomerular filtration rate significantly decreased and these are explained by an increased flow of renal portal blood to the kidney. The cranial renal portal receives branches from the cranial lobe of the kidney to the external iliac vein then the caudal renal portal vein are continuous with the internal iliac vein which anastomosis near the base of the tail in the caudal abdominal cavity, Ischiadic veins join to the caudal renal portal vein while the caudal mesenteric vein is a median unpaired from internal iliac vein where anastomosis with the caudal renal portal vein (Fig.11 and 12). This is supported by King and McLelland (1984) in the domestic fowl that the cranial and caudal renal portal veins form a venous ring which is at cranial end anastomosis with the left and the right renal portal veins and with internal vertebral venous sinus and the latter is different with the present study, in which there is no anastomosis with the vertebral sinus in pigeon.

Efferent venous drainage

The venous blood drainage from the kidney through the renal veins, observed in the racing pigeon with different veins:

- a- Cranial renal vein is draining the parenchyma of cranial lobe of the kidney by several branches and enters directly the common iliac vein.

- b- Caudal renal vein arises from several branches from the caudal lobe of the kidney and receives a branch from the middle lobe of the kidney. the caudal renal vein enters directly as in (Fig.13).

This is supporting by Robert and Wideman (1991) in fowl and Iuliis and Pulera (2007) in pigeon who showed that the efferent venous blood leaves the kidney via cranial and caudal vein, this is more acceptable than chiasson (1984) in pigeon who observed that the venous drainage is done through the cranial, middle and the caudal vein.

The ureter

The ureter carries the concentrated urine from kidney lobes which appeared evacuated their content directly into urodaeum, part of the cloaca (Fig.7 and 14). Carpenter (2003) in birds reported that all birds do not have urinary bladder except Ostrich and Rheas and this is due to separate storage of urine and feces. Each kidney has a ureter originated deeply on the mid-ventral surface of the cranial division and then passes caudally on the mid-ventral surface of the middle and caudal division of kidney. Continuous caudally empty into the urodaeum of the cloaca at renal papillae, where the later lied between phalluses bodies of male genital system. This is enhance by king and McLelland (1984) in fowl and Aughey and Frye (2001) in birds. However, Wake (1992) in pigeon showed that the ureter just located dorsal to the portal veins begins on each side at the groove between the anterior and middle lobes of kidney.

Histological results

The capsule of the squab kidney is composed of fine collagen and reticular fibers while the kidney of mature racing pigeon was covered by capsule similar to the structures presented in the squab with very fine blood vessels interfering with other fibers (Fig.15 and 16). This is supported by Al-Azawy (2005) in domestic fowls and geese, noticed that the capsule appeared consisting of smooth muscle with some of reticular fibers, while Hodges (1974) not mention the capsule especially in domestic fowls.

Parenchyma of the kidney

Squab and mature racing pigeons had uniform parenchyma. The nephrons lie at different depths of the kidney, so there is no line of demarcation between cortex and medulla in kidney of racing pigeon. This is supported by Nishimura *et al.* (1986), Carpenter (2003), Ritchison (2008) in birds, and Nicholson (1982) in wild adult starling *sturnus vulgaris*. Each lobule was demarcated in its out line by the ramifications of the interlobular veins of the renal portal system (Fig. 17, 18, 19 and 20). This is in parallel with work of Kurihara and Yasuda (1975b) and Bohle and Christen (1985) in fowl.

Squab and mature racing pigeons the peripheral area, consisted of proximal convoluted tubules, distal convoluted tubules, Bowman's capsule with their glomeruli and among them numerous number of small size glomeruli, this glomeruli there were more abounded with coalesces with each other in squab. However the reptilian type noticed peripheral with smaller glomeruli as compared with the mammalian type which concentrated in the medullary area (Fig. 18 and 19). The latter was discussed by Goldstein (2005) in *chukar*, who found that increased in cortical regions more than 90% of reptilian

type nephrons were developed after hatching. However this result in mature is supported by Casotti (2001) in *House sparrows* that the majority of the cortex consists of the proximal convoluted tubules, there were no significant differences in the absolute volumes of components within the cortex. Although this result agrees with Sperber (1960), King (1975); William and Braun (1980) and Sabat (2000) in fowl.

The medullary region contained collective bundles of tubules recognized as collecting ducts, ureteral branches and loops of Henle of mammalian- type nephrons (Fig. 20). However, in squab pigeon each bundle is difficult to recognized as that in mature through the connective tissue which is surrounded each bundles was thin and the entire of bundles appeared homologize (Fig.21). Goldstein (2005) explained in *chukar* that the kidney growth begins in the deepest regions of the kidney and then extends peripherally at which the full component of medullary cones was present at hatching. However Casotti *et al.* (2000) analyzed the renal medulla of the *Gambel's quail* and agreed that the renal medulla of birds is divided into smaller units than those occur for most mammalian kidneys and these units; medullary cones are made up of loops of Henle, collecting ducts and vasa recta. However, similarities of the kidney of racing pigeons also give architecture unity for the information of the function of kidney in birds. The current study enhanced with the previous studies by William and Braun (1980) in fowl; Chiasson (1984) in pigeon; Beuchat (1999) in *Anna's humming* bird and Ritchison (2008) in *honeyeaster*. In addition, Goldstein and Braun (1989) discussed the number of medullary cones tended to increase with kidney mass. In addition, Layton (2005) in *Japanese quail* showed that the avian kidney, like the mammalian kidney, can regulate blood plasma osmolarity when deprived of water, by producing hypertonic urine which localized in the medullary cone. Casotti and Braun (2000) analyzed kidneys of three species of *sparrows* with and without loop of Henle. On the other hand, Johnson and Mugaas (1970); Hodges (1974); Siller (1981); Islam *et al.* (2004) in their study on chickens, showed that third types of nephrons; the intermediate nephrons, which is an intermediate in structure between the first two types and is only infrequently present. In addition, Gambaryan (1992) showed in chick that from the 14th day of incubation, it is possible to isolate the mammalian -type nephrons which appear first. In this study isolated reptilian and mammalian -type nephrons are in one day-old squab pigeon.

Kidney glomerulus of squab pigeons is composed of capillaries greatly coiled around a compact connective tissue mass with the Bowman's space appeared distinct (Fig. 22). In mature racing pigeon the glomeruli revealed as a tuft of unbranched capillaries, surrounded by a double layers cup-shaped Bowman's capsule. However Braun and Dantzler (1972) in *desert quail* suggested that the variation in the size of the glomerular capsules corresponds to the extreme morphological heterogeneity of the nephrons. Goldstein and Braun (1989) found in *house sparrow* and in *white winged doves*, that the glomerular dimensions increased with kidney mass. The Bowman space which at urinary pole leads to the PCT. Each glomerulus contains a compact mass of mesangial cells, characterized by small

cells with large nuclei at its center (Fig. 24). Casotti and Braun (1995) in *callipepla* and *Gallus gallus*, discussed how the glomerular capillaries of looped nephrons are more complex than those of loopless nephrons where the glomerular capillaries of looped nephrons form a dichotomously branched net work, while those of loopless nephrons are arranged loosely and have no dichotomous branches.

Proximal convoluted tubule (PCT)

The PCT appeared in kidney of squab pigeon lined by tall cuboidal cells around to elliptical nucleus; the basal part of the cell appeared larger than the apical part which occupied by dense cytoplasm elements. The PCT in mature racing pigeon revealed had narrow lumen and the epithelium characterized by high cuboidal cells; the nucleus was pale oval or rounded in shape located in the center of cells and its cytoplasm was acidophilic. Strongly positive with PAS stain (Fig.24). Moreover, Nicholson (1982) in *starling* kidney suggested that the PAS positive reaction is due to the presence of sialic acid in the mucin component. On the other hand, McNabb *et al.* (1973) in pigeon, found that the reaction of mucoids were mucopolysaccharides, acid mucopolysaccharides including sulphur-bearing carbohydrates in the different tubule especially intensity material starting in the cytoplasm of the collecting duct, ureteral branches and ureter.

Distal convoluted tubule (DCT)

Collecting tubules and collecting ducts in kidney of squab pigeon. There was a gradual changes in cell characteristics of DCT and collecting tubule, which contained cuboidal epithelial cell types that were characteristics of both segments while the collecting duct had cuboidal cell with wide lumen (Fig. 27). This is enhanced by Bellairs and Osmond (2005) in one day-old chick. In mature the DCT was lined by low cuboidal epithelial cells. More cells lined these tubules with distinct borders observed more clearly defined than the PCT, the cells less acidophilic than PCT, also the nuclei of these cells were centrally to parabasal located in position (Fig. 27). This is in parallel with Casotti and Richardson (1993) in *honeyeaters* and Casotti and Braun (2000) in *sparrow*.

Collecting tubules and ducts

In mature racing pigeon the collecting tubule lined by one layer of pale cells with cuboidal to low columnar shape. The nucleus appears large and cell borders were distinct. This is supporting by Casotti and Richardson (1993) in *honeyeaters* and Casotti *et al.* (1998) in *Anna's hummingbird*. In addition, Casotti and Braun (2000) in *sparrows* found that the principal cells of collecting duct secrete mucous to prevent uric acid precipitation, thus preventing blockage of the tubule lumen.

The ureter

In squab pigeon the lumen of the ureter appeared star shape in cross section, lined by pseudostratified columnar, the cells has apically microvilli, the oval nucleus occupied variable levels in the cytoplasm. (Fig.29). Numerical variation were recognized between cranial portion of ureter of mature pigeon and its caudal portion where it ends in the urodaeum as renal papillae. The cellular mucosa arranged in folded manners was covered by pseudostratified columnar epithelium. Each cells relatively tall uniform in shape and possessed a single central

rounded nucleus. These cells have long microvilli at their apical borders. In addition, a few number of cuboidal cells lying close to the basement membrane. Moreover, the lamina propria was a thick layer of loose connective tissue (Fig.30 and 31). This is in parallel with Hodges (1974); King and McLelland (1984) in fowl and Aughey and Frye (2001) in birds. Certain marked and progressive changes, were observed in the caudal portion of the ureter, particularly the microvilli cells become changed in their shape and the folds of mucosa were less in number so, the lumen of ureter become narrow, also present intraepithelium acinar glands lining by mucous cells in the lumen of acinar gland appear cellular depress, revealed to holocrine secretion (Fig.30). This is supporting by Siller (1981) in fowl, Nicholson (1982) in *starling* and Mirabella *et al.* (2007) in duck. Although Nicholson (1982) in *starling* found that the mucin-secreting cells possessed a prominent supra nuclear Golgi apparatus and the apical vacuoles containing a strongly PAS positive mucigen, which indicated that the mucigen contained large amounts of a strongly sulphated component. In addition Bacha and Bacha (2000) in chicken mentioned that the apices of columnar cells contain numerous vacuoles filled with mucous. Moreover McNabb *et al.*, (1973) in pigeon suggested that the function of mucoids may be as physiological lubricants and binding agents for precipitated uric acid and this distribution of mucoids within the urinary tract corresponds to those parts handling the greatest amount of precipitated uric acid. Thus the acinar intraepithelial gland of the ureter in racing pigeon did not mention in the avian species (McNabb *et al.*, 1973, Siller, 1981, Mirabella *et al.*, 2007). This gland was described in the different parts of respiratory wall of the fowl and even in the some part in the digestive system (Hodges, 1974). In addition, the muscularis layer revealed an inner longitudinal arrangement of smooth muscle fiber, the smooth muscle arrangement become in circular manner and thicker than the former while the caudal end portion presented near the cloaca revealed longitudinal arrangement of smooth muscle, in addition to that present in the previous portion of the layer of the ureter. The outer layer was adventitia which consists of loose connective tissue, the ureter stained intensively with PAS stain (Fig.32). This is enforced by Mirabella *et al.* (2007) in duck that the ureteral wall thickness of the lamina propria and the tunica muscularis and the inner perimeter progressively in the ostium cloacale ureteris opening which were well developed papillae. Although Hodges (1974) in fowl that there is a third outer longitudinal muscle coat which develops towards the cloacal end of the ureter and at the junction of the ureter with the cloacal wall the ureter passes through the wall completely independently of the cloacal muscularis.

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