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& Scientific Research
University of Al-Qadisiyah
College of Veterinary Medicine

Anatomy and histology of the male reproductive system in rabbits

A Graduation Project Submitted to the Department Council of the Internal and Preventive Medicine-College of Veterinary Medicine/ University of Al-Qadisiyah in a partial fulfillment of the requirements for the Degree of Bachelor of Science in Veterinary Medicine and Surgery.

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Certificate of Supervisor

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Dedication

Chapter one

Introduction

Understanding reproductive biology and physiology is important to establish population models and to improve management decisions in captive and wild populations This knowledge is also important to recognize differences between healthy and unhealthy states Structures of male reproductive anatomy in terrestrial mammals are well known Basic components of the male reproductive system are the testes, epididymis deferent ducts, accessory sex glands (ampulla, vesicular glands, prostate and bulbourethral glands) and the penis

The reproductive role of the male is to produce sperm and be able to deposit the sperm in the female reproductive tract, the production of viable sperm to fertilize oocytes involves the testes epididymis and the accessory sex glands The testes produce and manufacture spermatozoa through the process of spermatogenesis. The testes produce testosterone inhibit and estradiol essential for normal production and maturation of spermatozoa.

The anatomical characteristics of the reproductive system of different mammals are basically similar but the difference is slight especially in the external genital organs The histological structure of the reproductive system in different animals is basically similar The scrotum, The Testes, Epididymis, Vas Deferens, Accessory Sexual Glands (Ampulla glands, Vesicular Glands, Prostate Gland, Penis)

Chapter two

Review and literature

Rabbits are unique animals found in many different continents and climatic zones Domestic rabbits are the descendants of Orthologous cuniculus a species native to the western Mediterranean basin (Spain and North Africa) and it is said to have originated from the European wild mk rabbit. Rabbits have been used as experimental animals in genetics and breeding since the beginning of the century Rabbit bucks are ready for reproduction at 32 weeks of age when sperm production is known to have stabilized Lack of detailed information about the anatomy and morphological structures of rabbit bucks their reproductive organs and its physiology hampers the reproductive index in multiplication and breeding of rabbits This review is centered on gathering relevant information about the morphology and reproductive physiology of rabbit bucks with emphasis on showing some aspects relating to their sexual maturity occurrence of puberty reproductive distinctiveness seminal characteristics number size of glands and their location sperm production and Spermatogenesis for a better breeding purpose.

Chapter Three

Reproductive Anatomy

Reproductive organs are not unconditionally necessary for the individual life but They have an essential role in the reproduction and life of species . They are dynamic organs in an animal of which proper understanding of the anatomy And physiological characteristics increases efficiency and production as they reflect very sensitively various changes in the environment Many times They are the only organs which at low toxicity show structural and functional Changes .The reproductive system of rabbit buck (Fig. 1) consists of the testes which Weighed over 6 grams in some breeds epididymis, ampoules, Vas deferens, urethra, penis, preputial glands, accessory glands, a well-developed Scrotum located adjacent to the penis and the urogenital opening .

Scrotum .1

The testicles are housed in the scrotum The scrotum is formed by the tunica vaginalis tunica dartos and cremaster muscle and said to have few hairs Its Main function is to keep the testicles away from the abdominal cavity so that the Right testicular temperature is maintained between 0.5˚C and 4˚C below body Temperature as required for normal spermatogenesis The scrotum and abdomen have communication through the inguinal ring which conveys the excretory duct (vas deferens) that comes from the epididymis

Penis .2

The penis is the copulatory organ. An unusual feature of the rabbit is the absence Of glans in the penis but the body of the penis is cylindrical, 40 – 50 mm long And the diameter decreases at its end. During rest from sex the p

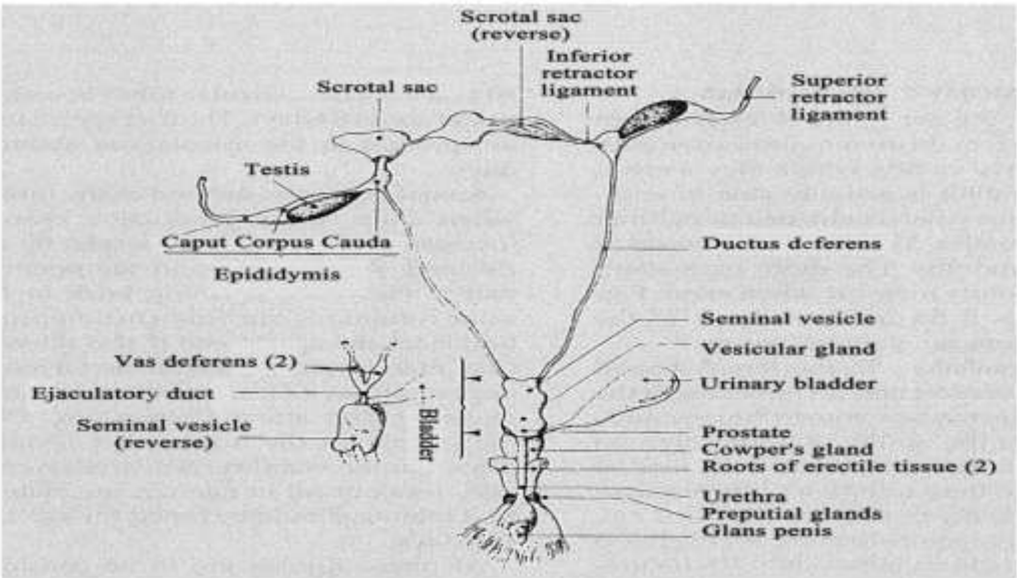


Figure 1. Genital anatomy of the male rabbit.

Epididymis .3

The epididymis is the place where sperm produced are stored before being reieased during ejaculation Its functional part consists of a single duct The epididymis originates in the efferent ducts highly curled over the head body and tail And connects straight to the vas deferens It is noted by some authors that the tail Of the epididymis is in the shape of a U The rabbit is one of the species in Which sperm stored in the cauda epididymis exhibit vigorous motility even in Their own fluid

Vas Deferens

The vas deferens extends dorsal-cranial to the body of the epididymis through The inguinal canal and enters in the abdominal cavity The final portion of the Vas deferens forms a loop around the ureter and at this point becomes fusiform Although the thickness of the diameter does not differ from the rest of The vas deferens, this segment is generally called ampulla (ampulla vas deferens (

Urethra .4

The urethra is a large canal that leads through the penile organ to the outside of The body It is the connection point at which the two vas deferens ducts converge from the left and right sides of the body to connect at its upper end very near to Where the urinary bladder opens into the urethra.

Testes .5

The testis of the buck is oval-shaped It is the main source of testosterone in rabbits which is the main androgen produced during sexual maturation They are positioned cranially to the penis located in the scrotum each One on one side of the inguinal line and positioned almost horizontally After birth the testes develop less quickly than the rest of the body From the age of five weeks they begin to grow very rapidly The rabbit’s testicles descend at About two months and they are said to be similar to those of cats but can move Freely from the scrotum to the abdomen through an opening in the inguinal Canal The testicles continue to grow and increase sperm production until Six (6) months of age The position of the testicles depends on many factors Including body position, body temperature reproductive activity repletion of The gastrointestinal tract amount of abdominal fat and stress During Periods of sexual inactivity or stress the testicles return to the abdominal cavity Through the inguinal ring and may go down again by the action of the cremaster Muscle According to

Fraser the appearance and testis weight de-Pend on the location For example testes located in the scrotum are heavier firm in texture and red in color Abdominal testes are light reddish-brown and limp Although their essential function is the maintenance of normal spermatogenesis, Serum testosterone above the baseline level do not appear to influence the efficiency of spermatogenesis.

6. Accessory Glands

The accessory sex glands are complex (Fig. 2) They secrete many compounds Found in the semen of other mammals such as fructose citric acid glycerylphos Phorylcholine and minerals Secretion of catalase is uniquely high in rabbit semen The accessory sex glands respond differentially to androgens and estrogens and the weights of this organ are a bioindicator of circulating steroid hormone levels. Accessory glands in the rabbit develop less quickly than the Rest of the body just like the testes but at a more even rate and are less precocious.

The glands of the rabbits reproductive tract differ in number location size and Proportion among other aspects like those in other mammals. This set of glands Consists of a vesicular gland bulbourethral gland and prostate gland and Vasquez affirm that the prostate consists of three lobes:- Proprostate, Prostate and Paraprostate. According to they contribute to the greater part of The volume of ejaculate. Each part of the gland plays a specific role in reproduction.

7. Prostate Gland

The prostate gland is yellowish-white in color and is located caudally to the vesicular gland and found in between the Pro prostate and bulbourethral glands. It Shares the same connective tissue capsule as the pro prostate only a small layer of tissue separates these two glands. The paraprostate glands are small and were Named as such because they are located on both sides of the prostatel They Have an irregular embossed surface and are hammer-shaped.

Bulbourethral Gland .8

The bulbourethral gland of the rabbit is a small mass of glandular tissue that is Surrounded by a capsule and widely covered by skeletal bulb glandular muscle that Separates it into lobules. This gland originates in the urethral wall as distinct from Other species. It is fairly small in rabbits but relatively larger than that of a man.

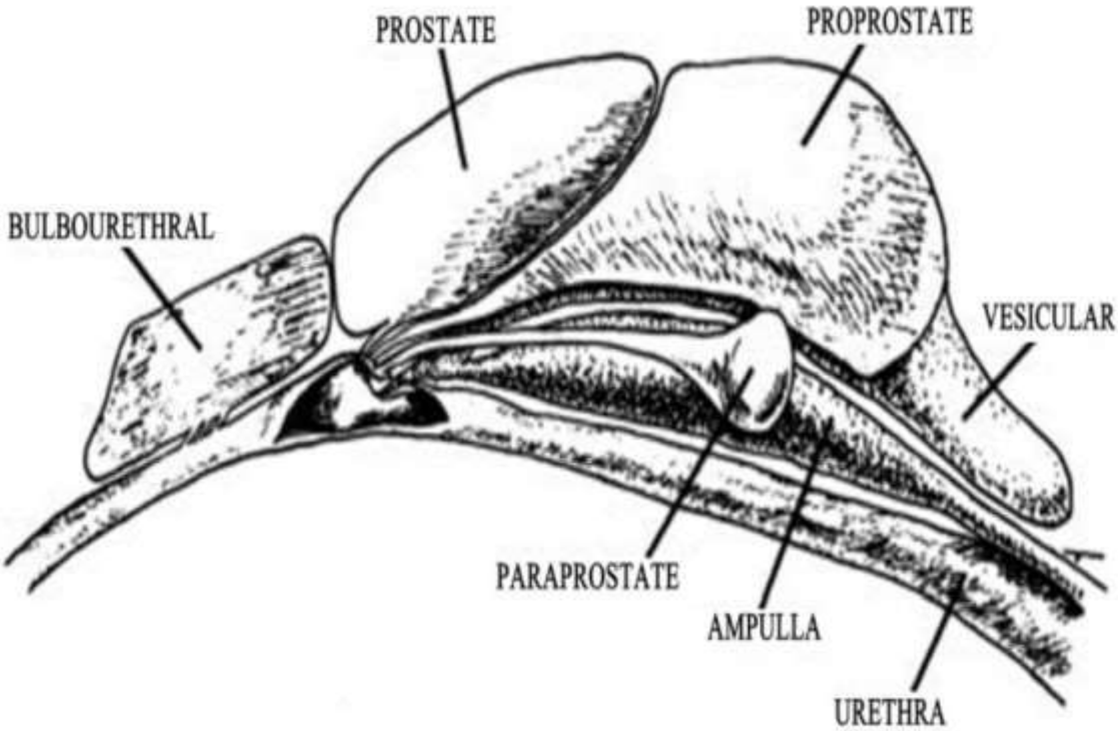
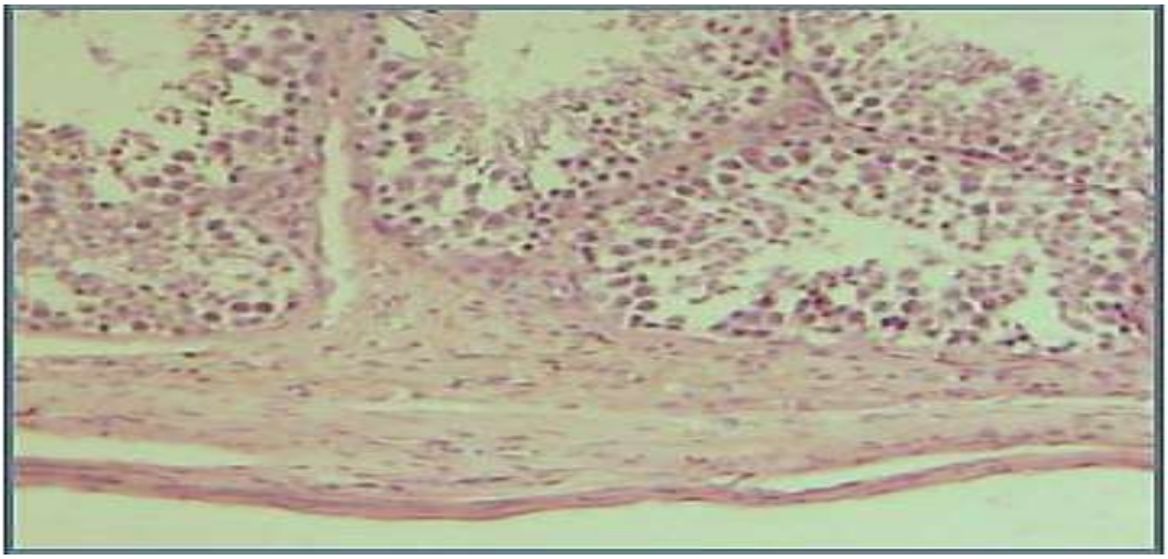


Figure 2. Midsagittal section through the urethra and the accessory sex glands of the domestic male rabbit. With the exception of the ejaculatory duct from (all ducts are paired)



Capture Four

Histological of Reproductive system

The rabbit testicles

The connective tissue septum originates in the albuginea tunica and enters the testicular parenchyma, with the effect of partially or fully dividing it into lobules, (Fig. 3). Each lobule is formed by four to six seminiferous tubules that are delimited by slightly manifest areolar connective tissue (Fig.4).

Fig 3. Rabbit testicle connective tissue and parenchyma (blue star)

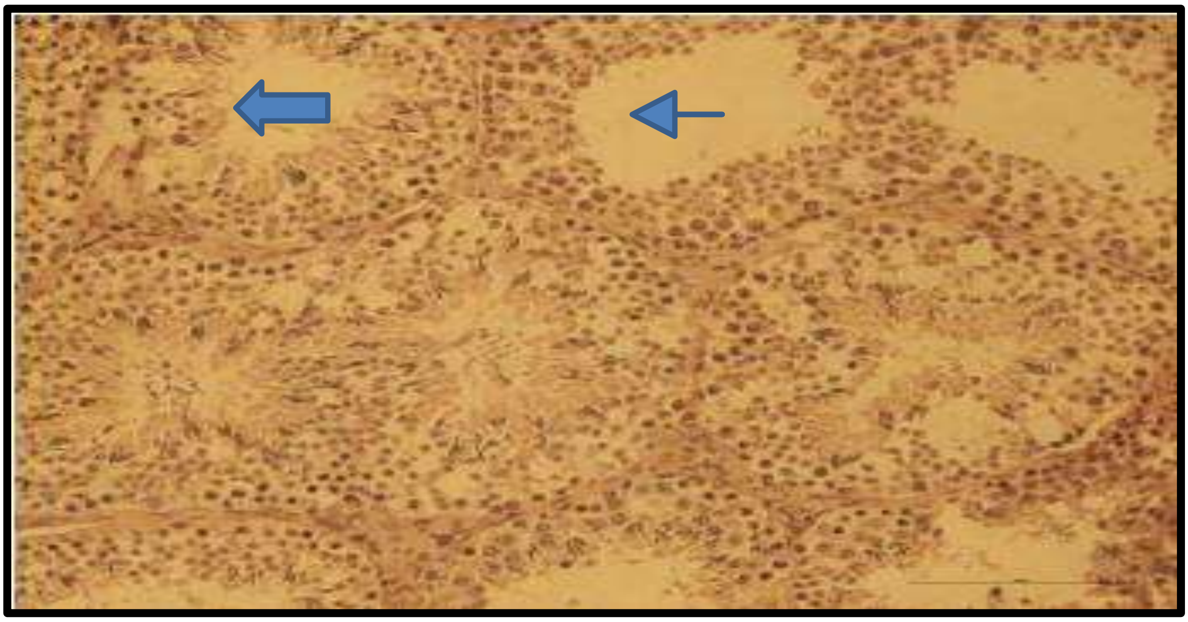


Fig 4. Rabbit seminiferous tubules.(blue arrow)

At the center of the testicle is the septum fused with the areolar connective tissue of the testicular mediastinum (Fig. 3) Testicular lobules contain the seminiferous tubules covered by stratified epithelium of spermatogenic cells and Sertoli cells (Fig.4) Spermatogenic cells form spermatozoids Spermatogonia are the most immature cells of the germ line and can be found in the basal membrane These are small oval or spherical cells that have the chromatin of their nuclei with varying degrees of condensation. Spermatogonia divide by mitosis to produce primary spermatocytes which are larger cells that carry out the first meiotic division As a result of the latter small secondary spermatocytes are produced and these are rarely visible in tissue preparations as they carry out the second mitotic division very quickly producing spermatids (Fig.4) Late-stage spermatids have small nuclei that are oval or elongated and dark and have long tails which project into the lumen (Fig.4)

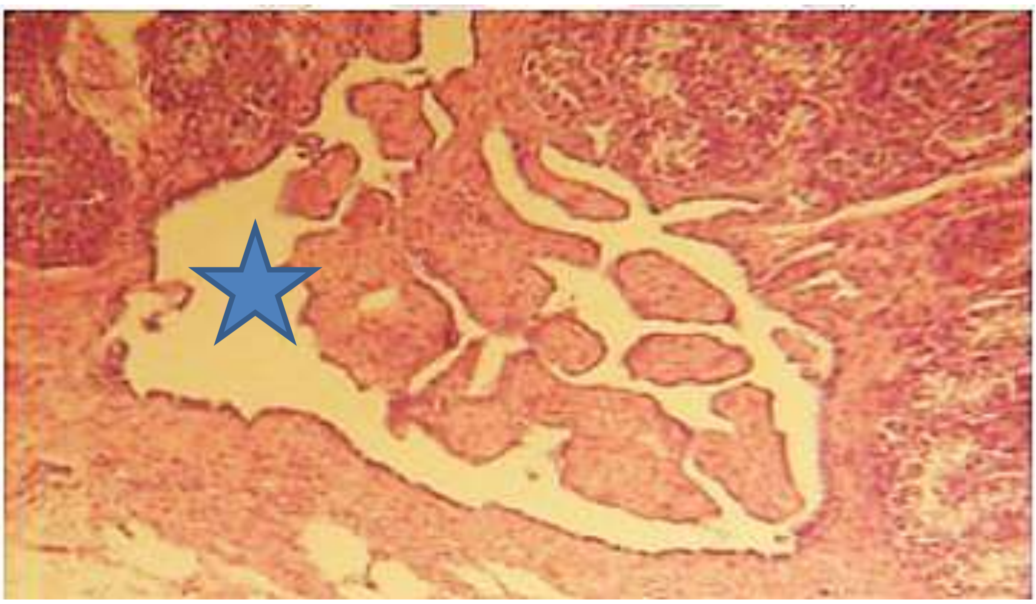


Fig 4. Center of the rabbit testicle (blue star)

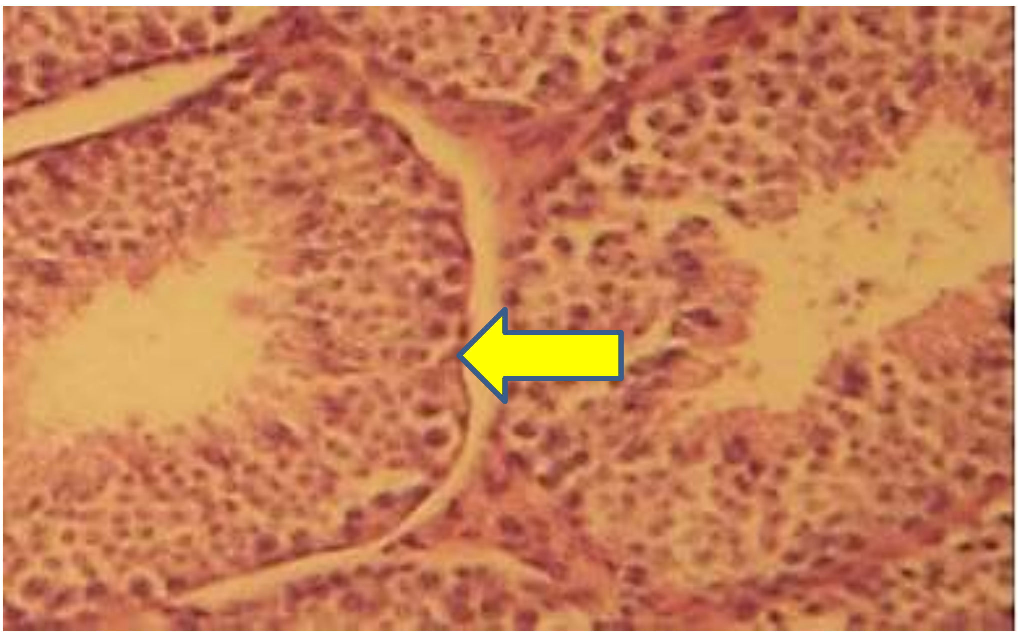


Fig 5. Rabbit testicular lobules (yellow arrow)

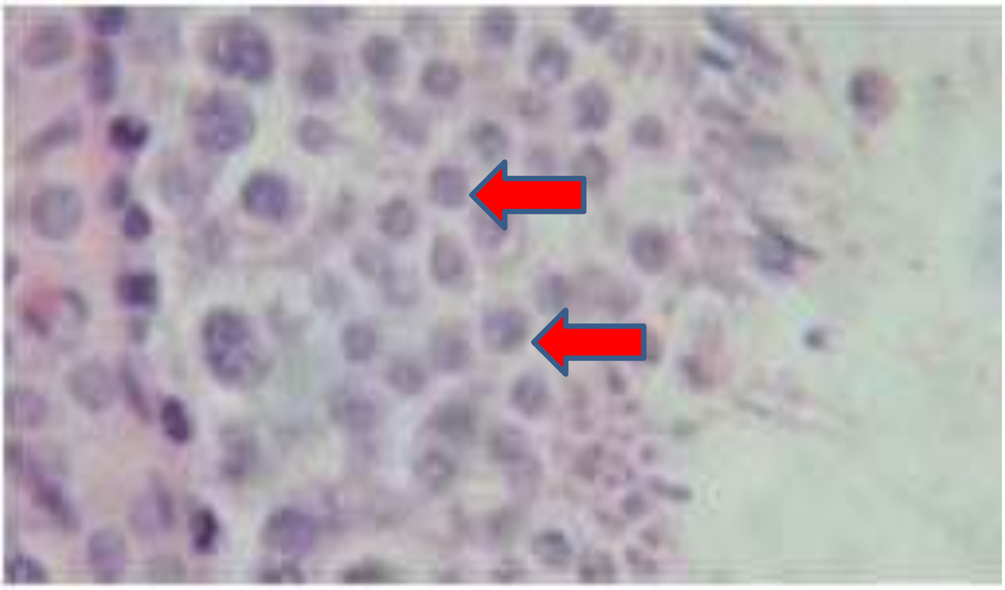


Fig. 6. Secondary spermatocytes formed in the rabbit testicles(red arrow)

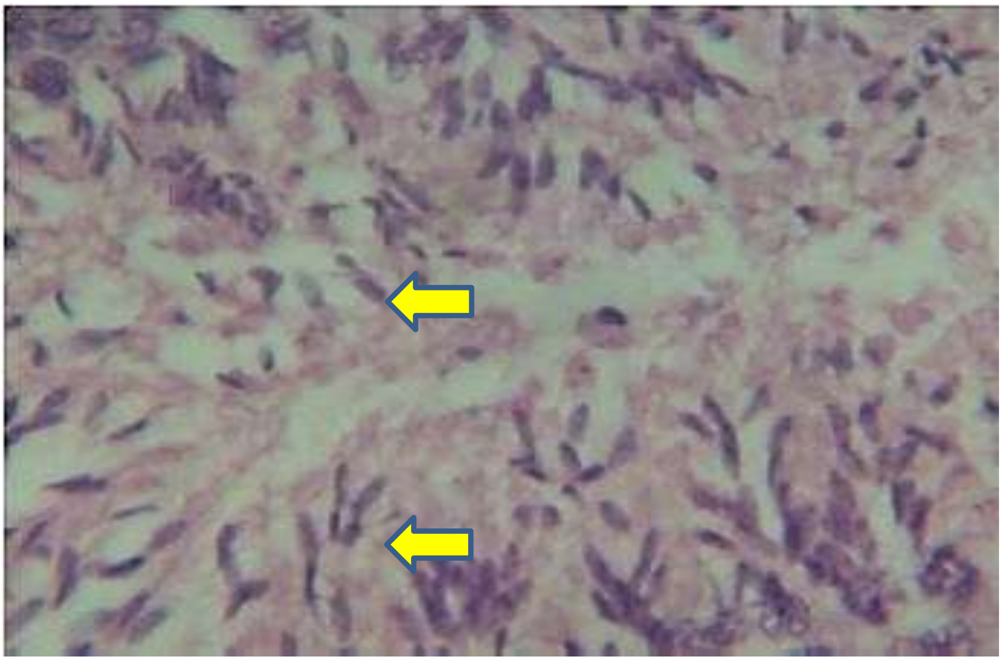
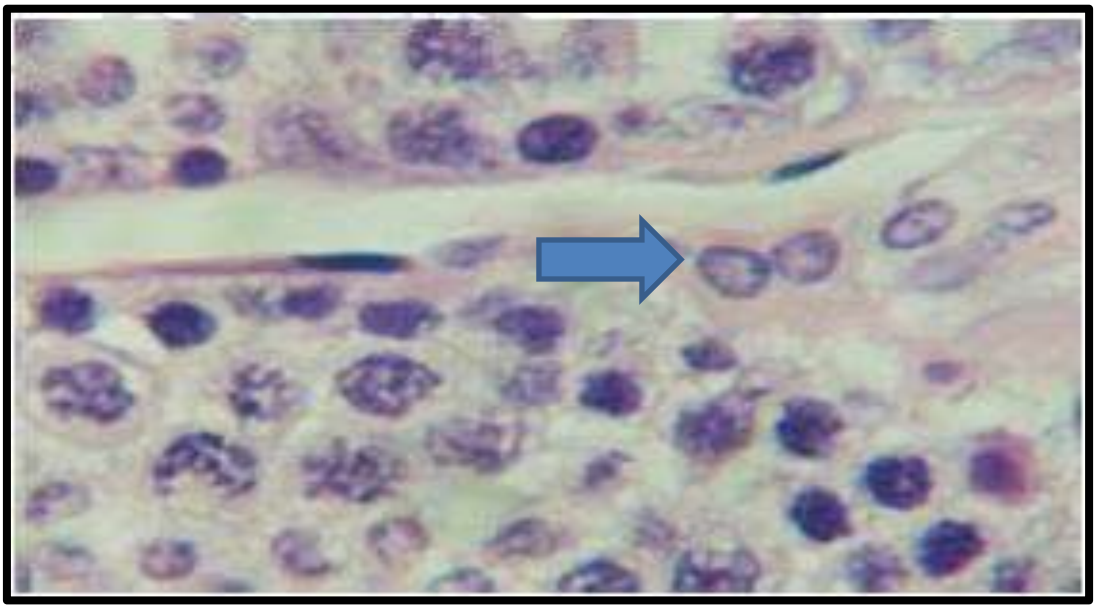


Fig.7. Rabbit permatids in late stage. (yellow arrow)

When spermatids are released in this stage into the tubule lumen they are known asspermatozoids. Cells of the spermatic line are not necessarily identical within all seminiferous tubules or among different segments of the same tubule. There are various combinations of cells at certain stages of spermatogenesis that are always associated among themselves. Each cell association occupies a specific segment within the seminiferous tubule In this manner a transverse cut of a tubule reveals only one of such cell associations while proximal or distal segments of the same tubule have totally different associations Sertoli cells are found in lesser numbers than germinal cells These have prominent pale nuclei that are oval or triangular with frequent cleavages. The ample cytoplasm extends from the basal membrane up to the luminal edge but the lateral limits become poorly visible in conventional preparations. The plasmatic membrane of the lateral and vaginal edges invigilate to form cavities where differentiating germinal cells are located. Outside the



basal membrane of the seminiferous tubule there are flat cells known as myoid cells (Fig.8)

. Fig.8Myoid cells outside the basal membrane of rabbit testicles. (blue arrow)

The connective tissue that separates the seminiferous tubules contains polyhedral cells that produce testosterone, the interstitial or Leydig cells which are recognized by their spherical nuclei and acidophilic cytoplasm that is commonly seen as foamy. The quantity of germinal cells decreases towards the end segment of the seminiferous tubules while the Sertoli cells increase. There is a transition region or segment that is lined exclusively by Sertoli cells which joins the seminiferous tubule to the straight tubule. Straight tubules can be lined by simple flat cubic or columnar epithelium and they end at a network of anatomical canals known as rete testis. The rete is lined by a simple flat or cubic epithelium. The canals are embedded within the areolar connective tissue of the testicular mediastinum. The efferent ducts originate from the rete testis go through the albugineas tunic and enter the head of the epididymis to form the epididymis duct The efferent ducts have a simple or pseudostratified columnar epithelium with some ciliated cells.

Histological of the rabbit epididymis

The epididymis is a tubular body on top of the testicle at its outer edge it is the place where spermatozoids acquire their fertilizing capacity In the rabbit there are three continuous areas that correspond to the head body and tail A capsule of moderately vascularized regular dense connective tissue was observed which corresponds to the albugineous tunic of the organ (Fig.9)The albuginous tunic projects as septa consisting of collagen and elastic fibers among histologically separate areas the head body and tail (Fig. 10)

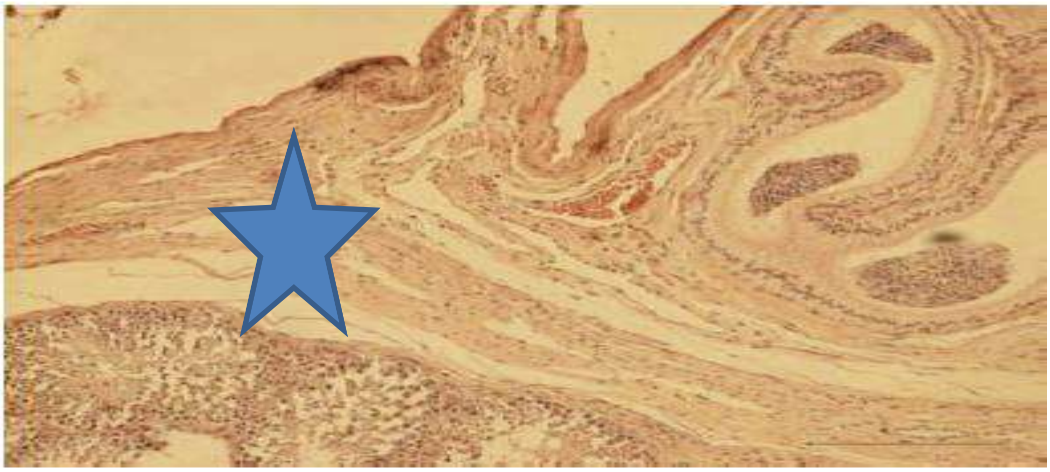
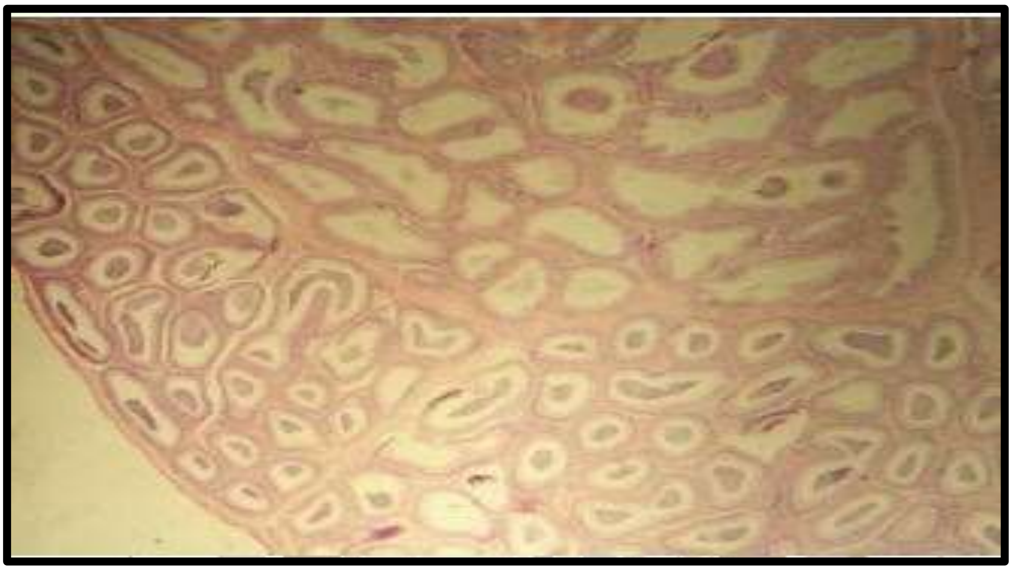


Fig.9 Albugineous tunic of the rabbit testicle (blue star)



. **Fig.10. Albugineous tunic separating the different regions of the rabbit epididymis.**

The epididymis duct follows a highly tortuous path and its structure varies along the various levels of the epididymis. The epithelium that lines the duct is pseudostratified columnar with stereocillia that reaches its highest height at the level of the epididymis head (Fig. 11) decreasing towards the tail (Fig. 12) The duct is surrounded by a layer of smooth muscle cells that is thin at the level of the head and body of the epididymis and becomes thick at the level of the tail.

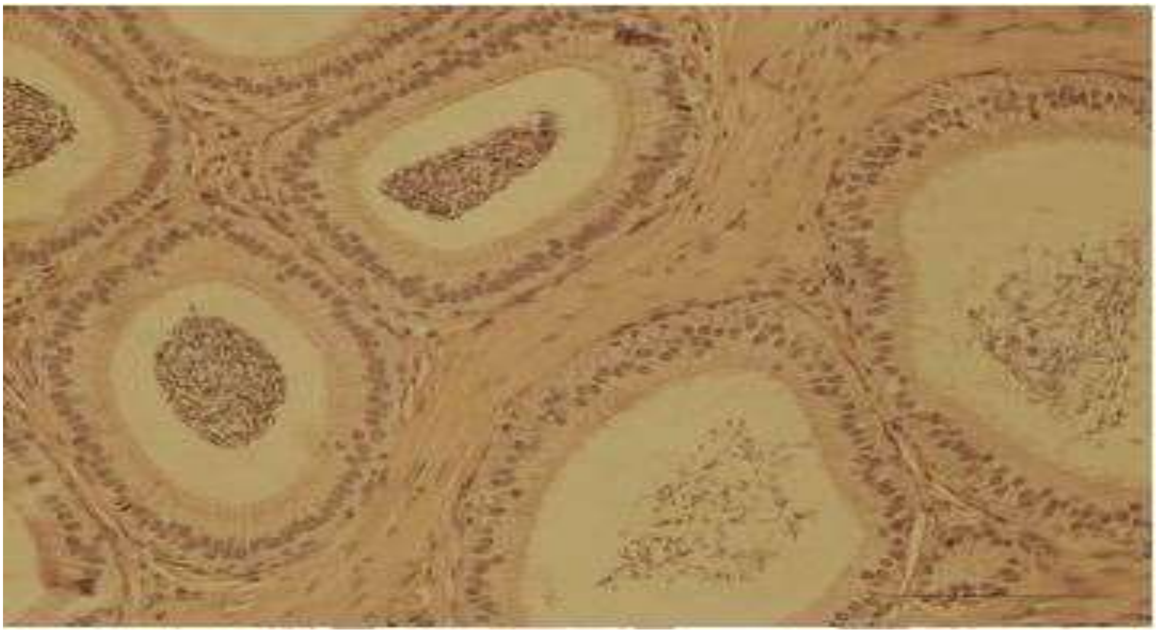


Fig.11. histological view show Rabbit epididymis head

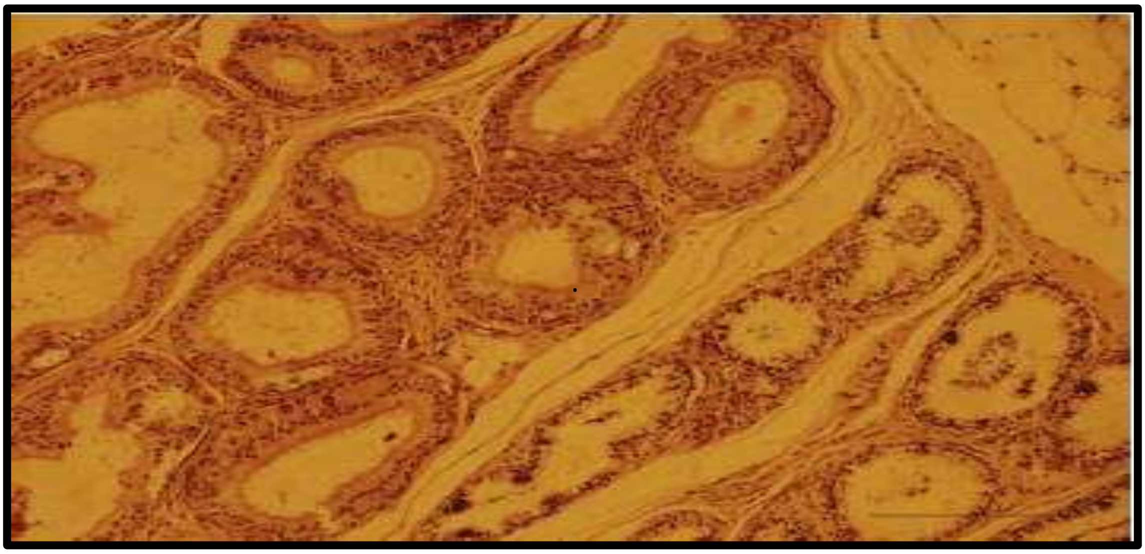


Fig.12. Rabbit epididymis body

Accessory genital glands in the rabbit

The vesicular gland (seminal vesicle) was a single gland in the shape of flattened sack or eyelid (Fig. 13). The gland's size was determined by the amount of fluid it contained. As observed in the cross-section the distal part of this gland was between the proprostate and ampulla ductus deferens where its lumen was covered by double-lined cylindrical epithelium. From the cranial side the vesicular gland was bilobed. The wall of this organ was composed of a well-developed mucous membrane which formed low wide folds reaching a height of 293 µm (Fig. 13). In the distal part between the folds large branching crypts invaded the wall of the organ. The surface which lines the lumen of the gland was covered by pseudostratified columnar epithelium (Fig. 13).

The secretory sections invaded the wall of the folds in the form of vesicles which were lined by simple cuboidal epithelium. The cell nuclei were of round or oval shape and were centrally located. Under the mucous membrane a moderately developed muscularis composed of smooth muscle fibres and clear adventitia was observed. The gland narrowed caudally to form the ejaculatory duct and opened out into the urethra.The lamina propria contains connective tissue and smooth muscle cells. The seminal vesicle is embryologically derived from the ductus deferens and like the latter it has a prominent muscularis. This provides for the expulsion of seminal vesicle fluid during ejaculation. The acidophilic secretory material in the lumen of the gland is rich in fructose thought to serve as an energy source for spermatozoa following ejaculation. Contrary to the implications of its name the seminal vesicle is not a site of spermatozoa storage

The prostate was viewed as a compound gland consisting of a prostate located in the skull (the prostate) a caudal prostate (prostate) and two lateral prostate analogs (paraprostata) (Fig. 13). The prostate and prostate are connected by a thin connective tissue septum and have two independent pairs of excretory ducts. In both organs the excretory ducts leave through the ventral surface of these glands. The prostate was a tubular porous gland with trabeculae connecting the opposite walls of the organ. Secretory sections were lined with simple or double-row cylindrical epithelium with eosinophilic cytoplasm. Cell nuclei of round or oval shape were located centrally or slightly closer to the base with the longer diameter oriented perpendicular to the basement membrane The apical part of the epithelial cells contains a granular substance that is secreted into the lumen of the gland in a secretory manner. Movats stain revealed different types of glandular cells by giving them different colors. One of them were cells that produced protein rich secretion and the other were cells that produced secretion rich in glycosaminoglycans (GAG). The parenchyma of the prostate gland contains a loose connective tissue composed of sufficiently blood vessels with strings of smooth muscle cells surrounding the organ and invading the trabeculae. In the histological picture many collagen fibers and few elastic fibers are observed. The prostate was a tube gland surrounded by a connective tissue capsule that was shared with the prostate. I left an excretory duct through the abdominal surface of each lobe and dorsal to the prostate duct Connective tissue bands divided the parenchyma into lobules .In cross section

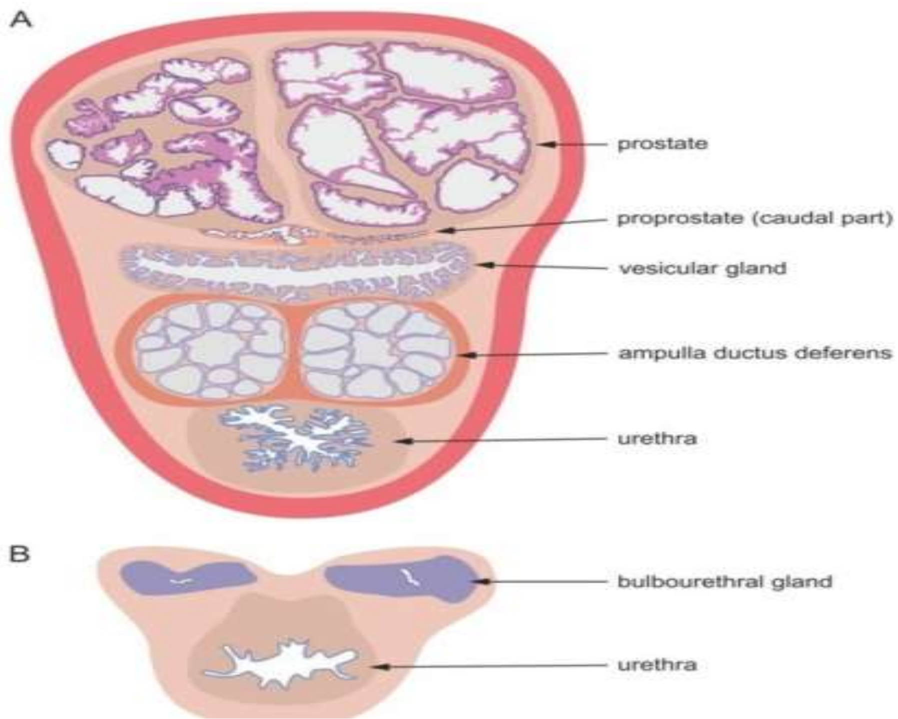
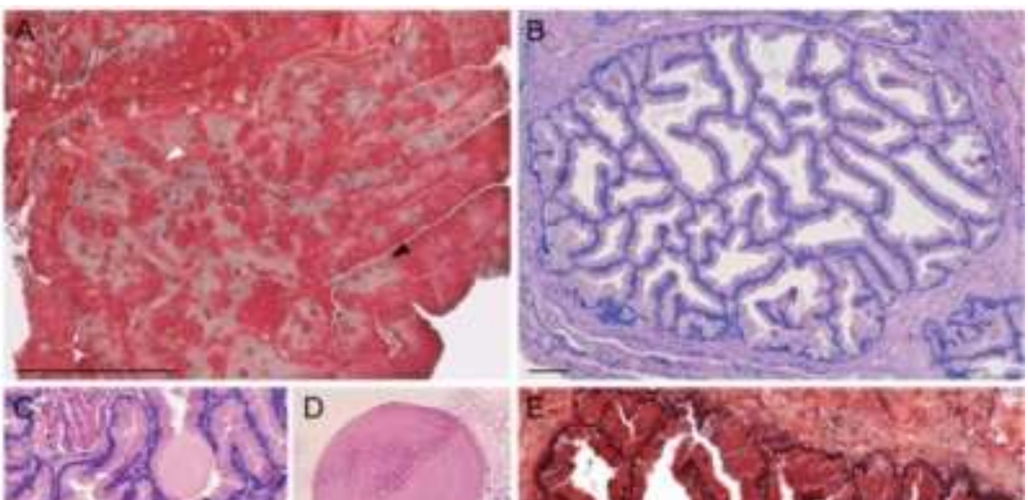


Fig. 13. Scheme of rabbit accessory genital glands in cross-section at the level of the prostate complex (A) and caudally from colliculus seminalis (B)

The bulbourethral glands (Cowper's glands)

were complex glands and consisted of two lobes one of which was located on each side of the urethra (Fig.1b). The lobes are clearly demarcated from each other and their ducts are noted around or around the seminal colliculus. Cowper's glands were embedded in the bulbar glandular muscle. The cross-sectional area of the glandular portion of each lobe was located in the caudal to the prostate and dorsally in the urethra. Abundant connective tissues divided the lobules into several lobules (Fig.3E) and the connective tissue between the lobules was accompanied by bundles of muscle fibers and clearly visible blood vessels (Fig. 3F) Some strands of connective tissue were penetrated between the lobes by striated irregularly oriented muscle fibers. The secretion is excreted from each lobe by a single outward channel with a folded lumen and lined with simple cylindrical epithelium or pseudoepithelium. These outgoing ducts opened on the dorsal wall of the urethra Secretory sections of tubular follicular shape were covered with simple cylindrical epithelium and produced mucosal secretion. This diverse group of glandular cells had round or slightly oval nuclei which were mainly present in the primary part of the cytoplasm The structure of this epithelium was similar to that of paraprostates. The outgoing ducts began with inserts observed in the lumen of the secretory sections. Moreover the outgoing ducts are drained into the interlobular ducts lined with simple cylindrical epithelium. The cell nuclei in this segment were oval and located in the middle while the cytoplasm was slightly eosinophilic.

Fig.14 Rabbit prostate complex. A – proprostate; note the presence of two differently stained types of glandular cells (arrowheads); B C and E – prostate; note the basally located nuclei and acidophilic cytoplasm of epithelial cells (arrowheads); D – corpus amylacea; F and G – paraprostate; note the resemblance of the parenchyma structure to that of the bulbourethral gland. Scale bar: 100 µm. Original magnification: 40× (F) 100× (B and G) 200× (C and E 400× (A)



The ampoule duct deferens (vascular ampulla deferentia) is found between the vesicular gland and the urethra. The cross section showed that each ampule was round in shape and consisted of a mucous muscular and adventitial membrane. In the cranial (proximal) part it was large in the caudal direction (distal)near the orifice. The mucosa is well developed and contained long crypts lined with a partially ciliated cylindrical epithelium extending from the main lumen. There were also large circular or oval glands lined with cubic or sometimes even squamous epithelium (Fig.3C and D). These glands opened to the main lumen or crypts. Occupy the glandular / inner portion of the ampulla duct in the cranial portion of the caudal section. In Movat staining the gland lumen was filled with a thick blue fluid indicating elevated GAG content. A thin smooth circular muscle layer and poorly developed connective tissue with blood vessels are observed. The ampulla tube shrinks gradually and opens to the ventral wall of the vesicular gland.

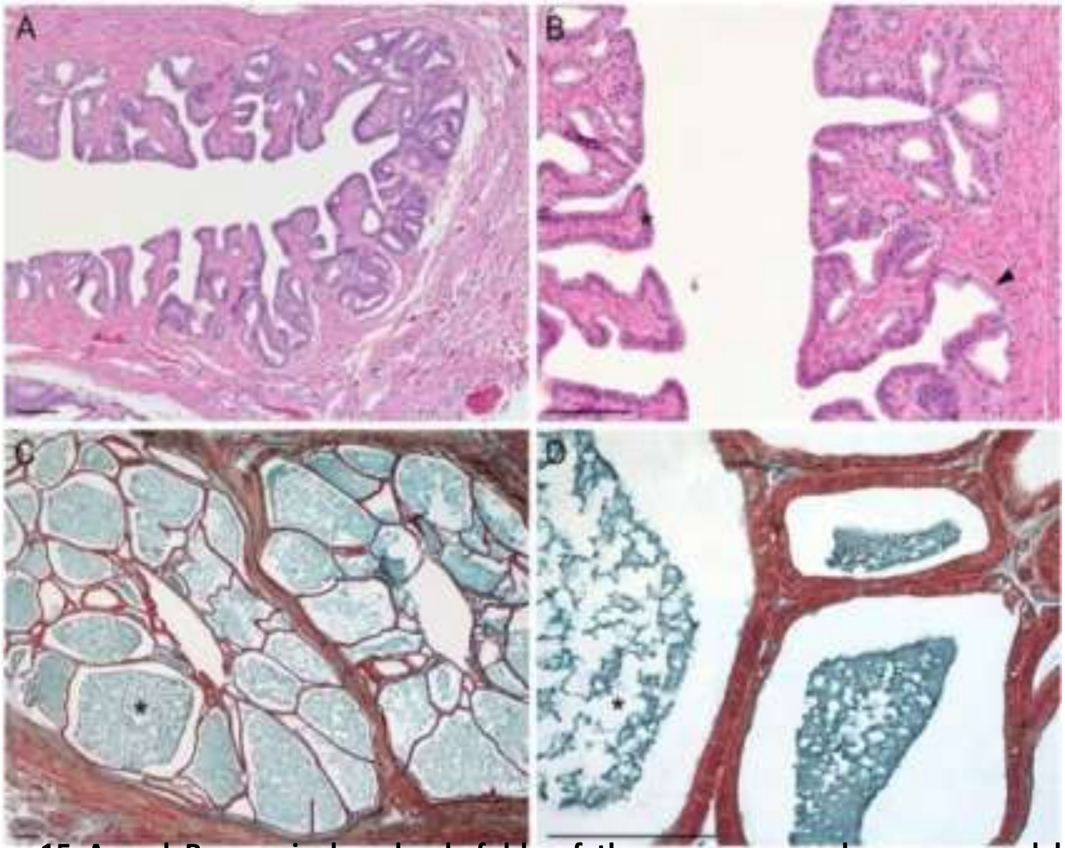


Fig. 15 A and B – vesicular gland; folds of the mucous membrane covered by pseudostratified (asterisk) or single columnar (arrowhead) epithelium; C and D – ampulla ductus deferens; the excretion is present in the lumen of the glands (asterisk); E and F – the bulbourethral gland surrounded by the bulboglandular muscle (arrowhead); note the large excretory duct (asterisk). Scale bar: 100 µm. Original magnification: 40× () 100× (A and E) 200× (B and F) 400× (D)

Vasa Deferentia

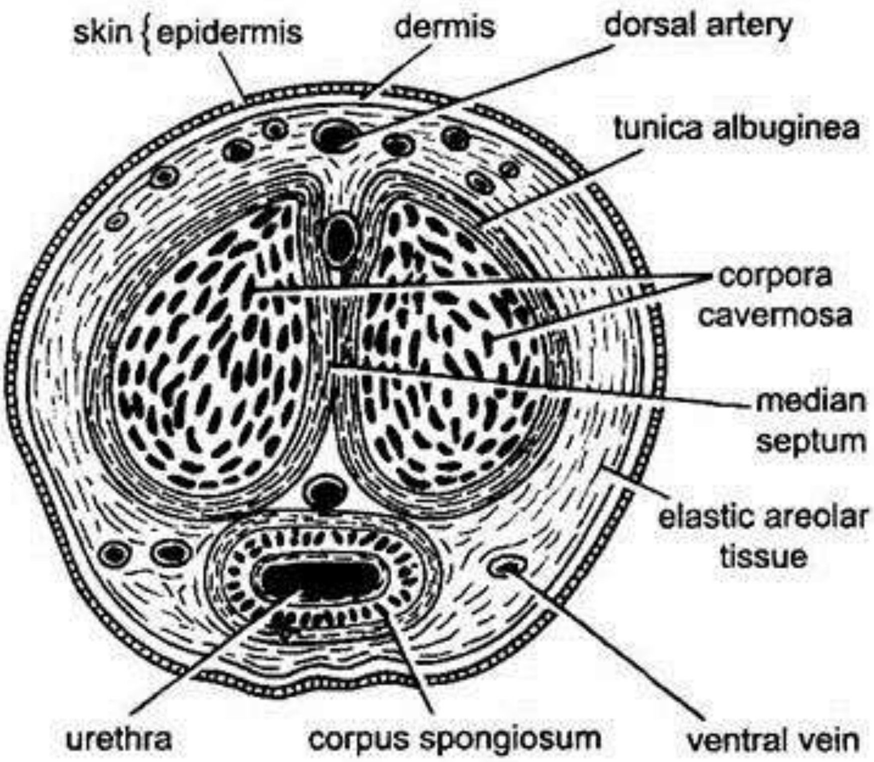
From the cauda epididymis of each testis arises a straight muscular tub the vas deferens or sperm duct. It passes forwards along the inner side of the scrotal sacs and then enters the abdominal cavity through the inguinal canal.Then it curves over the ureter and passes backwards to open in a small median bag called uterus masculinus or seminal vesicle situated above the neck of the bladder. The seminal vesicle opens dorsally into urethra. Urethra is the distal narrow part of the urinary bladder. The urethra thus serves as a passage for urine and the spermatic fluid. It opens at the tip of penis.

Urethra

The neck of urinary bladder and the seminal vesicle open into a thick-walled muscular duct called the urethra or urinogenital canal.

Penis

The penis is a muscular cylindrical and vascular erectile organ which hangs in front of the anus. The penis is covered by a loose sheath of skin which hangs freely over and beyond the tip of the penis as a prepuce. The cap-like tip of the penis covered by prepuce is called glans penis.



. Penis

The p … umns around u … rpora cavernosa … unica albuginea … umns is present elastic areolar tissue layer containing blood vessels and nerves. The blood spaces of the penis get filled with the blood at the time of sexual excitement to make the penis stiff and enlarged.

Chapter Five

Arterial supply to the rabbit male genital Organs

The rabbit testis epididymis deferent duct and accessory genital glands received their arterial supplies via the testicular deferential and prostatic arteries (Fig. 1). The pattern of arterial supply to these organs showed frequent individual variations without any clear correlation between the vascularization pattern of each organ. To distinguish the branching type of the epididymal branch and the prostatic artery the branching type of the epididymal branch is referred to as “Ep-Type and that of the prostatic artery is referred to as “Pro-Type”.

Arterial supply to the testis

The testis was supplied by the testicular artery that emerged from the abdominal aorta (Fig. 1).the right testicular artery emerged at a more cranial level than the left one the left testicular artery arose at a more cranial level than the right one. After originating from the abdominal aorta each testicular artery ran caudolaterally and passed through the inguinal canal to distribute to the testis. The testicular artery circled around twice on the testis in a sagittal plane (Figs. 1 and and2Fig.2). That is after reaching near the cranial extremity of the testis the testicular artery ran toward the caudal extremity along the epididymal border and then turned ventrally around the caudal extremity to run cranially along the free border. The testicular artery again went back toward the caudal extremity along the epididymal border medial to the first course and divided into 2 or 3 terminal branches near the caudal extremity (Fig. 2)Each of these branches ran to the cranial extremity along the free border to enter the testicular parenchyma there. In 19 halves each on the right and left sides (95%) (Fig. 2) the testicular artery divided into 2 terminal branches and in the remaining 1 half each on the right and left side (5%)the testicular artery divided into 3 terminal branches.

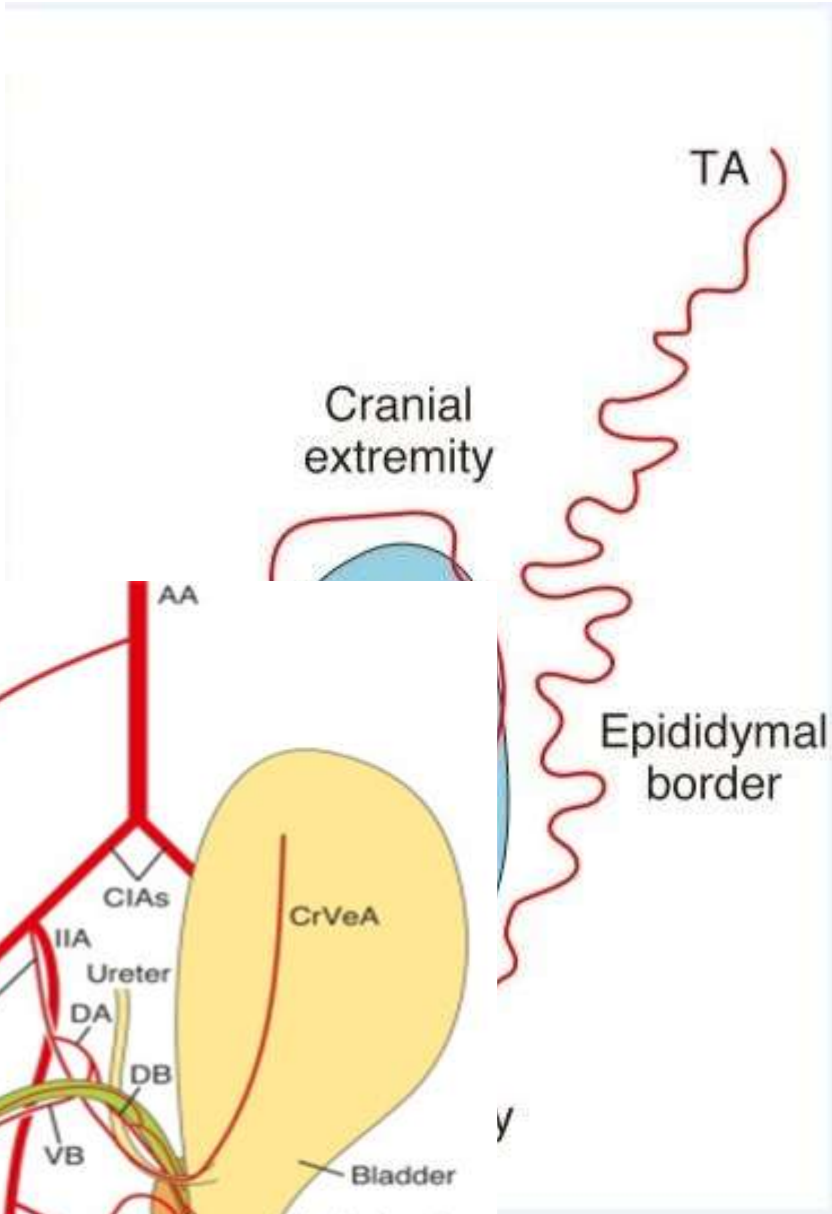
Arterial supply to the epididymis

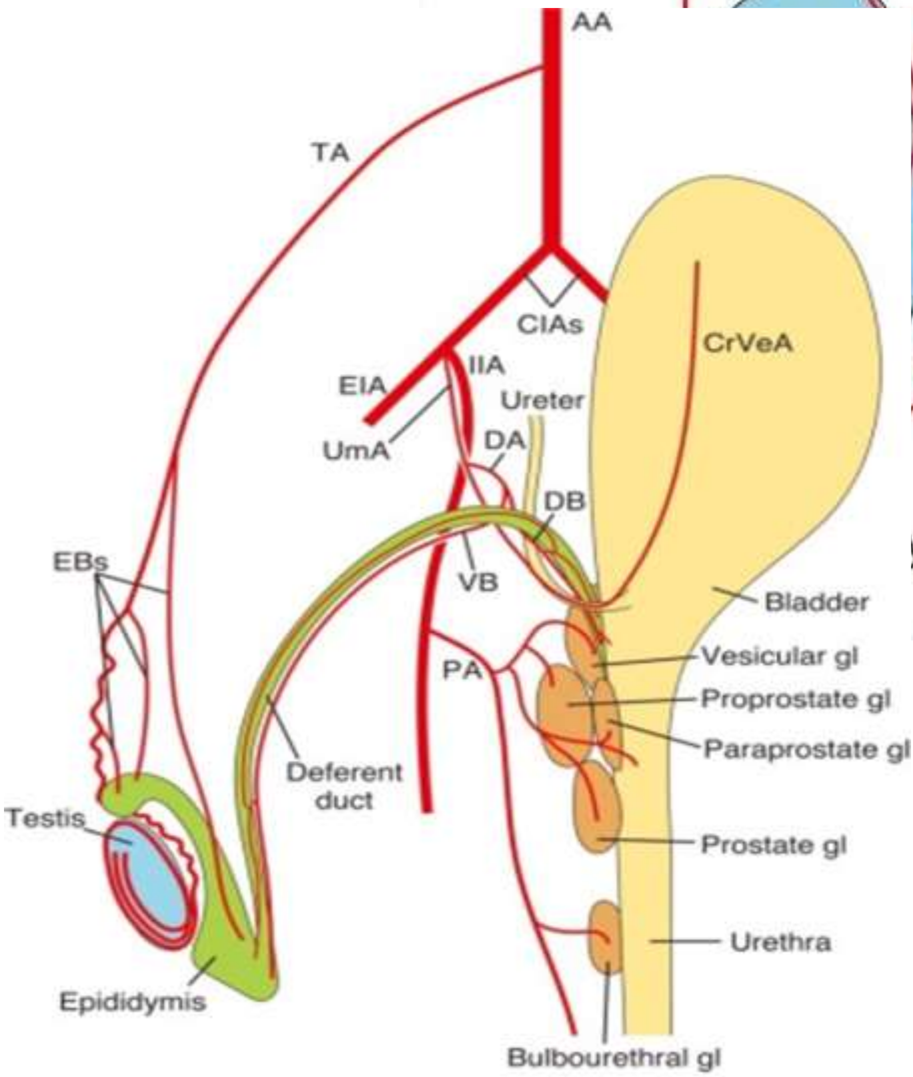
The epididymis received its arterial supply via the epididymal branches that emerged from only the testicular artery or from both The testicular artery and the abdominal aorta (Figs. 1 and 3). Furthermore the tail of the epididymis close to the initial part of the Deferent duct was supplied by the deferential artery (Fig. 4C and 4D). The epididymal branches originated from the testicular artery At up to 5 different levels along the proximodistal axis of the testicular artery depending on each half of the specimen the level of The inguinal canal the level just proximal to the convoluted portion of the testicular artery the level of the convoluted portion of The testicular artery the level proximal to the bifurcation or trifurcation of the testicular artery at the caudal extremity of the testis

Fig. 1Schematic drawing of the ramification patterns of the testicular deferential, and prostate arteries in the ventral view. Abbreviations used in this figure and Figs 2–5: AA abdominal aorta;BuB, branch to the bulbourethral gland; CIA,common iliac artery; CrVeA, cranial vesical artery; DA, deferential artery; DB, dorsal branch of the deferential artery; EB, epididymal branch;EIA, external iliac artery; gl, gland; IIA, internaliliac artery; PA, prostatic artery; ParaPB, branch to the paraprostate gland; PB, branch to the prostate gland; ProPB, branch to the proprostate gland; TA,testicular artery;

UmA, umbilical artery; UrB, urethral branch; VB, ventral branch of the deferential artery; and VesB, branch to the vesicular gland.

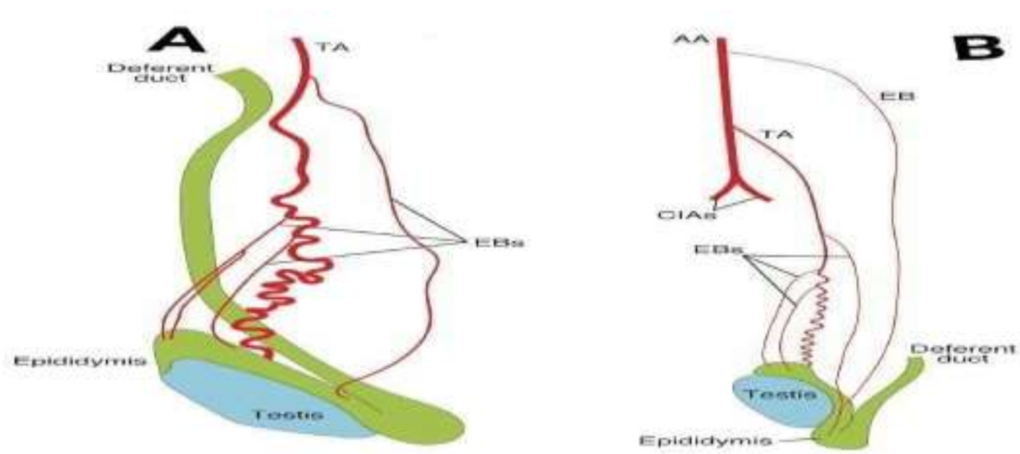
Fig. 2. Photograph of the testicular artery that circles twice around the right testis. Medial view. To show the course of the testicular artery, the epididymis is detached from the testis, and the testicular artery is displaced. The original course of the testicular artery is shown in Figs. 1 and 3.





and the level distal to the bifurcation or trifurcation. In the cases where the epididymal branch emerged from the abdominal aorta the branch issued between the branching levels of the ipsilateral renal and testicular arteries. The branching pattern of the epididymal branch was divided into 2 major types based on the number of parent arteries that Gave rise to the epididymal branches (Fig. 3). Ep-Type 1 included the cases where the epididymal branch emerged from only the testicular artery (Fig. 3A and 3B)while Ep-Type 2 included the cases where the epididymal branch emerged from both the Testicular artery and the abdominal aorta (Fig. 3C). Moreover in each type the cases that had 1 to 5 epididymal branches were Respectively categorized into subtypes a to e In any type The epididymal branches distributed to the head body and tail of the epididymis with frequent individual variations. Ep-Type 1 was observed in 15 halves on the right (75%) and 16 halves on the left (80%) One right half (5%) was categorized as Ep-Type 1a 5 right halves (25%) and 8 left halves (40%) were included in Ep-Type 1b, and 7 right halves (35%) and 6 left halves(30%) were categorized as Ep-Type 1c which was the most frequent type observed in the present study (Fig. 3A and 3B). Ep-Type 1d included 2 halves on the right (10%) and 1 half on the left (5%) and the remaining 1 half on the left side (5%) was included as Ep-Type 1e Ep-Type 2 included 5 halves on the right (25%) and 4 halves on the left (20%) which had 3 to 5 epididymal branches. Therefore in Ep-Type 2there were Ep-Types 2c to 2e only where only 1 epididymal branch originated from the abdominal aorta And the remaining 2 to 4 branches emerged from the testicular artery (Fig. 3C) Ep-Type 2c was observed in 2 halves each on the Right and left sides (10% each) Ep-Type 2d included 1 half on the right side (5%) and 2 halves on the left side (10%) (Fig. 3C) And the remaining 2 halves on the right side (10%) were categorized as Ep-Type 2e

Fig. 3. A: the branching pattern of the epididymal branch categorized into Ep-Type 1c. Lateral view of the left testis. B: Schematic drawing of the ramification pattern of the epididymal



branch categorized as Ep-Type 2d.

Arterial supply to the deferent duct

The deferent duct was supplied by the deferential artery on the right (90%) and 19 halves on the left (95%), the deferential artery emerged from the umbilical artery which usually emerged from the common iliac artery (Figs. 1 and 4). The deferential artery also originated directly from the common iliac or internal iliac artery in each 1 half on the right side (5% each) and from the external iliac artery in the remaining 1 half on the left side (5%). In all halves the deferential artery was divided into the dorsal and ventral branches near the crossing of the deferent duct and ureter (Figs. 1 and 4). The dorsal branch ran medially to distribute to the distal portion of the deferent ductand in 8 halves on the right (40%) and 9 halves on the left (45%) the dorsal branch anastomosed to a branch from the prostatic artery near the terminal portion of the deferent duct. The ventral branch ran along the deferent duct and passed through the inguinal canal to distribute to the proximal portion of the deferent duct and the tail of the epididymis close to the initial portion of the deferent duct (Fig. 4A and 4B(

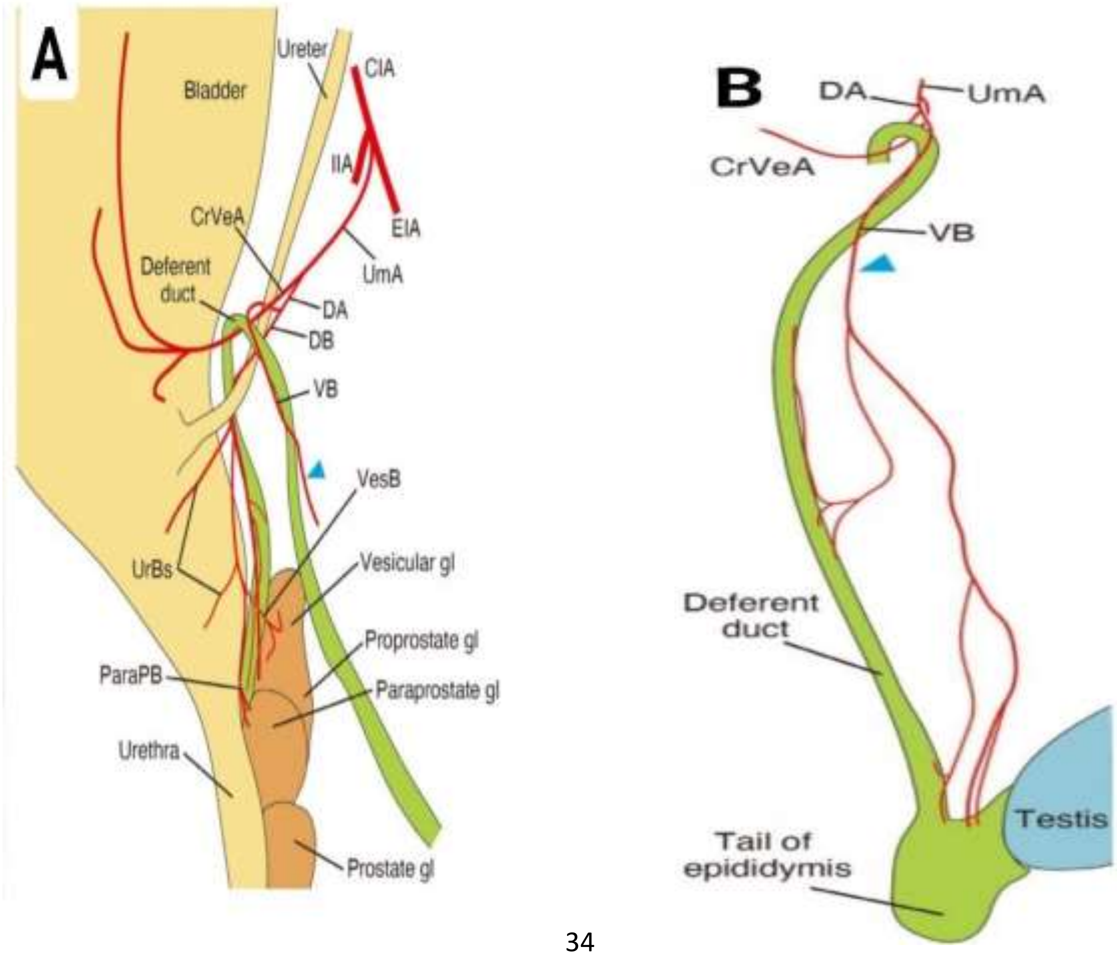


Fig. 4. schematic drawings of the dorsal (A) and ventral (B) branches of the deferential artery. Arrowhead in each panel indicates the same ventral branch of the deferential artery. A: the ramification pattern of the dorsal branch of the deferential artery from a left ventrolateral view The distal portion of the ventral branch is not illustrated. B: the ramification pattern of the ventral branch of the deferential artery in the medial view.

Arterial supply to the accessory genital glands

The vesicular proprostate, prostate paraprostate and bulbourethral glands were usually supplied by both the dorsal branch of the deferential artery and the prostatic artery (Figs. 1, 4 and 5).The dorsal branch of the deferential artery distributed to the vesicular proprostate and paraprostate glands with frequent individual variations (Fig. 4A)but in 1 half on the right (5%) and 2 halves on the left side (10%) this branch did not supply the accessory genital glands. In 10 halves on the right (50%) and 13 halves on the left (65%) (Fig. 4A) the dorsal branch of the deferential artery distributed to the vesicular and paraprostate glands. In other halves this branch supplied the vesicular gland (2 halves on the right [10%] and 4 halves on the left [20%])the paraprostate glands (4 halves on the right [20] the paraprostate and proprostate glands (2 halves on the right [10%] and 1 half on the left [5%])and the vesicular and proprostate glands (1 half on the right [5%] The prostatic artery emerged from the internal iliac artery and ran caudoventrally to supply the accessory genital glands. The ramification pattern of the arterial branches to the accessory genital glands was categorized into 3 types based on the number of branches that originated directly from the prostatic artery to the accessory genital glands (Fig. 5). There were 2 to 4 branches and in all halvesthe most distal branch supplied the bulbourethral gland and the other branches distributed to the vesicular proprostate prostate and paraprostate glands with frequent individual variations. Pro-Type 1 (Fig. 5A) having 2 branches that emerged from the prostatic artery was observed in 4 halves on the right (20%) and 2 halves on the left side (10%). Pro-Type 2 (Fig. 5D) having 3 branches that emerged from the prostatic artery included 11 halves on the right (55%) and 9 halves on the left (45%). This was the most frequent type observed in the present study. Pro-Type 3 (Fig. 5C) was observed in 5 halves on the right (25%) and 9 halves on the left (45%), where 4 branches emerged from the prostatic artery.

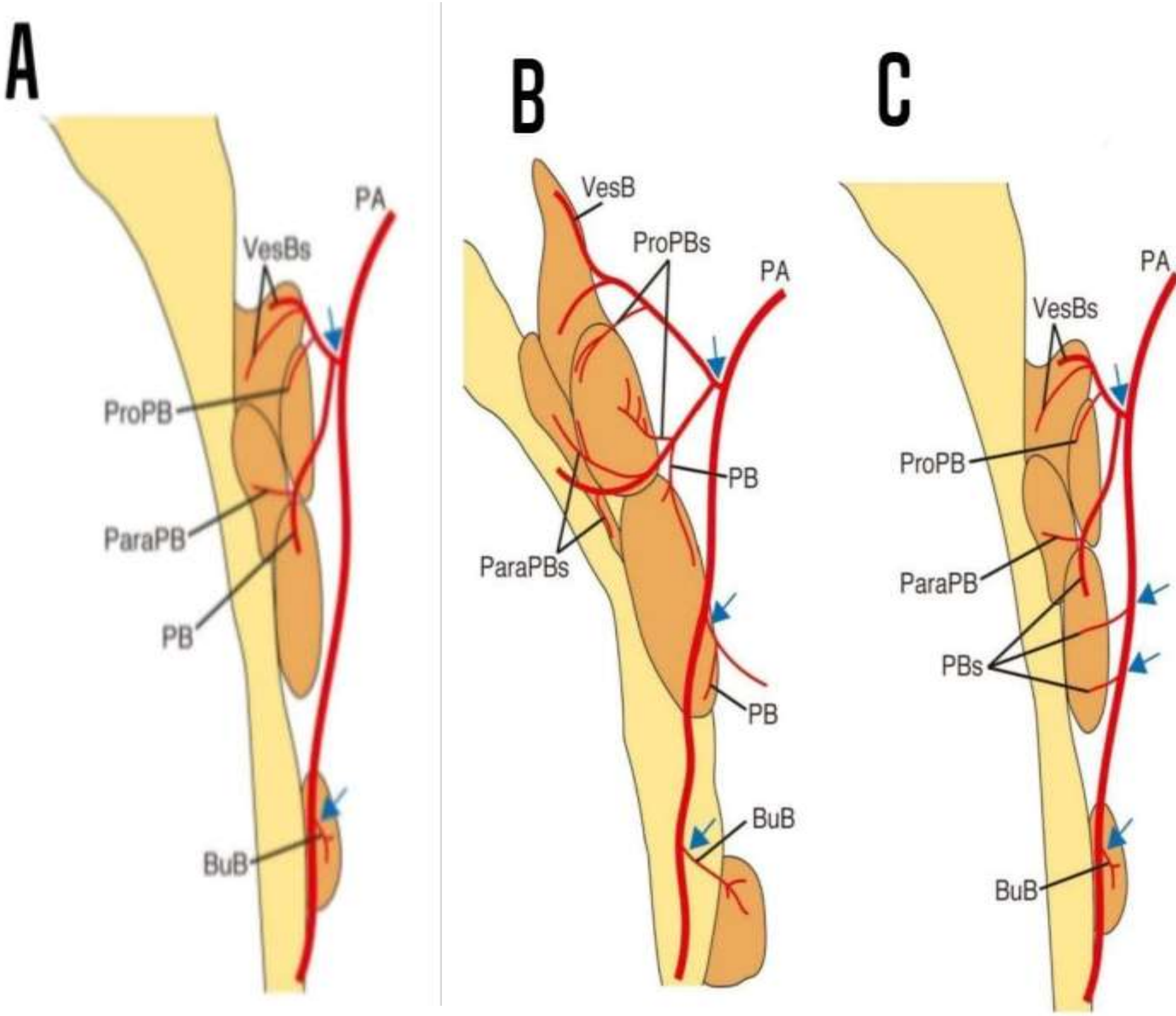


Fig. 5. schematic drawings of the pattern of the arterial supply to the accessory genital glands in the left lateral view. Arrows indicate the branches from the prostatic artery to the accessory genital glands. In A B and C.

REFERENCES

- Arredondo, J., Saucedo, R., Recillas, S., Fajardo, V., Castelán, O., González-Ronquillo, M. and Hernández, W. 2017. Visceral branches of the Abdominal aorta in the New Zealand rabbit: ten different patterns. Int. J. Morphol. 35: 306–309. [CrossRef]
- Banco, B., Binanti, D., Penna, V. and Grieco, V. 2018. Sertoli cell tumour in a pet rabbit (Oryctolagus cuniculus): histological and Immunohistochemical characterization. Open Vet. J. 8: 250–255. [Medline] [CrossRef]
- Banco, B., Stefanello, D., Giudice, C., D'Acierno, M., Di Giancamillo, M. and Grieco, V. 2012. Metastasizing testicular seminoma in a pet rabbit. J. Vet. Diagn. Invest. 24: 608–611. [Medline] [CrossRef]
- Barone, R. 2011. Artères. Pp. 103–448. In: Anatomie Comparée des Mammifères Domestiques, Tome 5: angiologie, 2nd ed., Editions Vigot, Paris.
- Chubb, C. and Desjardins, C. 1982. Vasculature of the mouse, rat, and rabbit testis-epididymis. Am. J. Anat. 165: 357–372. [Medline] [CrossRef]
- Felix, W. 1912. The development of the urogenital organs. Pp. 752–979. In: Manual of Human Embryology, Vol. 2. (Keibel, F. and Mall, F. P. eds.), Lippincott, Philadelphia.
- Harcourt-Brown, F. M. 2017. Disorder of the reproductive tract of rabbits. Vet. Clin. North Am. Exot. Anim. Pract. 20: 555–587. [Medline] [CrossRef]
- Kigata, T. and Shibata, H. 2018. Arterial supply to the rabbit adrenal gland. Anat. Sci. Int. 93: 437–448. [Medline] [CrossRef]
- Kigata, T., Ikegami, R. and Shibata, H. 2018. Macroscopic anatomical study of the distribution of the cranial mesenteric artery to the intestine in the Rabbit. Anat. Sci. Int. 93: 291–298. [Medline] [CrossRef]
- Krause, W. 1884. Die Anatomie des Kaninchens. Wilhelm Engelmann, Leipzig.

- Lempert, M. 2019. Urinary obstruction due to a prostatic abscess in a young neutered rabbit. J. Exot. Pet Med. 29: 15–21. [CrossRef]
- Nomina Anatomica Veterinaria. 2017. International Committee on Veterinary Gross Anatomical Nomenclature. 6th ed. Hannover, Germany: Editorial Committee.
- Orsi, A. M., Pinto e Silva, P., Fernandes de Abreu, M. A. and Mello Dias, S. 1979. Artères viscérales pelviennes chez le lapin (Oryctolagus Cuniculus). Acta Anat. (Basel) 104: 72–78. [Medline] [CrossRef]
- Rajtová, V. and Danko, J. 2001. Vasculature of testis, epididymis and ductus deferens of rabbit. The arteries. Acta Vet. Brno 70: 3–7. [CrossRef]
- Schummer, A., Wilkens, H., Vollmerhaus, B. and Habermehl, K. H. 1981. The Anatomy of the Domestic Animals. The Circulatory System the Skin and the Cutaneous Organs of the Domestic Mammals, Vol. 3. Paul Parey Berlin.
- Singh, B. 2018. Dyce Sack and Wensing's Textbook of Veterinary Anatomy. 5th ed. Elsevier, St. Louis.
- Skonieczna, J., Madej, J. P. and Będziński, R. 2019. Accessory genital glands in the New Zealand White rabbit: a morphological and histological Study. J. Vet. Res. (Pulawy) 63: 251–257. [Medline] [CrossRef]
- Tsuzaki, K. 1935. Domestic rabbit. In: The Anatomy of the Experimental Animals, Kanehara Shoten, Tokyo (in Japanese).
- Varga, M. 2014. Rabbit basic science. Pp. 3–108. In: Textbook of Rabbit Medicine, 2nd ed., Butterworth-Heinemann, Oxford.
- Flacknell P (2003). Manual of Rabbit Medicine and Surgery, BSAVA: 47-56.
- Harcourt-Brown F (2007). Radiographic signs of renal disease in rabbits, Veterinary Record 160(23):787-794.
- Harcourt-Brown F (2002). Diet and husbandry, Textbook of Rabbit Medicine, Elsevier:19-51.
- Keeble E and Shaw D J (2006). Seroprevalence of E cuniculi in domestic rabbits in the United Kingdom, Veterinary Record 158:539-543.
- Melillo A (2007). Rabbit clinical pathology, Journal of Exotic Pet Medicine 16(3):135-145.
- Meredith A and Crossley D A (2002). Rabbits. In Meredith A and Redrobe S (eds), BSAVA Manual of Exotic Pets (4th edn), BSAVA: 76-92.
- Oglesbee B L (2006). The Five Minute Veterinary Consult: Ferret and Rabbit, Blackwell Publishing: 178-387.
- O'Malley B (2006). Rabbits. In Clinical Anatomy and Physiology of Exotic Species, Elsevier Saunders: 173-195.
- Quesenberry K and Carpenter J (2000). Ferrets, Rabbits and Rodents: Clinical Medicine And Surgery (2nd edn), Saunders: 183-193.
- Richardson V (2006). Sludgy urine in rabbits, UK Vet 11(7):28-29.
- Suckow M A and Douglas F A (1997). Experimental methodology, The Laboratory Rabbit,CRC Press: 71.
- Abdou, M. S., Moussa, M. H., Ragab, R. S., & el-Menoufy, A. A. (1985). On the regional Histology of the ductus epididymidis in the buffalo (Bubalus bubalis). Anatomia, Histologia, Embryologia, 14(3), 226–235.

- Ackerman, B. B. (1995). Aerial Surveys of Manatees: A Summary and Progress Report. In T. J.
- O'Shea, B. B. Ackerman, & H. F. Percival, Population biology of the Florida manatee.
- National Biological Service Information and Technology Report 1 (pp. 6–12). Washington.
- Agrawal, Y., & Vanha-Perttula, T. (1988). Electron Microscopic Study of the Secretion Process In Bovine Reproductive Organs. Journal of Andrology, 9(5), 307–316.
- Amann, R., & Schanbacher, B. (1983). Physiology of male reproduction. Publications from USDA-ARS / UNL Faculty.
- Amaral, R. S., Rosas, F. C. W., Viau, P., d' Affonsêca Neto, J. A., da Silva, V. M. F., & de
- Oliveira, C. A. (2009). Noninvasive Monitoring of Androgens in Male Amazonian Manatee (Trichechus inunguis): Biologic Validation. Journal of Zoo and Wildlife Medicine, 40(3), 458–465.
- Anderson, M. J., Nyholt, J., & Dixson, A. F. (2004). Sperm competition affects the structure of The mammalian vas deferens. Journal of Zoology, 264(1), 97–103.
- Assis, M. F. L., Best, R. C., Barros, R. M. S., & Yassuda, Y. Y. (1988). Cytogenetic study of Trichechus inunguis (Amazonian Manatee). Rev. Bras. Genét, 11(1), 41–50.
- Atkinson, S. (1997). Reproductive biology of seals. Reviews of Reproduction, 2(3), 175–194.
- Aughey, E. (2001). Comparative veterinary histology: with clinical correlates. Ames: Iowa State University Press.
- Bacha, W. J., & Bacha, L. M. (2000). Color atlas of veterinary histology (2nd ed). Philadelphia, PA: Lippincott Williams & Wilkins.
- Bearden, H. J., & Fuquay, J. W. (1992). Applied animal reproduction (3rd ed). Englewood Cliffs, N.J: Prentice Hall.
- Beck, C. A., & Reid, J. P. (1995). An automated photo-identification catalog for studies of the
- Life history of the Florida manatee. In T. J. O'Shea, B. B. Ackerman, & H. F. Percival, Population biology of the Florida manatee. National Biological Service Information and Technology Report 1 (pp. 120–134). Washington.
- Bengtson, J., & Magor, D. (1979). Survey of Manatees in Belize. Journal of Mammalogy, 60(1), 230–232.
- Berta, A., Sumich, J. L., Kovacs, K. M., Folkens, P. A., & Adam, P. J. (2006). Marine mammals:
- Evolutionary biology (2nd ed). Amsterdam ; Boston ; London: Elsevier/Academic Press.
- Bland, K. P., & Kitchener, A. C. (2001). The anatomy of the penis of a Sperm Whale (Physeter
- Catodon L., 1758). Mammal Review, 31(3-4), 239–244.
- Bonanno, V. L., & Schulte-Hostedde, A. I. (2009). Sperm competition and ejaculate investment In red squirrels (Tamiasciurus hudsonicus). Behavioral Ecology and Sociobiology.
- Bonde, R. K. (2009). Population Genetics and Conservation of the Florida Manatee: Past, Present and Future. (PhD Dissertation). University of Florida, Gainesville, FL

- Arrayago M.J., Bea A. 1986: Atlas de citología e histología del aparato reproductor masculino de Los anfibios y reptiles del país vasco. 20-61.
- Bacha W.J., Wood L.M. 1991: Atlas color de histología veterinaria. Ed. Intermédica. 189-198.
- Parra R., Del Sol M. 2002: Estudios histológicos e histoquímicos del epidídimo del conejo (Oryctolagus cuniculus), Rev. Chil. Anat., 20 (3): 269-274.
- Sánchez M.B., 1994: Evolución testicular felina, estudio histológico, inmunohistoquímico y
- Ultraestructural. Departamento de patología animal, Facultad de Medicina Veterinaria, Universidad Complutense de Madrid. 106-165.
- Sociedad Mexicana de Histología AC. Memorias del XXVIII Congreso nacional de histología. Memorias 2004. Universidad Autónoma Metropolitana Iztapalapa. 41-50.