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Research Article

Comparative Morphological and Histochemical Characteristics of the Nasal Cavity and Paranasal Sinuses of Adult Rabbits and Domestic Cats in Egypt

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ABSTRACT

Studying the anatomical differences of the nasal cavity and paranasal sinuses of both rabbit and cat offers a valuable evidence for clinicians regarding the possibility of utilization of the respiratory system of rabbit and cat as models to human being studies. This work was conducted using clinically healthy ten adult domestic cats and ten *White New Zealand* rabbits, of different sexes and weights. Different techniques were applied from drying, fixed specimens as well as histological and histochemical studies. The nostrils of rabbit were slit like opening with complete deep cleft with two nasal pads while the cat nostrils were semicircular with shallow grooved philtrum. The nasal septum of rabbit was three layers while that of the cat was only single layer. The nasal septum of both rabbit and cat showed high level of acidic mucins in the lining epithelium and low level of neutral mucins. In the rabbit, the nasal cavity regions were the nasal vestibule, maxilloturbinates, nasomaxillary and ethmoturbinates. The nasal conchae were; dorsal, ventral, middle and ethmoidal nasal conchae in addition to the atrioturbinate. In the cat, the nasal cavity was divided into three regions; nasal vestibule, nasal cavity proper and the nasal fundus, it had four conchae; dorsal, ventral, middle and ethmoidal conchae. The paranasal sinuses of rabbit were the dorsal conchal, maxillary and ethmoidal sinuses with absence of frontal and sphenoidal; on the other hand, in the cat there were frontal, sphenoidal and maxillary sinuses.

Key words: Rabbit, Cat, Nasal Cavity, Paranasal sinuses, Anatomy, Histology

INTRODUCTION

The nasal cavity of rabbit and cat have different aspect of similarity and dissimilarity which has a great clinical important as a model for the human being (Badran *et al*., 2017& Kushnaryov *et al*., 2014). The importance of studying of normal anatomy of the nasal cavity helps in the treatment of different respiratory diseases (Panerari *et al*., 2008).

Rabbits and cats are often used as human substitutes in olfaction and inhalation tests, both of which require the knowledge of the nasal airway structure and airflow dynamics within it **(**Norris Reinero *et al*., 2004 & Xi *et al*., 2016)

The present study aimed to provide a description of the comparative morphological and histochemical features of the nasal cavity and paranasal sinuses of rabbit and cat to offer a valuable evidence for clinicians regarding the possibility of utilization of the respiratory system of rabbit and cat as models to human being studies.

MATERIALS AND METHODS

This work was conducted using clinically healthy ten adult domestic cats and ten *White New Zealand* rabbits, of different sexes and weights collected from El-Giza & Cairo governorates. The animals were euthanized by Pentobarbital sodium 65 mg, 3mL/2.5 kg of body weight through intravenous route; the animals were exsanguinated through bleeding the common carotid artery. Four specimens (2 cats and 2 rabbits) were dissected freshly directly after exsanguination. \Six specimens (3 cats & 3 rabbits) were flushed with warm normal saline through the common carotid artery then fixed by injection of 80-100 ml of 10% formalin solution then left in cold room 5 C for 4 days before dissection. Two specimens (1 cat and 1 rabbit) were dried in open air then colored with acrylic colors *(*Rezk, 2010*). Nomina Anatomica Veterinaria* (2012) was used for nomenclature. All the specimens were photographed by Sony camera h400, 20.1 megapixels, 63X optical zoom cyber shot.

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Eight specimens (4 cats and 4 rabbits) were used for histological and histochemical studies, Samples were immediately fixed in 10% neutral buffered formalin, dehydrated and embedded in paraffin blocks. Paraffin sections 5-6 µm were stained using; Harris Hematoxylin and Eosin (H & E) stain for general tissue structure studies, Alcian blue pH 2.5 for demonstration of acidic mucins (mucopolysaccharides), Masson's trichrome stain (MTC) for determination of muscles and connective tissue and Periodic Acid Schiff technique (PAS) for neutral mucins as outlined by *Bancroft and Gamble (2008).*

RESULTS

The rhinarium is the most rostral part of the nose and includes the nostrils and the philtrum in the rabbit and cat. In the rabbit, the nostrils (Fig. 1, A/1) were the rostral openings of the nasal cavities and were two oblique slit-like openings directed dorsally, while in the cat, the two nostrils (Fig. 1, B/1) were semicircular C- shaped medially. The nostrils medial angles in the rabbit had a kidney shaped cutaneous diverticulum; the nasal pad (Fig. 1, A/3) which was concave medially and convex laterally. While in the cat, the two nostrils were separated by nasal Fig. which was granulated non- hairy area and was inverted anchor shape. The most upper part of the cat nose was the *Radix nasi* and extended rostroventrally as the *Dorsum nasi* (Fig. 1, B/8) then inclined ventrally forming *Apex nasi* (Fig. 1, B/9) which extended on both sides forming the right and left wings of the nose; *Alae nasi* (Fig. 1, B/10).

The philtrum in the rabbit (Fig. 1, A/4) formed Y-shape complete cleft in the lower third of the face and related laterally to the oblique paramedian ridges (Fig. 1, A/5), while in the cat, the philtrum (Fig. 1, B/4) was a shallow straight groove began in midline between the two nostrils and extends downward to the upper lip without complete separation of the latter.

In the rabbit, the nasal cartilages were the median nasal septum, the right and left lateral nasal septum, paraseptal cartilage, the dorsolateral and ventrolateral nasal cartilages, while in the cat, the nasal cartilages were the median nasal septal cartilage, dorsal and ventral lateral nasal cartilages, in addition to the medial and lateral accessory cartilages.

In the rabbit, the medial nasal septum (Fig. 2, A, B & C/1) was rectangular in shape, it was attached dorsally to the nasal bone, extended from the cartilaginous tip of nasal bone rostrally to the perpendicular Fig. of ethmoid bone caudally (Fig. 2, A, B &C/5), and attached ventrally to the vomer bone which represent the osseous nasal septum as in cat (Fig. 2, A/ 4). This median nasal septum was formed from three layers; two outer membranous **(**Fig. 2, B&C /2) with a cartilaginous one in between. Histologically the nasal septum supported medially by a Fig. of hyaline cartilage (Fig. 4, C) and showing highly fibrous submucosal connective tissue housing fewer amount of cavernous tissue and blood vessels when stained by MTC stain (Fig.8, A). In level I, it was lined by stratified squamous epithelium formed of 4-5 cells thick (Fig. 4, E) While in level II, it lined by pseudo stratified columnar ciliated epithelium the lamina propria carry many small BVs and serous glands (Fig. 5, C&E)

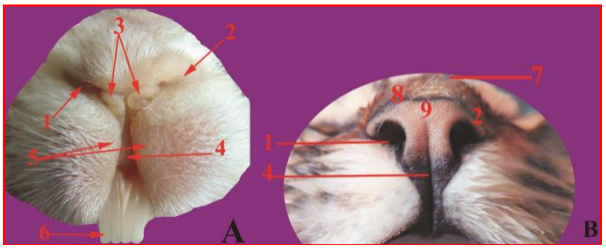

Fig. 1: A, B Photographs showing the rhinarium of the rabbit and cat respectively. 1.Nostrils, 2 .Wing of nostril (Alae nasi), 3. Nasal pad, 4. Philtrum, 5. Para median ridges, 6. Upper incisor teeth 7. Radix nasi, 8. Dorsum nasi, 9. Apex nasi.

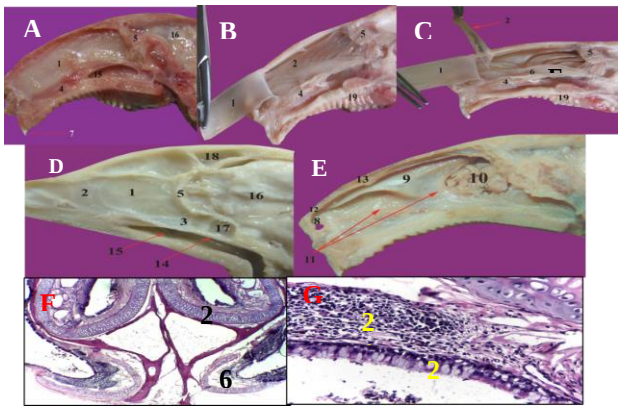

Fig. 2: Photographs showing **(A, D)** the nasal septum of rabbit and cat respectively. **(B, C)** The reflection of the nasal septum layers of the rabbit**. (E)** the lateral nasal septum of rabbit**. (F)** the para septal cartilage of the rabbit stained by H&E(40X). **(G)** Higher magnification from (F) (400X).

1. Nasal septum (septum nasi), 2. Membranous nasal septum, 3. Caudal process of nasal septum 4. vomer bone, 5.Perpendicular lamina of ethmoid, 6. Paraseptal cartilage, 7. Upper incisors teeth 8. Atrioturbinate 9. Nasomaxillary region (dorsal nasal concha|), 10.The remained part of the ethmoturbinates, 11.lateral nasal septum, 12. dorsolateral nasal cartilage, 13. Nasal bone 14. Vomer process of vomer bone, 15. Choanae, 16. Brain, 17. Sphenoidal sinus, 18. Frontal sinus, 19. Hard palate 20. Vomernasal organ 21.pseudo stratified columnar ciliated epithelium 22.goblet cells.

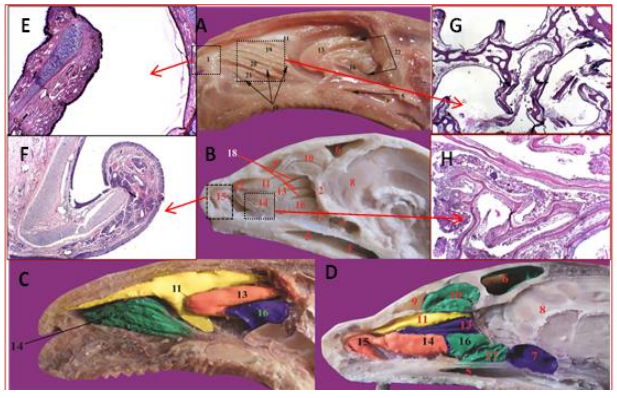

Fig. 3: Photographs showing **(A.B),** the nasal cavities of the rabbit and cat respectively after the removal of the median nasal septum. **(C, D)**, the nasal cavities of rabbit and cat respectively colored with acrylic. **(E),** the Atrioturbinate of rabbit stained by H&E **(40X). (F),** the alar fold of cat stained by H&E **(40X). (G, H)**, the maxilloturbinates of rabbit and cat respectively stained by H&E **(40X).**

1. Atrioturbinate, 2. Perpendicular Fig. of ethmoid bone, 3. Upper incisor teeth,4. Nasopharyngeal duct, 5. Choana, 6. Frontal sinus, 7. Sphenoidal sinus, 8. Brain, 9. Dorsal recess of nasal cavity10. Ectoturbinates, 11. Dorsal nasal concha.12. Straight fold 13. Middle nasal concha14. Ventral nasal concha. 15. Alar fold, 16. Dorsal part of ethmoidal concha , 17. Ventral part of ethmoidal concha,18. Middle nasal meatuses, 19. Dorsal respiratory zone of ventral nasal concha, 20.Ventral respiratory I zone of ventral nasal concha, 21. Ventral respiratory II zone of ventral nasal concha, 22.Ethmoturbinate region.

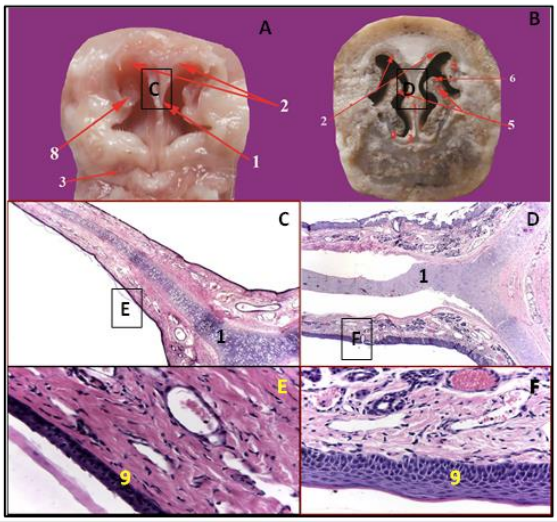

Fig. 4: a photographs showing **(A),** cross section of the nasal cavity of rabbit taken immediately posterior to the upper incisor teeth. **(B),** cross section of the nasal cavity of cat taken in front of the canine teeth and behind the first incisor. **(C, D)** nasal septum of rabbit and cat stained by H&E respectively **(40X). (E, F)** higher magnification of nasal septum of rabbit and cat stained by H&E respectively **(400X).**

1. Nasal septum, 2. Dorsolateral nasal cartilage, 3. Ventrolateral nasal cartilage, 4.lateral accessory nasal cartilage, 5. Medial accessory nasal cartilage, 6 .Alar fold, 7. Straight fold, 8. Atrioturbinate. 9. Stratified squamous epithlium

however in its caudal part III (Fig. 6, C&E). and IV (Fig. 7, C&E). levels was covered by olfactory epithelium with many nerve bundles appeared in the underlying propria as well as serous *Bowman's* glands By alcian blue pH 2.5 the nasal septum demonstrated strong reactivity of most of goblet cells and glandular structures at (Fig. 8,C). By PAS stain the nasal septum of rabbit showed negative reactivity of most of lining cells (Fig.8, E).

In the cat, the median nasal septum (Fig. 2, D/1) composed of a cartilaginous vertical Fig. transformed in its middle into membranous part (membranous nasal septum) (Fig. 2, D/2) and its caudal portion was osseous part of nasal septum which composed of the perpendicular lamina of the ethmoid (Fig. 2, D/ 5) and vomer bone (Fig. 2, D/ 4). Histologically the dorsal part was supported by central (medially) hyaline cartilage Fig. and covered by fibrous connective tissue containing several glands and rich in blood vessels (Fig. 4, D) as observed by H&E stain and (Masson trichrome stain 40X) (Fig. 8, B). Higher magnification, of level I revealed that it was lined by stratified squamous epithelium keratinized 12-15 cells thick. With underlying highly vascularized fibrous connective tissue containing several glands and rich in blood vessels as well as serous glands (Fig.4, F). While level II, it lined by pseudo stratified columnar ciliated epithelium with goblet cells (Fig.5, D&F) as well as the level III lined by olfactory epithelium with many serous glands in underlying connective tissue with cartilaginous support only (Fig. 6, D&F). While its level IV supported by large hyaline cartilage Fig. surrounded with osseous tissue and lined with olfactory epithelium (Fig.7, D&F). By alcian blue pH 2.5 the nasal septum showed strong reactivity in lining epithelium as well as underlying propria glands (Fig.8, D). By PAS stain the Nasal septum showed weak reactivity of most of lining cells (Fig. 8, F).

In the Rabbit and Cat, the median nasal septum extended dorsolaterally forming the dorsolateral nasal cartilage on both sides (Fig. 4, A/2) and extended ventrolaterally forming the ventrolateral nasal cartilages (Fig.4, A/3) on both sides of the median septum.

In the rabbit, the paraseptal cartilages (Fig. 2, C/6) were attached to the ventral borders of the membranous septum at the vomer, they extended ventrally forming the vomeronasal cartilages (Fig. 5, A/3) which enclosed the vomeronasal organs on both sides (Fig. 5, A/2) which confirmed histologically, the para septal cartilages were hyaline in nature and related to the vomeronasal cartilage (Fig. 5, G). IT lined with pseudo stratified columnar ciliated epithelium with goblet cells with underlying nasal associated lymphoid tissue (Fig.5, I). The right and left lateral nasal septum (Fig. 2, E/11) carried the nasal conchae medially and related to the nasal and maxillary bones laterally. The lateral nasal septum extended from the dorsolateral cartilage dorsally to the ventrolateral nasal cartilage ventrally, forming a tube with the median nasal septum that enclosed the nasal cavity inside.

In the cat, the ventrolateral cartilage (Fig. 4, B/3) enriched by a small anchor shape lateral accessory nasal cartilage (Fig. 4, B/4) to support the ventrolateral wall of the nostril. The medial accessory nasal cartilages (Fig. 4, B/5) was large C- shaped and originated from the upper part of lateral accessory nasal cartilage and the rostral protrusion of the ventral nasal concha. The medial accessory nasal cartilages lodged rostrally inside the alar fold (Fig. 4, B/6).

In the rabbit, the nasal cavity regions were the nasal vestibule, maxilloturbinates, nasomaxillary and ethmoturbinates. While In the cat, the nasal cavity (Fig. 3, B&D) was divided into three regions; nasal vestibule, nasal cavity proper and the nasal fundus. The nasal conchae in both rabbit and cat were; dorsal (Fig. 3, A, B, C&D/11), ventral (Fig. 3, A, B, C&D /14), middle (Fig. 3, A, B, C&D /13) and ethmoidal nasal conchae (Fig. 3, A, B, C&D / 16) in addition to the atrioturbinate (Fig. 3, A/1) in the rabbit.

The nasal vestibule was the most rostral part of the nasal cavity, it was narrow rostrally then widened caudally forming the entrance of the nasal cavity. In the rabbit, it contained the bulged triangular shaped atrioturbinate (pate 3, A/1). It appeared histologically with supporting central hyaline cartilage Fig. and covered by fibrous connective tissue reach in blood vessels and lymphatic (Fig. 3, E), while in the cat, occupied by the straight fold (Fig. 3, B/12) dorsally as rostral extension from the dorsal nasal concha and alar fold (Fig. 3, B&D/15) ventrally as rostral extension of ventral nasal

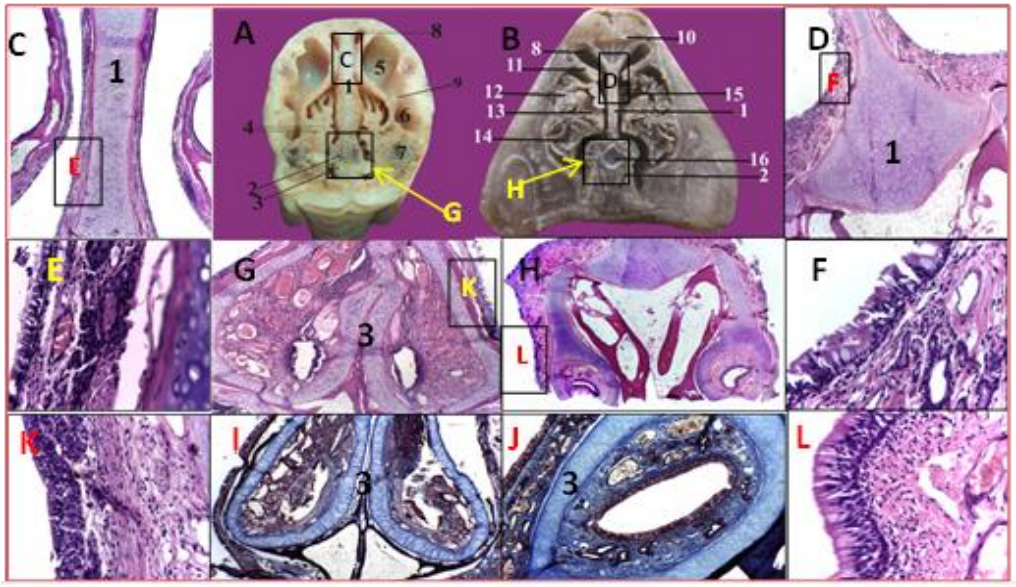

Fig. 5: a photographs **showing (A)** the Cross section of the nasal cavity of rabbit taken at the first palatal ridge**. (B)** the Cross section of the nasal cavity of cat taken just behind the third palatine ridge caudal to the canine teeth. **(C, D)** the nasal septum of rabbit **(10X)** and cat **(40X)** respectively stained by H&E **(E, F)** higher magnification of the nasal septum of rabbit and cat respectively stained by H&E **(400X). (G, H)** the vomeronasal organ of rabbit **(40X)** and cat **(100X)** respectively stained by H&E**. (I, J)** the vomeronasal organ of rabbit **(40X)** and cat **(100X)** respectively stained by MTC**.(K&L)** higher magnification of **G&H (400xX).**

1. Nasal septum 2. Vomeronasal organ 3. Vomeronasal cartilage, 4. Terminal part of the ventral nasal concha 5. Dorsal conchal sinus 6. Maxillary sinus (dorsal recess), 7. Nasolacrimal duct, 8. Dorsal nasal meatus, 9. Conchomaxillary sinus, 10. Ectoturbinates, 11. Dorsal nasal concha 12. Middle nasal concha, 13. middle nasal meatus, 14. Ventral nasal concha, 15.common nasal meatus, 16.Vomer process of vomer bone

concha. Histologically, the alar fold supported with hyaline cartilage Fig. surrounded with connective tissue layer housing many small blood vessels as well as mucosal associated lymph nodules (Fig.3, F).

The nasal cavity proper in the cat was the middle part of the nasal cavity occupied by nasal conchae; dorsal, middle, and ventral nasal conchae which were named all as the endoturbinates as well as the dorsal recess of the nasal cavity. While in the rabbit, the middle area contained two regions, the nasomaxillary and maxilloturbinate regions. The nasomaxillary region contained the T- Shaped dorsal nasal concha (Fig. 3, A&C/11) which originated from the nasal bone and placed on the top of nasal cavity while the maxilloturbinates region (Fig. 3, A&C/14) contained the ventral nasal conchae which originated from the maxilla and rest on the lateral nasal septum

The dorsal nasal concha in the rabbit (Fig. 3, A&C/11) was T-Shaped, narrow rostrally and widened gradually till its middle then tapered caudally where it extended to reach the ventral nasal recess to form a large dorsal conchal sinus (Fig. 5, A/5) in between the ventral and the middle nasal conchae. While in the cat, the dorsal nasal concha (Fig. 3, B&D/11) occupied the area along the ventral side of the dorsal recess and it was spindle shaped as it was wide at its middle and tapered at the free ends. It originated from the upper part of the perpendicular Fig. of ethmoid bone (Fig. 3, B&D/2) so considered as the endoturbinate I and extended rostrally in between the dorsal recess and the middle nasal concha. It formed the straight fold rostrally in the nasal vestibule. In transverse section (Fig. 4, B/ 7), the straight fold appeared as a small elevation on the lateral wall of the nasal vestibule, dorsolateral to the alar fold.

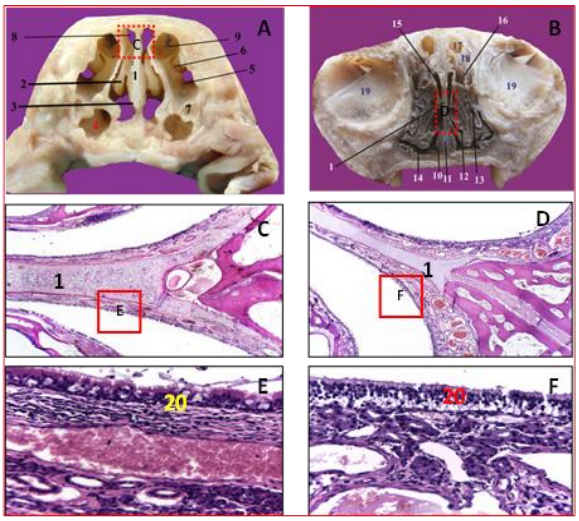

Fig. (6): Photographs showing **(A)** the Cross section of the nasal cavity of rabbit taken immediately anterior to the first premolar teeth. **(B)** the Cross section of the nasal cavity of cat taken behind the second teeth. **(C, D)** the nasal septum of rabbit and cat respectively stained by H&E (40X). **(E, F)** higher magnification of nasal septum of rabbit and cat respectively stained by H&E (400X).

1. Nasal septum, 2. Middle nasal concha, 3. Paraseptal cartilage, 4. Maxillary sinus (ventral recess), 5. Maxillary sinus (dorsal recess), 6 .Conchomaxillary sinus, 7. Nasolacrimal duct, 8. Dorsal nasal meatus, 9. Dorsal conchal sinus, 10. Vomeronasal organ, 11. Vomer process of vomer bone, 12. ventral nasal concha, 13. middle nasal meatus, 14. Ventral nasal meatus, 15. common nasal meatus, 16. dorsal nasal concha, 17. Dorsal recess of the nasal cavity, 18. ectoturbinates, 19. Orbit of the eye. 20. Olfactory epithelium.

The ventral nasal concha in the rabbit divided into three zones; dorsal respiratory, ventral respiratory I and ventral respiratory II. The dorsal respiratory zone (Fig. 3, A/19) was the largest zone represented by four double layers of the turbinate bones covered by mucous membrane, with a branching shape (Fig. 5, A/4) in cross section. The ventral respiratory zone I (Fig. 3, A/20) and ventral respiratory zone II (Fig. 3, A/21) were simple and each formed from a single double layer of turbinate bones. The ventral respiratory zone II was the most ventral part of the ventral nasal conchae and formed the dorsal boundary of the ventral nasal meatus. Histologically, the highly branched maxilloturbinates were covered by transitional epithelium with underlying loose connective tissue rich with lymphocytes devoid of goblet cells (Fig.3, G). It has fibrous connective tissue of submucosal layer rich in blood vessels, secretory glands and supported by bony Fig.s by MTC stain (Fig.8, G). By alcian blue pH 2.5, the maxilloturbinates had a very mild reactivity at the apical border of lining epithelial cells. (Fig., 8/I). However, by PAS stain, the Maxilloturbinate had more strong reactivity of lining epithelium (Fig.8, K). While in the Cat, the ventral nasal concha (Fig. 3, B&D/ 14) was formed of four spirally scrolled arranged lamella compressed and represented in the first half of the nasal cavity, related dorsally to the middle nasal concha. The alar fold of the cat (Fig. 3, B&D/15) appeared as a large comma shaped extension in the nasal vestibule which reinforced by the medial accessory nasal cartilage (Fig. 4, B/5), microscopically, the maxilloturbinates composed of highly branched primary and secondary processes supported with bony lamellae and covered by pseudo stratified columnar ciliated epithelium rich with goblet cells (Fig. 3, H). It had fibrous connective tissue of submucosal layer rich in blood vessels, secretory glands and supported by bony Fig.s by MTC stain (Fig. 8, H). By alcian blue pH 2.5 it had strong reactivity in lining epithelium as well as underlying propria glands (Fig. 8, J), the Maxilloturbinate revealed negative reactivity of most of the lining epithelium to PAS stain (Fig. 8, L)

The ethmoturbinate region in the rabbit (Fig. 3, A/22) contained dorsally from the middle nasal concha (Fig. 3, A&C/13) and ventrally the ethmoidal nasal conchae (Fig. 3, A&C/16). While in the cat, the caudal part of the nasal cavity was occupied by the ethmoidal conchae and only the caudal part of middle nasal conchae.

The middle nasal concha in the rabbit was large comma shaped consisted of two large lamina arranged in longitudinal pattern In the cross sections of nasal cavity, the middle nasal concha appeared on both sides of the median nasal septum as a closed rostral end (Fig. 6, A/2). While in the cat, the middle nasal concha (Fig. 3, B&D/ 13) was relatively large situated at the caudal two third of nasal cavity bounded dorsally by the dorsal nasal concha, ventrally the ethmoid and ventral nasal conchae. It formed two spiral lamellae; dorsal and ventral. The dorsal one extended rostrally in contact with the ventral border of the dorsal nasal concha. The ventral one extended rostrally to a midpoint of the nasal cavity where it diverged into dorsal and ventral limbs to include the ventral nasal concha (Fig. 3, B&D/ 14); the dorsal limb intermingled between the dorsal spiral lamella and the ventral concha while the ventral limb insinuated between the ventral concha rostrally and the ethmoidal concha caudally. Both lamellae originated from the perpendicular Fig. of ethmoid bone and considered as endoturbinates II and tapered rostrally to end at the commensalism between the nasal vestibule and the nasal cavity proper. In transverse section (Fig. 5, B/ 14), at the mid nasal cavity, it formed several scrolls.

The ethmoidal nasal concha in the rabbit (Fig. 3, A&C/16) was scroll like triangular in shaped ventral to the middle nasal concha and originated from the perpendicular Fig. of the ethmoid bone, the ethmoidal concha was related ventrally to the large maxillary sinus and medially to the median nasal septum in the cross section of the nasal cavity (Fig. 7, A/2). While in the cat, the ethmoidal nasal conchae (Fig. 3, B&D/ 16) were two in number located at the caudal third of the nasal cavity; the dorsal large one was dome shape and situated between the middle nasal concha and the smaller caudal one which was formed from two spiral lamella and rest on the vomer. They originated from the perpendicular Fig. of ethmoid bone and constituted the largest nasal concha in the nasal cavity and termed endoturbinates III and IV respectively. In transverse section, the caudal part of the nasal cavity, the dorsal one of ethmoidal nasal concha (Fig. 7, B/ 5) formed one scroll, while the ventral one formed an ethmoidal sinus (Fig. 7, B, 2) which opened with the sphenoid sinus (Fig. 3, B&D/ 7).

The dorsal nasal recess (Fig. 3, B&D/ 9) of the nasal cavity in the cat was the space situated between the nasal and frontal bones dorsally and separated from the dorsal nasal concha ventrally by a thin Fig. of bone and related caudodorsal to the frontal sinus where the communication together by ostium of frontal sinus and caudoventral to the perpendicular Fig. of ethmoid bone. It occupied by the ectoturbinates bones (Fig. 3, B&D/ 10) which formed from two longitudinal arranged scroll like lamellae.

In the rabbit, the vomeronasal organs (Fig. 5, A/2) were bilateral well developed elongated tubular diverticula situated on either side of the nasal septum and dorsal to the incisive and vomer bones, during the course of the vomeronasal organ it partially surrounded by the descending hook like shape vomeronasal cartilages of the paraseptal cartilage (Fig. 5, A/3) microcsopically, the vomeronasal organ has highly cellular connective tissue of proprial connective tissue with rich many blood vessels as observed by H&E and MTC stains (Fig.5, G&I) and lined with olfactory epithelium with many nerve bundles are noticed in lamina propria (Fig.5, K). In the cat, the vomeronasal organs (Fig. 6, B/ 10) were short tubes appeared at the middle of the nasal cavity on both sides of the vomer bone, related to the ventral end of the median nasal septum, while ventrally in contact to the dorsal aspect of the palatine bone. Histologically, it was showed highly fibrous connective tissue of submucosa housing many blood vessels by H&E and Masson trichrome stain (Fig.5, H&J) and covered with olfactory epithelium lining with N.L.D(Fig.5, L). The choanal opening, in the rabbit (Fig. 7, A/4) was circular in shape in the cross section and then the choana leaded to a single nasopharyngeal duct.

In the cat, choanae **(**Fig. 7, B/4) were the double openings formed by the osseous structures separating the nasal cavity from the nasal part of the pharynx. The

choanae were divided by the vomer bone **(**Fig. 7, B/8) into right and left openings. In the rabbit, the paranasal sinuses were dorsal conchal, maxillary, and ethmoidal sinuses with the absence of the frontal and the sphenoid sinuses. Microscopically, all the paranasal sinuses were lined with pseudo stratified columnar ciliated without goblet cells with the underlying propria was packed with serous glands and mucosal associated lymph nodules. (Fig.9, D&E). While in the cat, the paranasal sinuses were the dorsal conchal, maxillary, frontal, sphenoidal and ethmoidal sinuses. Histologically, the maxillary sinus lined with pseudo stratified columnar **(**Fig. 9, G). While the frontal and sphenoidal sinuses were lined by olfactory epithelium with underlying propria housing serous Bowman's gland and rich in blood and lymph vessels. (Fig. 9, F)

The dorsal conchal sinus in the rabbit (Fig. 5, A/5) was ovoid in shape in cross section and communicated with the dorsal compartment of the maxillary sinus (Fig. 9, A/12) at level in front of the first upper premolar maxillary cheek tooth (Fig. 6, A/5) forming the conchomaxillary sinus (Fig. 6, A/6). While in the cat, the dorsal nasal concha formed one coil of spiral lamella with narrow dorsal conchal sinus.

The maxillary sinus (Fig. 9, A/12, 13) was the largest paranasal sinus in the rabbit it was present in the maxillary region and extended caudally towards the rostral orbital edge. It comprised of two compartments; dorsal and ventral which separated by the nasolacrimal duct (Fig. 9, A/14). The dorsal compartment of the maxillary sinus (Fig. 9, A/12) was nearly triangular. It was located lateral to the middle nasal meatus and ventral to the dorsal conchal sinus and it was oval in cross section (Fig. 5, A/6), it communicated with the dorsal conchal sinus to form the conchomaxillary sinus at a level in front of the first upper premolar tooth (Fig. 6, A/6). In cross section (Fig. 5, A), at the level of the middle of hard palate the dorsal conchal sinus appeared dorsally then the dorsal recess of the maxillary and ventrally the nasolacrimal duct appeared without the presence of the ventral compartment of the maxillary sinus at this level. The ventral compartment of the maxillary sinus (Fig. 9, A/13) was spindle elongated in shape where its base caudally situated at second molar maxillary cheek tooth it tapered rostrally from the perpendicular Fig. of ethmoid bone, the vomer and the hard palate till reaching its middle part in contact relationship with the nasolacrimal duct (Fig. 9, A/14), where the latter lies in between the dorsal and ventral compartment of the maxillary sinus. In cross section at a level in front of the first molar maxillary cheek teeth (Fig. 7, A), the ventral compartment of the maxillary sinus (Fig. 7, A/3) appeared only at this level with the ethmoidal sinus **(**Fig. 7, A/2**).** While in the cat, the maxillary sinus **(**Fig. 9, B/5**)** was relatively medium sized recess irregularly circular in outline which located between the orbital lamina of the ethmoid bone medially and the maxillary bone laterally and rostral to the orbit and caudal to the infraorbital foramen as well as above the roots of the molar cheek teeth. This sinus communicated to the nasal cavity by the nasomaxillary opening through the middle nasal meatus.

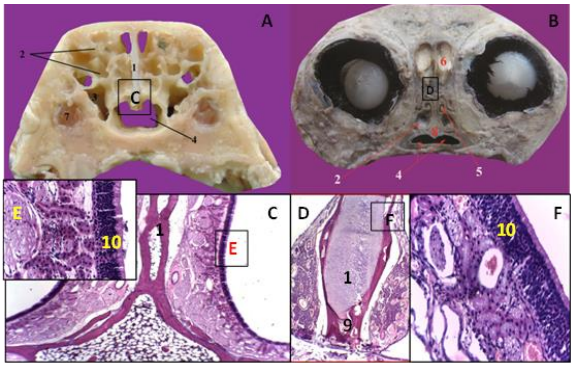

Fig. 7: a photographs showing (**A)**; Cross section in nasal cavity rabbit taken immediately anterior to the first upper molar teeth**, (B)**; Cross section in nasal cavity cat taken at last palatine ridge, **(C, D)** the nasal septum of rabbit and cat respectively stained by H&E (40X). **(E.F)** higher magnification of C&D respectively stained by H&E **(400X**).
1. Nasal septum. 2. Ethmoidal nasal sinus, 3. Maxillary sinus, 4. Choanae, 5.ventral part of ethmoid, 6. Brain, 7. infraorbital canal, 8. Vomer process of vomer bone, 9. Osseous tissue, 10. Olfactory epithelium.

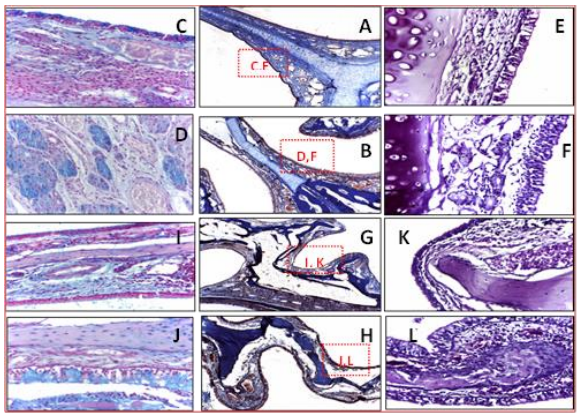

Fig. 8: a photographs showing the nasal septum of rabbit and cat respectively; **(A, B)**; stained by MTC. **(C, D) (40X)**; stained by alcian blue PH 2.5**(400X)**. **(E, F)**; stained by PAS**(400X)**. The maxilloturbinates of rabbit and cat respectively; **(G, H)** stained by MTC **(40X). (I, J)** stained by alcian blue PH 2.5. **(400X) (K, L)** stained by PAS **(400X)**

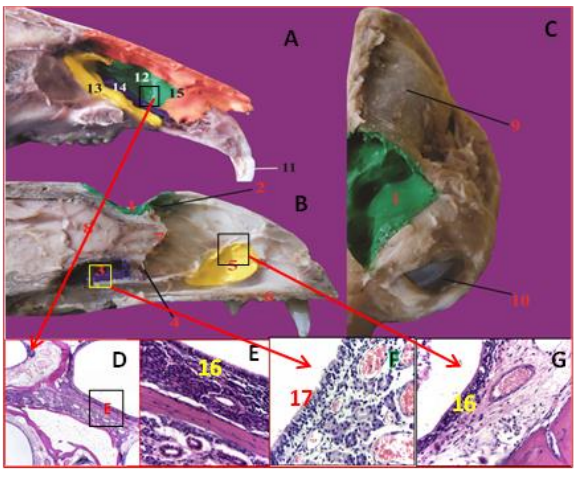

Fig. 9: Photographs showing **(A)** the Para nasal sinus of rabbit, medial view**. (B, C)** the Para nasal sinus of the nasal cavity of cat, medial and dorsal views respectively**. (D (40X), F (400X)** Para nasal sinus of rabbit stained by H&E. **(F, G)** Para nasal sinus of cat stained by H&E **(400X).**

1. Frontal sinus, 2. Aperture of frontal sinus, 3. Sphenoidal sinus, 4. Ostium of Sphenoidal sinus, 5. Maxillary recess, 6. Hard palate, 7. Ethmoid bone, 8. Brain, 9. Partial bone, 10. Eye, 11. Upper incisor teeth, 12. Dorsal recess of the maxillary sinus, 13. Ventral recess of the maxillary sinus, 14. Nasolacrimal duct, 15. Conchomaxillary sinus, 16. Pesudo stratified columnar epithelium, 17. Olfactory epithelium

The ethmoidal sinuses in the rabbit **(**Fig. 7, A/2) formed from open recesses and spaces insinuate the scroll like triangular shape of the ethmoidal conchae where they communicated with the common nasal meatus. While in the cat, the ethmoid sinus (Fig. 7, B/2) were present within the endoturbinates of the ethmoidal conchae located on the floor of the nasal cavity and related to the sphenoid sinus where it communicated with it through the sphenoidal ostium.

The frontal sinus in the cat (Fig. 9, B&C/1) was a true undivided large sinus triangular in its outline, lying between the superficial and the deep bony layers of the frontal bone rostrodorsal to the cranial cavity. It was connected with the dorsal recess of the nasal cavity rostrally through the aperture of frontal sinus.

The sphenoid sinus of the cat (Fig. 9, B/3**)** was a small sized sinus, located ventral to the olfactory bulb of the brain as an excavation in the presphenoid bone. It communicated rostrally with the nasal cavity through the ostium of sphenoid sinus. It appeared rectangular in sagittal section (Fig. 3, B&D/7).

DISCUSSION

The rhinarium was the rostral part of the nose in a line with the statement of (Aspinall and Cappello, 2015) in the cat and (Haidarliu *et al*., 2012) in the rat.

The nostrils of rabbit in the present study were two slit like openings, obliquely situated and the cat nostrils were semicircular shape. On the other hand, (Haidarliu *et al.,* 2012) reported that the rat nostrils were semicircular in shape, (Miller, 2004) in the dog recorded that the nostrils were circular in shape and (Frandson *et al.,* 2006) in the pig noted that, the nose was flat and disk like. The results under discussion achieved the septum nasi on the rabbit was formed of three layers; two membranous intermingled with cartilaginous one. In contrast to the finding of (Hadad, 2015, Daoyu *et al.,* 2014 and Marcia *et al.,* 2011) in the rabbit stated that the nasal septum was only one cartilaginous layer.

Our assumption was based on the nasal septum in rabbit was supported medially by a Fig. of hyaline cartilage and lined with stratified squamous epithelium that was formed of 4-5 cells thick this statement was agreed with (Hadad, 2015 and Pereira *et al.,* 2011) in the rabbit. In agreement with (Ozkadif and Eken, 2012) in the rabbit, right and left lateral nasal septum were observed after the removal of the nasal and maxillary bones. Also, the two lateral septa formed tubes with the median nasal septum, enclosing the nasal cavity inside them. The lateral and medial accessory cartilages and the alar cartilage were absent in the rabbit, these findings were observed by (Daoyu *et al*., 2014 and Marcia *et al.,* 2011) in the same animal.

In the currently examined cats, the nasal septum was cartilaginous at its rostral part, membranous at the middle part and finally osseous at the caudal portion, these results were nearly similar to that asserted by (Dyce *et al*., 2010) in the dog and cat. On the other hand, (Colville and Bassert, 2009, Miller, 2004 and Smith, 1999) in the dog stated that the median nasal septum was composed of cartilaginous and osseous parts only.

In the studied cat, tissue samples the alar fold supported with hyaline cartilage Fig. surrounded with connective tissue layer housing many small blood vessels as well as mucosal associated lymph nodules and covered by keratinized stratified squamous epithelium, our available literatures denied this information.

In regard to the description of (Xi *et al.,* 2016) in the rabbit, the nasal cavity comprised four regions; the nasal vestibule, maxilloturbinates, nasoturbinates and ethmoturbinates.

In our finding reported that, the maxilloturbinates region of the rabbit contained the ventral nasal conchae which took its origin from the maxilla so it called the maxilloturbinates, these results similar to that showed by (Xi *et al.,* 2016, Hadad, 2015 and Daoyu *et al.,* 2014) in the rabbit, the former author stated that the maxilloturbinate region was divided into three zones; dorsal respiratory zone, ventral respiratory zone I and ventral respiratory zone II as described in our current study.

We have found that the maxilloturbinates was lined by transitional epithelium, which was unlike the findings of (Yang *et al.,* 2017) in bama minipigs that reported by the ventral nasal concha was covered by pseudo-stratified columnar ciliated epithelia. Our results discussed that the epithelium of maxillaoturbinate of rabbit was lacked to goblet cells, which was in a line with (Pereira *et al.,* 2011) in the rabbit. In the examined cat, the maxilloturbinates were covered by pseudo stratified columnar epithelium rich with goblet cells. On the other hand (Craven *et al.,* 2007) in the dog cited that the anterior maxilloturbinate region was lined by the transitional epithelium.

The maxilloturbinate of rabbit has weak expression of acidic mucins in the apical border of lining epithelial cells and has strong level of neutral mucins while in the cat, The maxilloturbinate has acidic mucins in lining epithelium as well as underlying propria glands and has minimal expression of neutral mucins, (Venema *et al.,* 2013) in the cat the mucosubstances were acidic or neutral when identified by AB/PAS staining within the epithelium of the floor of nasal cavity. (Pereira *et al.,* 2011) in the rabbit the lamina propria of the epithelium of the turbinate was has two types of glands, a periodic acidSchiff–positive and a periodic acid-Schiff–negative. (Salazar *et al.,* 1996) in the cat the vomeronasal organ has epithelium showed higher neutral mucins and minimal acidic mucins expression.

In viewing of the current work, the dorsal nasal recess of the nasal cavity of cat was a space which situated between the nasal and frontal bones dorsally, while ventrally was separated from the dorsal nasal concha by a thin Fig. of bone and related caudallodorsally to the frontal sinus where the communication together by ostium of frontal sinus and caudoventrally to the perpendicular Fig. of ethmoid bone. It occupied by the ectoturbinates which were formed from two longitudinal arranged scroll like lamellae, these statements were nearly pointed out by (Sis, 1965).

The vomeronasal organ in the rabbit was a bilateral well developed elongated tubular diverticulum situated on either side of the nasal septum and dorsal to the incisive and vomer bones. These findings were asserted by (Elgayar *et al.,* 2013), as well as (Pereira *et al.,* 2011) which revealed that, the rabbit vomeronasal organ was surrounded by the vomeronasal cartilage.

The vomeronasal organ of cat was a short tube appeared at the middle of the nasal cavity on both sides of the vomer bone, related to the ventral end of the median nasal septum, while ventrally in contact to the dorsal aspect of the palatine bone, the latter statements were observed by (Kostov, 2007).

The present study noted that, the choana in the rabbit was a single opening, circular in shape leading to a nasopharyngeal duct which connecting the nasal cavity with the pharyngeal cavity. These findings were in accordance to the observation of (Hadad, 2015). On the other hand, (Badran *et al.,* 2017) in the rabbit described that the choana was divided into two passages by the nasal septum then continued as the nasopharynx.

The choanae of cat were divided by the vomer bone into right and left openings and formed by the osseous structures separating the nasal cavity from the nasal part of the pharynx. However, (Adams, 2004) in the dog cited that, the choana was a single opening.

Our study in the rabbit revealed that, the paranasal sinuses were dorsal conchal, maxillary, and ethmoidal sinuses, while (Varga, 2014, Casteleyn *et al.,* 2010, Saunders and Davies, 2005 and Brown, 2002) in the rabbit described only the presence of maxillary and dorsal conchal. On the other hand, (Ozkadif and Eken, 2013, Pereira *et al.,* 2011 and Kara, 2004) in the rabbit reported only one pair of maxillary paranasal sinuses.

The ethmoidal sinuses in the rabbit in the present study were confirmed in accordance with the statement of (Hadad, 2015 and Ozcan *et al.,* 2011).

The absence of frontal and sphenoidal sinuses in the rabbit in this study was in a line with that cited by (Varga, 2014, Ozkadif and Eken, 2013, Ozkadif and Eken, 2012, Saunders and Davies, 2005 and Brown, 2002) while (Casteleyn *et al.,* 2010) in the same animal reported the presence of the sphenoidal sinus.

In the examined cat assessed, the frontal sinus was a true undivided large sinus triangular in its outline, in accordance with (Done *et al.,* 2009 and Adams, 2004) in the cat. While (Miller, 2004) in the dog stated that, the frontal sinus divided into three compartments; rostral, lateral and medial,

In viewing of the present findings designated that, the sphenoid sinus in the cat was a small sized sinus, located ventral to the olfactory bulb of the brain as an excavation in the presphenoid bone, this results were confirmed by (Dyce *et al.,* 2010), while (Done *et al.,* 2009) in the cat described the sphenoid sinus as larger in size than that of the dog.

The results applied in this investigation on the rabbit recorded that the paranasal sinuses were lined with pseudo stratified columnar ciliated without goblet cells. The observed data where matched with that noted by (Pereira *et al.,* 2011) in rabbit. On other hands, (Hadad, 2015) in the rabbit revealed that, the maxillary sinus was lined with ciliated pseudo stratified columnar epithelium with goblet cell.

Conclusions

There were multiple differences between nasal cavity of rabbit and cat. The nostrils of rabbit were slit like opening while the cat nostrils were semicircular. The nasal septum of rabbit was three layers while in the cat was only single layer. In the rabbit, the nasal cavity regions were the nasal vestibule, maxilloturbinates, nasomaxillary and ethmoturbinates. The nasal conchae were; dorsal, ventral, middle and ethmoidal nasal concha in addition to the atrioturbinate. In the cat, the nasal cavity was divided into three regions; nasal vestibule, nasal cavity proper and the nasal fundus. It had four conchae; dorsal, ventral, middle and ethmoidal. The maxilloturbinate of rabbit revealed a weak expression of acidic mucins and strong to neutral mucins while in the cat, it has acidic mucins and minimal expression of neutral mucins.

The paranasal sinuses of rabbit were the dorsal conchal, maxillary and ethmoidal sinuses with absence of frontal and sphenoidal. On the other hand in the cat there were frontal, sphenoidal and maxillary sinuses.

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