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ANATOMICAL FEATURES OF NASAL CAVITY AND PARANASAL SINUSES IN THE BACTRIAN CAMEL (*Camelus bactrianus*)

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ABSTRACT

The structures of the nasal cavity and paranasal sinuses of the bactrian camel were comparatively investigated using computed tomography (CT) and gross anatomy. The results showed that the bactrian camel owes large and complex concha, narrow nasal meatus and large sinuses in volume. These properties may relate to its living conditions of frequent sand-storms and aridity. This will offer the anatomical knowledge to the research of the adaptive physiological mechanism to its environment. The results and methods present useful references to the construction of nasal airflow model in the bactrian camel.

Key words: Bactrian camel, computed tomography (CT), nasal cavity, paranasal sinuses

The bactrian camel (*Camelus bactrianus*) is one of the most important domestic animals in the deserts and steppes of Central Asia. Many specialised organs and structures, such as the eyes, nose, humps, and metacarpus, as well as many special physiological mechanisms allow the bactrian camels to survive in the typically atrocious conditions of their environment. Nasal cavity is the portal of respiratory meatus and directly contact with the environment. So, the nasal part is closely related to the adaptability of animal to its environment, and it is most different in all morphologies of animals.

The 64-sliced spiral computed tomography (CT) scanner can be used to investigate the complex structure and 2 dimensional images of some organs, which have thin layer, higher spatial and density resolution and no overlap of anatomical structures (Hu, 2005; Wang, 2007). The anatomy of nasal cavities in horse, swine and dog etc, especially in moose and high nose antelope, has been studied (Arencibia *et al,* 2000; Morrow *et al,* 2000; Witmer *et al,* 2001; Márquez, 2002; Clifford and Witmer, 2004a, b) but report is not available on nasal cavity and sinuses in the bactrian camel. The nasal cavity and sinuses of the normal bactrian camel were investigated using 64-slices spiral CT and gross anatomy in present study.

Materials and Methods

The heads of 2 healthy, undetermined sex and adult bactrian camels were collected from the local slaughterhouse in Inner Mongolia, China, after the animals were killed by exsanguination. The specimens were fixed, within 24h, by infusing them with 10% formalin through the common carotid artery. The nasal cavity and paranasal sinuses of each specimen were dissected macroscopically to observe the gross morphology and scanned with 64-slices spiral CT to obtain the images. The head was positioned in frontal plane with the ventral surface of the maxilla to be parallel with CT platform. The image plane was perpendicular to the sagittal plane of the head. The tube voltage was 120 kV at 140 mA, and a 512×512 image matrix. Continuous images of 0.8mm thickness of the nasal cavity and sinuses were obtained. The nasal cavity and sinuses were studied for gross anatomy. The CT scanning and gross anatomy images were compared to show the nasal cavity and paranasal sinuses structures in the bactrian camel.

Results

The CT images were presented with right to the viewer's left in the coronal plane. The nose was scanned in 0.8mm slice thickness from rostral to caudal to show the structures of nasal cavity and sinuses of the bactrian camel. The nasal part was

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scanned using 64-slices spiral CT and images a- h (Fig 1) were selected to show the morphology of nasal cavity and paranasal sinuses. The images were reconstructed using Mimics 10.01 to show the facial structure of nasal part (Fig 1).

The nasal cavity of the bactrian camel is long. The length from cribriform plate to the anterior margin of nasal septum is 60% of the length of the head. The volume of the nasal cavity is about 1,000 cm^3. The CT images of bactrian camel nasal part showed that the dorsal nasal concha, middle nasal concha, ventral nasal concha, the dorsal, middle and ventral nasal meatus, ethmoid bone and paranasal sinuses were accurately described.

Nasal vestibule (*Vestibulum nasi*)

The nasal vestibule caudally extended from nostril (*Naris*) to crescentric rostral border of basal infolding of threshold of nose (*Limen nasi*). Similarly as dromedary, the nostrils are slit like and placed at an angle which slopes dorsoventrally from the lateral to the medial commissure. They face laterally (Smuts and Bezuidenhout, 1987). The rostral part of the nasal vestibule is lined with skin and fine hairs. The wing of nose (*Ala nasi*) flatly covers on nostril. The hair present rigid and long in lateral wing of nose, and present soft and short in medial wing of nose. These properties may be related to its living conditions, which can prevent the sand storm and clean the air. The base of the wing of nose distributes alar cartilage (*Cartilagines alares*) and nasal muscle (*Musculus nasalis*), which accretes the nostril on the dorsal part of rostral maxillary bone (Fig 2a). The dorsolateral nasal cartilage attaches muscle and forms the lateral stand of nasal vestibule. The caudal and ventral border of dorsolateral nasal cartilage connects with nasal bone and maxillary bone.

Proper nasal cavity (*Cavum nasi propium*)

The proper nasal cavity extends from threshold of nose to nasopharynx canal. The middle portion of the nasal cavity contains the nasal concha while the ethmoidal concha is situated caudally. Caudo-ventrally, the posterior naris (*Choana*) communicates with the nasopharynx. The mucosa of proper nasal cavity consisted of respiratory mucosa and olfactory mucosa, which presents pink and straw yellow colours, respectively in fresh tissue.

Mucosal fold (*Plica mucosa*)

Mucosal fold consists of basal infolding (*Plica basalis*), alar folds (*Plica alaris*) and *Plica recta* (Figs 2a-d). The basal infolding is located in the ventral nasal cavity. The alar folds are formed by rostrally extending ventral nasal concha (*Concha nasalis ventralis*). It extends from basal infolding caudally to form the part of ventral nasal concha. The *Plica recta* formed rostrally extending dorsal nasal concha (*Concha nasalis dorsalis*).

Dorsal nasal concha (*Concha nasalis dorsalis*)

The dorsal nasal concha (Fig 2b-d) is continued rostrally by the straight fold (*Plica*). On the medial surface of the latter, an opening is present which leads into a narrow channel within the vascular rostral fourth of the dorsal concha. The caudal half of the dorsal concha contains sinuses, *S. concha dorsalis*, which communicates with the middle meatus. The sinuses have a long pointed ventrolateral extension which reaches the nasomaxillary opening and partly occludes it. The mucosa of dorsal nasal concha is a thick olfactory membrane.

Middle nasal concha (*Concha nasalis media*)

The middle nasal concha (Figs 2c,d; Fig 3) lies caudally to the bulbous rostral part of the ventral concha and contains sinus (*S. concha mediae*). The latter is almost as long as the dorsal concha sinus. It has a large ventral extension which lies laterally to the caudal part of the ventral concha, but can not exchange the airflow with common nasal meatus. It communicates with the *Fundus nasi* through a fairly large opening caudally in its roof.

Ventral nasal concha (*Concha nasalis ventralis*)

The ventral nasal concha (Figs 2c-e; Fig 3) consists of a large rostral part which almost entirely occupies the rostral half of the osseous nasal cavity and a smaller caudal part which is situated at a more ventral level, partly occupying the caudal nasal passage. It does not contain a sinus. The nasal lamina divides to form 2 spirals, both of which enclose a recess and bulla. Rostrally, the ventral concha is continuous with the rostrodorsally directed alar fold (*Plica alaris*), and the rostroventrally directed basal fold (*Plica basalis*).

Nasal meatuses

The dorsal and middle meatuses are narrow. The former is an olfactory passage. The latter divides at the junction of the middle and caudal 3rd of the nasal cavity into dorsal and ventral passages due to the position of the middle nasal concha. The ventral meatus is relatively spacious and leads directly to the *Choanae*. The nasolacrimal duct is situated in the lateral aspect of the ventral meatus, covered by mucous membrane (Fig 2c,d; Fig 3).

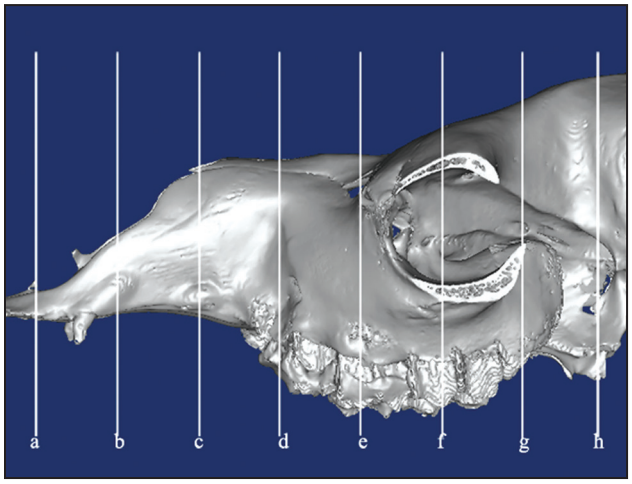

Fig 1. 3-D reconstruction of osteological structures of nasal cavities in bactrian camel. The lines a- h are corresponding with CT images a- h in Fig 2.

Vomeronasal organ (*Organum vomeronasale*)

The vomeronasal organ is 160-190mm long and opens into the rostral part of the ventral meatus. The incisive canal (*Incisor canaliculus*) ends blindly and does not communicate with the oral cavity. The widest part of vomeronasal organ is 23-26mm, which consists of many ostioles (Figs 2b, c; Fig 4).

Nasal septum (*Septum nasi*)

The most part of nasal septum is cartilage, the dorsal border of which is T- like connecting with nasal bone and frontal bone; the ventral border connects with the channel formed by vomer. The length of nasal septum in bactrian camel is about 220-240mm, and the height is about 70- 80 mm (Figs 2b-e).

Paranasal sinuses (*Sinus paranasales*)

In the bactrian camel, the paranasal sinuses which are similar to that of the dromedary are present: maxillary sinus (*Sinus maxillaris*), frontal sinus (*Sinus frontalis*), sphenoidal sinus (*Sinus sphenoidalis*), lacrimal sinus (*Sinus lacrimalis*) and ethmoid sinus (*Sellulae ethmoidales*) in the ethmoid bone (Figs 2e-h). The maxillary sinus excavates a small part of the maxilla as well as the rostral part of the zygomatic bone. It communicates freely dorsally with the lacrimal sinus. The 2 cavities are partly separated by the osseous lacrimal duct. They communicate with the dorsal limb of the caudal extension of the middle meatus. The nasomaxillary opening is partly occluded by the pointed lateral extension of the dorsal conchal sinus. It is situated approximately half way between the medial canthus of the eye and the dorsal midline. The maxillary sinus

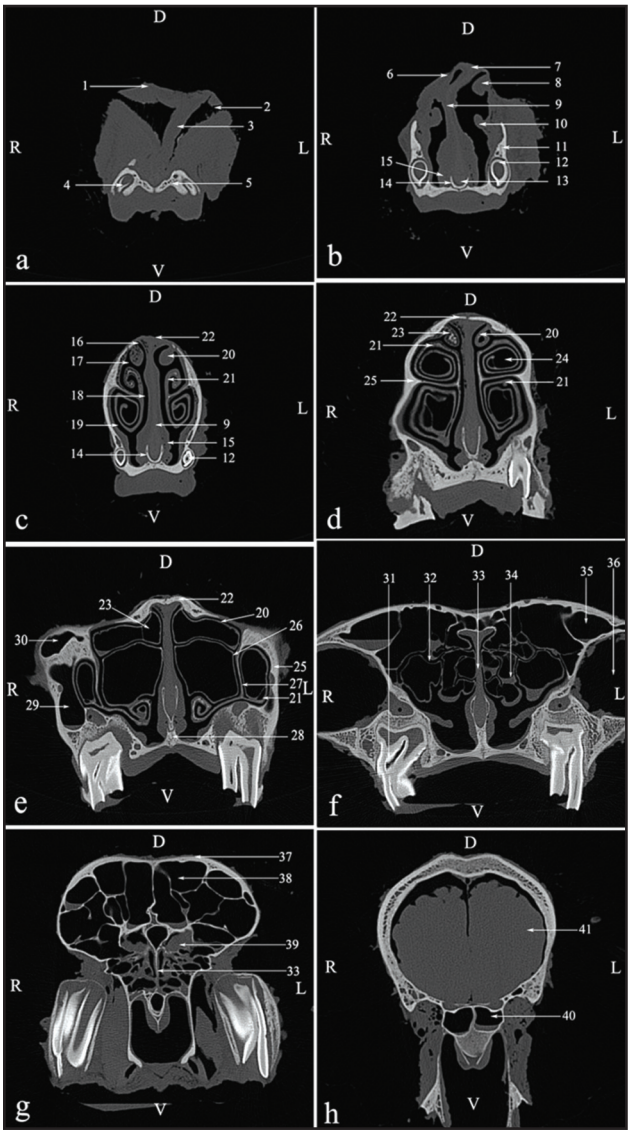

Fig 2. a- h present transverse images of nasal cavities and sinuses in different positions. R, L, T and B present 4 directions right, left, top and bottom in bactrian camel. 1. Ala nasi; 2. Naris; 3. Septum nasi; 4. Dentes incisive; 5. Os incisivum; 6. Cartilagines nasi; 7. Septum nasi processus dorsalis; 8. Plica recta; 9. Cartilago septi nasi; 10. Plica alaris; 11. Os premaxillare. processus nasalis; 12. Dentes canini; 13. Septum nasi processus ventralis; 14. Vomer; 15. Organum vomeronasale; 16. Meatus nasi dorsalis; 17. Meatus nasi medius; 18. Meatus nasi communis; 19. Meatus nasi ventralis; 20. Concha nasalis dorsalis; 21. Concha nasalis ventralis; 22. Os nasale; 23. Sinus conchae dorsalis; 24. Recessus conchae nasalis ventralis; 25. Os maxillare; 26. Concha nasalis media; 27. Basal lamina conchae nasalis ventralis; 28. Processus frontalis maxillae; 29. Sinus maxillaris rostralis; 30. Sinus maxillaris caudalis; 31. Dentes molares; 32. Labyrinthus ethmoidalis; 33. Lamina perpendicularis ossis ethmoidalis; 34. Conchae ethmoidales; 35. Sinus lacrimalis; 36. Bulbus oculi; 37. Os frontalis; 38. Sinus frontalis; 39. Bulbus olfactorius; 40. Sinus sphenoidalis; 41. Lobus frontalis cerebralis.

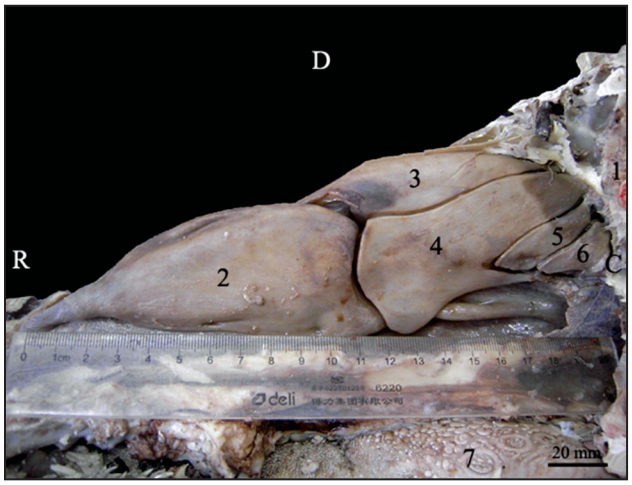

Fig 3. The medial surface of right nasal concha in bactrian camel. D, R and C present directions dorsal, rostral and caudal. 1. Bulbus olfactorius; 2. Concha nasalis ventralis; 3. Concha nasalis dorsalis; 4. Concha nasalis media; 5 &6. Endoturbinalia; 7. Vallate papillae.

contains a well developed lateral nasal gland which produces a mucous secretion.

The frontal sinus in the bactrian camel is not as extensive as that in the other domestic ruminants. Left and right sinuses are separated by an irregular bony plate and each sinus is subdivided into a labyrinth of smaller spaces which may intercommunicate. The larger compartments communicate with the fundus nasi through relatively small openings.

The sphenoidal sinus occurs in the presphenoid bone. It may communicate with a sinus in the *Crista galli* of the ethmoid or open directly into the *fundus nasi*.

One of two cavities is present in the substance of the *Crista galli* of the ethmoid bone. They open independently into the *Fundus nasi* or communicate with the frontal or sphenoidal sinuses.

Discussion

64-slices spiral computed tomography is an excellent imaging modality to visualise the structures of nasal cavity and paranasal sinuses in bactrian camel. In CT images, all of the structures of nasal cavity and sinuses and tissues were clearly identified (Fig 2). In some respects, the spiral CT can provide a reliable evidence for basic researches and clinical diagnoses of nasal cavity and sinuses to replace gross anatomy.

The nasal cavity in bactrian camel is special among mammals, which is similar to that of dromedary, but owed difference to other domestic animals. Similarly to dromedary, the nostrils are slit- like and placed at an angle which slopes dorsoventrally from the lateral to the medial

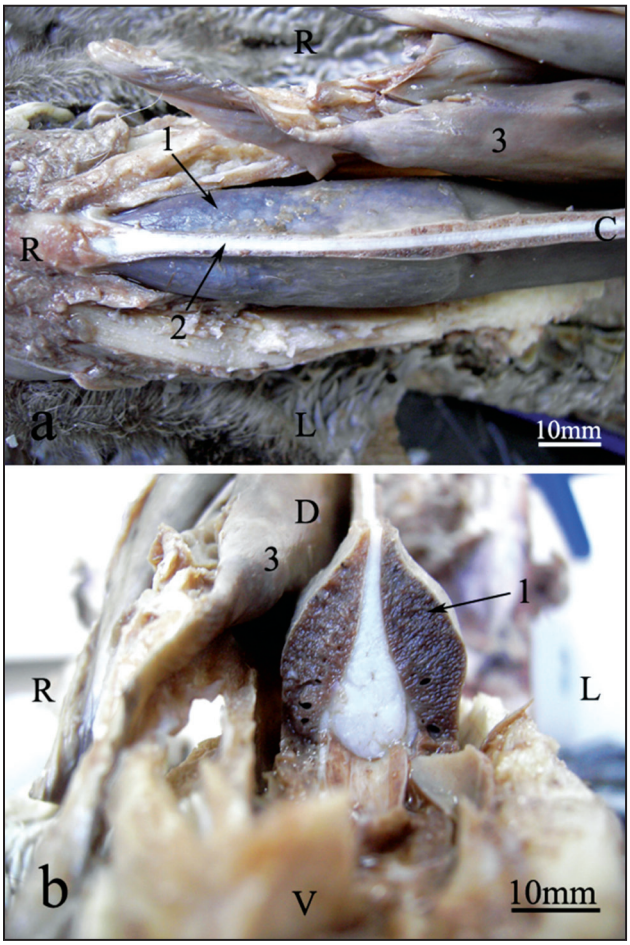

Fig 4. The structure of vomeronasal organ in bactrian camel. a presents the morphology, in which R, L, R and C present the directions right, left, rostral and caudal. b presents the transverse slice, in which D, V, R and L present dorsal, ventral, right and left. 1. Organum vomeronasale; 2. Septum nasi; 3. Concha nasalis ventralis.

commissure (Smuts and Bezuidenhout, 1987). They faced laterally. The rostral part of the nasal vestibule is lined with skin and fine hairs. The wing of nose (*Ala nasi*) flatly covers on nostril. The hairs present are rigid and long in lateral wing of nose, and soft and short in medial wing of nose. These properties may be related to its living conditions, which can prevent the sand storms and clean the air. Different to horse and cattle in which the nostrils are oval and opens anteriorly (Klimov, 1955), the nostrils of bactrian camel faced laterally. It may relate to olfactory and effectively collect different odour from the environment, which is similar to the nostrils of moose (Clifford and Witmer, 2004a, b).

The nasal concha in bactrian camel owes special property. The air flow in nasal meatus is different with individual variation. The changes of resistance and pressure of air flow in nasal cavity are faster and exchange area of air to mucosa is more increased than

that of other domestic animals due to complex nasal concha. The middle and ventral concha of bactrian camel has T- like ramus and curled to dorsal and ventral. Different animal owes different structure and curliness of middle and ventral nasal concha. The ventral concha of horse is curled ventrally, but no ramus exists (Reznik, 1990; Morrow *et al,* 2000), which is similar to that of tapirs- another *Perissodactyla* (Witmer *et al,* 2001). The nasal concha owns ramus in *Canidae* (Wang *et al,* 1993). The dorsal and middle meatus are narrower and the ventral meatus is wider than that of horse. The *Saiga* also owns the wide ventral meatus, which may be related to the adaptability to desert and arid environment (Clifford and Witmer, 2004b).

The results showed that the nostrils, nasal concha and nasal sinuses possess special properties. These may relate to the adaptability of olfactory and respiratory physiological mechanism to its arid and desert living conditions (Wang *et al,* 1993).

Acknowledgements

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DR.T.K. GAHLOT VISITS EGYPT AND FRANCE, INVITED AS CAMEL EXPERT BY OIE

Dr. T.K. Gahlot, Head, Department of Veterinary Surgery and Radiology, College of Veterinary and Animal Science, Bikaner, Rajasthan was invited by African Association of Veterinary Anatomists in their 2nd congress at Cairo (Egypt) from 20-21 March 2010. Dr.Gahlot was given a memento and a certificate of honour in the inaugural session for his significant contributions in Camel Science and literature. Dr.Gahlot also lectured on equine and camel surgery at Faculty of Veterinary Medicine, Minufia University, Sadat City, Egypt.

Dr. T.K. Gahlot was invited by OIE (Office International des Epizootics) at headquarters of OIE, Paris (France) as camel expert to participate in the meeting of ad hoc group on Diseases of Camelids which held from 3-5 May 2010. Dr.Gahlot presented scenario of camel diseases in South Asia. Dr.Gahlot presented a copy of Journal of Camel Practice and Research and Selected Research on Camelid Parasitology edited by him to the library of OIE. The meeting was attended by six experts on diseases of camelids from different countries.

Participants of Meeting of Ad hoc group on Diseases of Camelids at OIE Head Quarters, Paris, 3-5 May 2010
(Dr Medhi El Harrak (Chairperson), Dr Bernard Faye, Dr Ulrich Wernery, Prof. Mohammed Bengoumi, Dr Abdelmalik Khalafalla Dr. Daniel de Lamo, Dr Tarun Kumar Gahlot, Dr François Diaz)

NATIONAL CONSULTATION "SAVING THE CAMEL AND RAJASTHAN'S BIODIVERSITY"

This meeting in which about 300 local camel breeders as well as about 20 national and international scientists participated took place on 24th February at Khaba near Jaisalmer. It featured the newly developed products as well as working groups on how to improve camel economics and overcome some of the difficulties associated with marketing camel milk.

A special effort was made to include and actively involve the women from camel breeding families in the programme through competitions in camel drawing, camel embroidery and camel mud sculpture.

The Camel Saviour Award 2010 was given to Dr. T.K. Gahlot by Ilse Köhler-Rollefson

The Camel Saviour Award 2010 was given to Dr. T.K. Gahlot, Editor, Journal of Camel Practice and Research and Head, Department of Veterinary Surgery and Radiology at College of Veterinary and Animal Sciences, Bikaner, India for his tireless services to camel breeders and dedication to camel research. The award – appropriately inked on camel dung paper - was handed over by a famous dancing camel

The day finished with an amateur camel race for camel breeders from the area.

Source: By Ilse Köhler-Rollefson