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Department of Zoology, National Science Museum, Tokyo

The Guttural Pouch is not Present in the White Rhinoceros (*Ceratotherium simum*); Morphology of the Eustachian Tube and Nasopharynx

H. ENDO[1], MANGLAI[2], M. FUJISAWA[2], M. KUROHMARU[2] and Y. HAYASHI[2]

Address of authors: [1]Department of Zoology, National Science Museum, Shinjuku-ku, Tokyo 169, [2]Department of Veterinary Anatomy, Faculty of Agriculture, The University of Tokyo, Bunkyo-ku, Tokyo 113, Japan

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Summary

The nasopharynx and eustachian tube (auditory tube) were morphologically examined in the white rhinoceros. The narrow nasopharynx cavity was enlarged dorsoventrally. The most lateral part of both sides sharply rises in a dorsal direction and the volume is estimated at 173 cc. The eustachian tube is 145 mm in length from the auditory bulla to the nasopharynx. The hyaline cartilage is well-developed in the middle region of the eustachian tube wall. The results demonstrated that the white rhinoceros does not have a guttural pouch. We suggest that the occurrence of the guttural pouch may not be dependent on the phylogenetic status of perissodactyls such as horse, donkey and tapir.

Introduction

The eustachian tube (auditory tube) connects the pharynx with middle ear to regulate the air pressure within the middle ear region. It has been established that the domesticated horse possesses the guttural pouch; a pair of symmetrical enlarged diverticula of the eustachian tube in the dorsocaudal part of nasopharynx (Bourdelle and Bressou, 1949; Ellenberger and Baum, 1974; Sisson, 1975; Popesko, 1977; Dyce et al., 1987). Some articles mentioned that the guttural pouch is equipped not only in the horse but also in the other perissodactyls (Bourdelle and Bressou, 1949; Fischer 1986; Lindsay and Clayton, 1986; Dyce et al., 1987). However, no reports have dealt with the morphology of the eustachian tube and the nasopharynx in the rhinoceros. Therefore, it remains unclear whether the occurrence of guttural pouch is due to the phylogenetic status of perissodactyls.

Materials and Methods

We were donated a carcass of a male white rhinoceros (*Ceratotherium simum*) which died of hepatorrhexis on 4th January, 1997 at Ueno Zoological Park (Tokyo, Japan). The animal was estimated approximately 2300 kg in body weight and 31 years of age. Fixation of the carcass in formalin was avoided, so that the skeleton specimen could be well prepared. The head part was separated from the body. Trachea and esophagus were removed, then we approached the nasopharynx from the larynx portion.

The carcass head was observed from caudal area at the macroscopic level. In the rostral region of larynx, the dorsal wall of the esophagus was partly removed. After the pharynx shape was observed and the choana was filled, silicone rubber (Product No. TSE-350: specific gravity = 1.18 g/cc, Toshiba Silicone Inc., Tokyo Japan) was injected from the larynx portion. The silicone hardened within the nasopharynx cavity, and it was taken out through the caudal hole. The silicone replica was observed and the nasopharynx volume was estimated from the replica weight and silicone specific gravity. The nasopharynx wall of right side was cut out from the carcass head, fixed in 10 % formalin and observed by the naked eye.

The tissues were sampled in the part of cartilage of the left eustachian tube and immersed in Bouin's fixative for 12 h at room temperature, then dehydrated in ethanol, and cleared in xylene. The specimens were embedded in paraffin and cut into serial sections of 4 μm. The sections were stained with hematoxylin-eosin and examined by light microscopy. In the skull specimen (Specimen No: M31319, stored in the Department of Zoology, National Science Museum, Tokyo, Japan), the auditory bulla and external ear region were observed.

Results

The nasopharynx cavity was laterally compressed at the caudal area of the choana (Fig. 1). The choana was a vertical small,

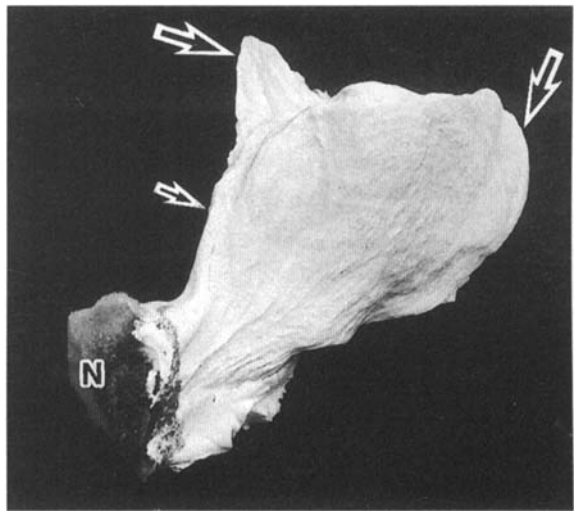

Fig. 1. Silicone rubber replica of the nasopharynx cavity. Rostrolateral view of left side. The cavity curves in the dorsal direction with sharp and long edge in a sagittal plane (small arrow). In caudal area the nasopharynx cavity is symmetrically enlarged in both sides (large arrows). A choana from nasal cavity has been plugged up (N).

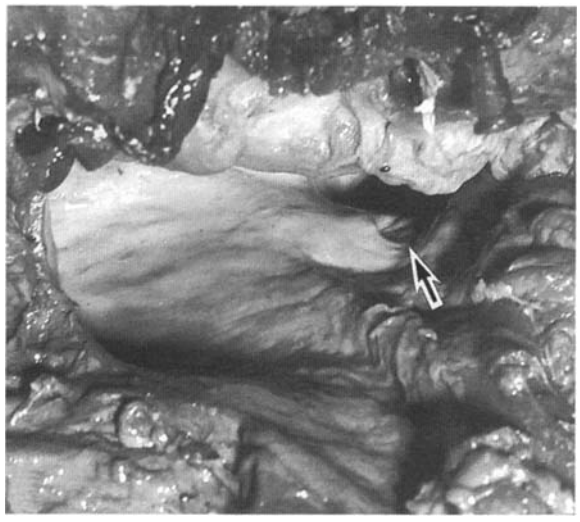

Fig. 2. The nasopharynx cavity from caudal part. Dorsal direction at the left. The pharyngeal opening of the left eustachian tube can be seen in the nasopharynx wall (arrow).

Fig. 3. dorsal direction at the top. The left eustachian tube is longitudinally dissected (small arrows). Cartilage is well-developed in the tube wall. The tube ventrally descends from the tympanic cavity, and reaches the pharyngeal opening (large arrow).

slit-like hole. The narrow nasopharynx cavity gradually curved in the dorsal direction with a sharp and long edge in a sagittal plane. In caudal space, the nasopharynx cavity was enlarged dorsoventrally. The most lateral part of both sides sharply rose in a dorsal direction (Fig. 1). The nasopharynx cavity volume was estimated at 173 cc from the replica weight of 204.2 g.

The pharyngeal opening of the eustachian tube was discerned in each side of rostroventral part in the nasopharynx wall (Fig. 2). The opening was 25 mm in dorsoventral length. The eustachian tube cartilage was well-developed and could be palpated from the nasopharynx wall (Fig. 3). The tube ventrally

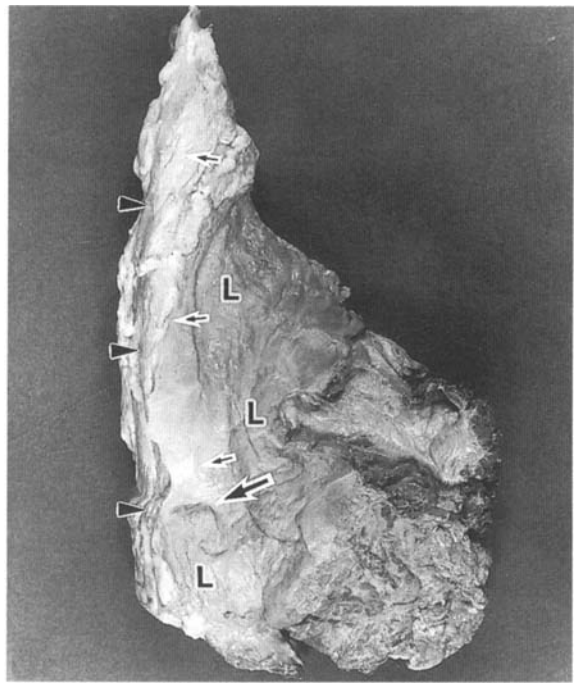

Fig. 4. The inner surface of the right side of the nasopharynx wall. Dorsal direction at the top and rostral at the left. From the pharyngeal opening (large arrow), the eustachian tube runs dorsally (small arrows). The levator veli palatine muscle (L) surrounds the pharyngeal opening and the tensor veli palatine muscles (arrowheads) accompany the eustachian tube.

descended from the tympanic cavity, curved slightly to the caudal direction and reached the pharyngeal opening. It was about 145 mm in length and 7 mm in diameter. The levator veli palatine and tensor veli palatine muscles accompanied the eustachian tube. The levator veli palatine muscle surrounded the pharyngeal opening (Fig. 4). The tubal tonsil could not be found around the opening. The eustachian tube was a simple canal and did not possess the diverticulum, the guttural pouch, around the nasopharynx.

The cartilage was well-developed in the middle region of the eustachian tube wall (Fig. 5). It was composed of hyaline cartilage and stained blue with hematoxylin-eosin (Fig. 6). Many chondrocytes were discerned in the cartilage cavities. Collagen and elastic fibres were not observed among cartilage cavities. Thick collagen fibres were observed in both inner and outer regions of the cartilage zone (Figs. 5 and 6). Some valve-like structures contained collagen fibres and extends towards the lumen (Fig. 5).

The auditory bulla was complicated in shape and extremely small in size (Fig. 7). The cartilage part of the eustachian tube connected with the bulla from the ventral pharynx area. The small bulla was located medial to retroarticular and paracondylar processes. The external acoustic meatus was observed between the retroarticular and mastoid processes in the temporal bone (Fig. 8).

Discussion

The guttural pouch has been morphologically detailed in the horse (Bourdelle and Bressou, 1949; Way and Lee, 1965; Cook, 1966; Ellenberger and Baum, 1974; von Berg, 1974; Sisson, 1975; Popesko, 1977; Dyce et al., 1987). Lindsay and Clayton

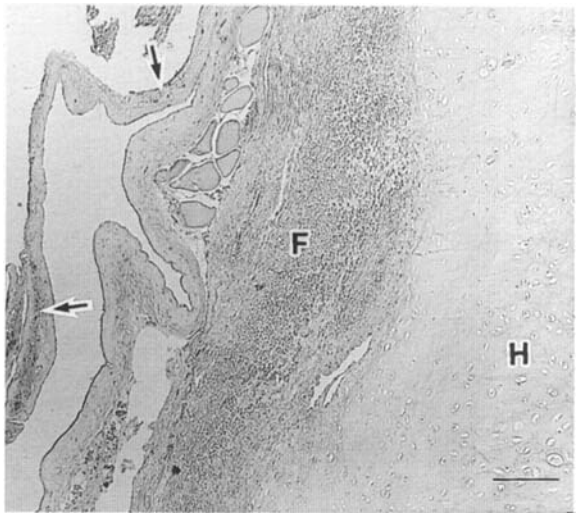

Fig. 5. The hyaline cartilage (H) is well-developed in the intermediate region of the eustachian tube wall. Thick collagen fibres are observed in the inner region of the cartilage zone (F). A Valve-like structure (arrows) extends towards the lumen (L). Bar = 200 μm.

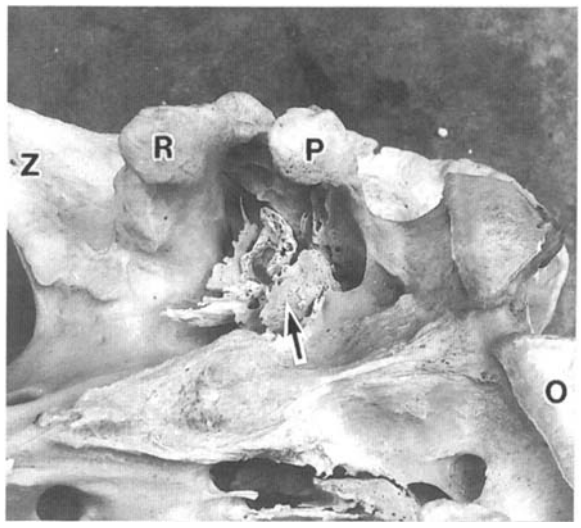

Fig. 7. Skull in the ventral view. Rostral direction at the left. The small auditory bulla (arrow) is located medial to retroarticular (R) and paracondylar (P) processes. Z, zygomatic arch. O, occipital condyle.

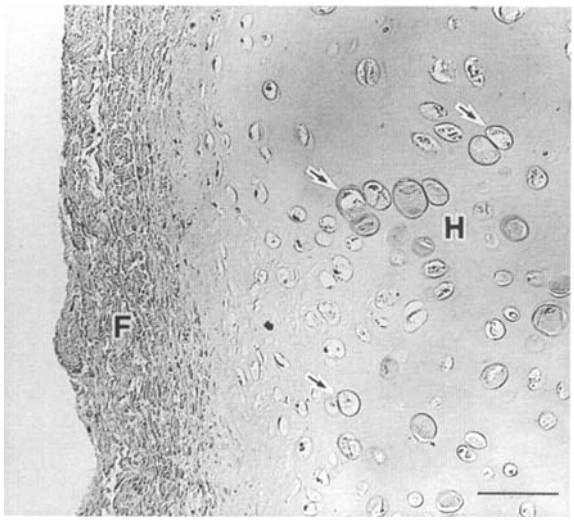

Fig. 6. The hyaline cartilage (H) is well-developed in the intermediate region of the eustachian tube wall. Many chondrocytes are discerned in the cartilage cavities (arrows). F, collagen fibres. Bar = 100 μm.

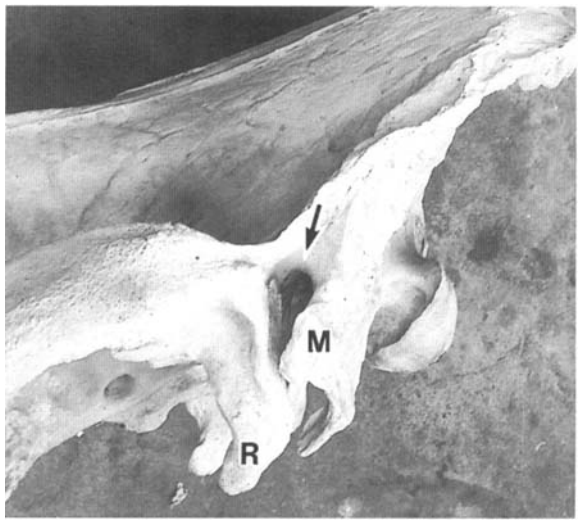

Fig. 8. Skull in the left side view. Rostral direction at the left. The external acoustic meatus (arrow) is observed between the retroarticular (R) and mastoid (M) processes in the temporal bone.

(1986) dissected the guttural pouch in the domesticated donkey, whereas Fischer (1986) described it in the tapir. From these results, the well-developed guttural pouch has been suggested to have a relation with the evolutionary status of perissodactyls. It has been mentioned that the guttural pouch is equipped, not only in the horse, but also in other perissodactyls (Bourdelle and Bressou, 1949; Lindsay and Clayton, 1986; Dyce et al., 1987), although they did not show any morphological data on the rhinoceros. This study demonstrated that the white rhinoceros, at least, does not have a guttural pouch. The eustachian tube, consisting of a simple canal with cartilage wall, does not form any enlarged space. We suggest that the occurrence of the guttural pouch may not be dependent on the phylogenetic factor of perissodactyls.

The silicone replica indicates that the nasopharynx cavity is well-developed in a dorsoventral direction. It is not consistent with the results in horse that the nasopharynx is enlarged in a rostrocaudal direction (Bourdelle and Bressou, 1949; Way and Lee, 1965; Ellenberger and Baum, 1974; von Berg, 1974; Sisson, 1975; Popesko, 1977; Dyce et al., 1987). It is thought that the dorsoventrally-developed nasopharynx may have an influence on the respiratory function of rhinoceros.

The histological studies have been carried out in the eustachian tube of various vertebrates (Sucheston and Cannon, 1971; Yang, 1985). Yang (1985) described the morphological variation of tube wall in some mammals. The most noteworthy results in the white rhinoceros is the occurrence of the hyaline cartilage in the wall. It does not agree with the results in the horse that possessed well-developed elastic cartilage (Sucheston and Cannon, 1971).

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