Macroscopic Anatomy of the Auditory Tube Diverticulum
(Guttural Pouch) in the Thoroughbred Equine
——A Silicon Mold Approach——

By

Dugarjaviin MANGLAI, Ryuichi WADA*, Hideki ENDO**, Masamichi KUROHMARU, Toyohiko YOSHIHARA***, Motoki SASAKI****, Masa-aki OIKAWA*** and Yoshihiro HAYASHI

Department of Veterinary Anatomy, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Bunkyo-ku, Tokyo 113-8657, *Epizootic Research Station, The Equine Research Institute, Japan Racing Association, Shimotsuga-gun, Tochigi 329-0072, **Department of Zoology, National Science Museum, 3-23-1 Hyakunin-cho, Shinjuku-ku, Tokyo 169-0073, ***Clinical Science and Pathobiology Division, The Equine Research Institute, Japan Racing Association, Utsunomiya-shi, Tochigi 320-0856, ****The University Museum of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-0033, Japan

—Received for Publication, September 9, 1999—

Key Words: Auditory tube diverticulum (guttural pouch), Macroscopic anatomy, Silicon mold, Thoroughbred horse

Summary: The characteristics of the equine auditory tube diverticulum (guttural pouches) were studied in detail by the naked eye and silicon mold method. First, we examined the anatomical relationship between the guttural pouches and their associated bones and muscles. Secondly, a silicon mold was fabricated to clarify the three-dimensional aspect of the guttural pouches, paying a special attention to the distribution of major arteries and nerves surrounding it. Thirdly, the volume of the silicon mold was measured by immersing it in water. The guttural pouches are a pair of pouches located dorso-posteriorly to the posterior pharynx. The pouches had a close contact rostrally with the Os sphenoidale, ventrally with the pharynx and the esophagus, and caudally with the Articulatio atlantoaxialis. The left and right guttural pouches had almost the same capacity in each horse. The A. carotis interna, cranial ganglia of cervical nerves and cervical Truncus sympathicus, as well as the N. vagus, N. glossopharyngeus, N. hypoglossus, and Radices spinales of the N. accessorius, were present in the mucosal crease extending from the roof of the guttural pouches towards the middle of the caudal wall. The N. facialis appeared from the Foramen stylomastoideum ran dorsocaudally along the lateral recess. The N. mandibularis appeared from the Foramen lacerum went over the muscular process of an ear bone, ran along the roof of the lateral recess and finally continued with the rostral side of the guttural pouches. Lymph nodes, scattered on the mucosal surface, appeared as tiny indentations with approximately millet seed size on the silicon surface. The capacity of guttural pouches in adult horses (472 ± 12.4 cm³) was three-fold larger than that in foals (145 ± 9.4 cm³).

The guttural pouches, highly extensive mucosal pouches, have a close contact with the Recessus pharyngeus. The pouches are an extended part of the auditory tube (Sisson, 1975). The left and right pouches are symmetrically separated by the septum. Each pouch is divided into wider lateral recess and narrower medial recess by the stylohyoid bone with a capacity ratio of 2:1 (Sisson, 1975).

Although clinical medicine frequently requires the detailed macroscopic anatomy of the target organ, veterinary anatomy often fails to provide sufficient information regarding some peculiar organs (Sisson, 1975; Babptiste et al., 1996). In particular, little information is available on the macroscopic anatomy of the guttural pouches, primarily because this organ is absent in domesticated animals other than horses. In recent years, equine veterinary medicine has commonly employed the endoscopy for accurate examination, diagnosis, and treatment of that organ. To aid in the application of endoscopy for clinical practice, a macroscopic anatomy on the guttural pouches, focusing on the distribution of major arteries and nerves underlying the mucous membrane, and on their relationship with the surrounding muscles and bones, were investigated in this study.
Materials and Methods

Animals

Six adult female thoroughbreds with an average age of 9 years and 5 months and three young female thoroughbreds with an average age of 4 months were used in this study. The animals were anesthetized with an intravenous injection of a mixture of 2 g sodium thiopental (Ravonal®; Tanabe Seiyaku Co., Osaka, Japan) and 500 mg suxamethonium chloride (Succine®; Kyorin Pharmaceutical Co., Tokyo, Japan), and subsequently sacrificed by giving incision on the left common carotid artery. Three of them were subjected to macroscopic examination, and the rest of the animals were used for fabrication of silicon molds.

Fabrication of silicon mold

To fabricate silicon mold of the guttural pouches, the equine’s head was kept in a normal position. After severing the maxilla approximately 5 cm before the pharyngeal ostium of the auditory tube and at the opening to the guttural pouches, the silicon (Product No. KE-12, specific gravity = 1.30 g/cc, Shin-Etsu Chemical, Tokyo, Japan) was injected into the left and right guttural pouches. Approximately 24 hr later, when the silicon mold became hardened with the help of a hardening agent (Product No. KE42W, Shin-Etsu Chemical Co., Tokyo, Japan), the silicon mold of the guttural pouches was extracted.

Measurement of capacity of guttural pouch

The molds from three adults and three foals were immersed in water to measure their volume based on the relative silicon density. The volume thus recorded was defined as the capacity of the guttural pouches.

Bones, muscles, arteries and nerves associated with guttural pouches

In the present study, we observed in detail the bones and muscles surrounding the guttural pouches, as well as the distribution of major arteries and nerves with the help of magnifying glass. The results were illustrated with photographs and drawings.

Results

Anatomical findings on guttural pouches

The guttural pouches are a pair of pouches located dorsoposteriorly to the posterior pharynx. The left and right pouches were symmetrically separated by the M. rectus capitis ventralis on the caudal side and by the septum on the rostral side. Each pouch was divided into wider lateral recess and narrower medial recess by the stylohyoid bone. On the rostral side, the pouches had a close contact with the Os sphenoidale, ventrally with the pharynx and the esophagus, and caudally with the Articulatio atlantoaxialis. The pouches opened into the pharynx at the pharyngeal ostium of the auditory tube. The ostium was divided by intermediate disc to form a slit-like opening. Its rostral side was wider than the caudal. The intermediate disc, composed of fibrous cartilages, ran caudoventrally along the pharyngeal wall. The funnel formed by a crease-like structure lateral to the mucous membrane of the auditory tube connected to the exterior wall of the pharynx by the intermediate disc.

Subsequently to the narrow pharyngeal ostium of the auditory tube, the medial recess of the guttural pouch adjacent to the upper wall of the Os sphenoidale and the Os occipitale appeared as a complicated structure. The other regions were in contact with muscular tissues, except for the region neighboring to the stylohyoid bone (Figs. 1, 2 and 3). The lower wall was located between the pharynx and the beginning of the esophagus and covered with the Mm. pterygoidei, and the parotid and mandibular glands. Major arteries and nerves, supplying the head, ran just below the mucous membrane (Fig. 4). Lymph nodules with approximately millet seed size (5 mm) were dispersely distributed on the caudal mucosal wall (Fig. 5c). Posterior to the caudal wall, retropharyngeal lymph nodes were also recognized.

The A. carotis interna, cranial ganglia of cervical nerves and cervical Truncus sympathetic, as well as the N. vagus, N. glossopharyngeus, N. hypoglossus, and Radices spinales of the N. accessorius, were present on the mucosal crease extending from the roof of the guttural pouches towards the middle of the caudal wall. Ramus pharyngeus of the N. vagus, cervical ganglia on the cranial side, and retropharyngeal lymph nodes were present underneath the mucous membrane that formed the floor of medial recess of the guttural pouches.

The A. carotis externa ran rostroventrally along the lateral recess of the guttural pouches. A part of the A. carotis externa ran parallel to the N. glossopharyngeus and N. hypoglossus. The arteries and nerves were found around the dorsal side of the pouches. The arteries were merged in the A. maxillaris. Then they extended on the caudal side of the V. maxillaris along the dorsolateral wall of the lateral recess and crossed the branches of the N. tympanicus and N. maxillaris. At the end of nerve extensions inside the guttural pouches, the N. maxillaris on the M. tensor veli palatini finally entered
Fabrication of silicon mold of guttural pouch

Table 1. Capacity of the guttural pouches in thoroughbreds (cm³)

<table>
<thead>
<tr>
<th>No. of animals</th>
<th>Adult Left</th>
<th>Adult Right</th>
<th>Foal Left</th>
<th>Foal Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>488</td>
<td>459</td>
<td>134</td>
<td>138</td>
</tr>
<tr>
<td>2</td>
<td>474</td>
<td>473</td>
<td>158</td>
<td>141</td>
</tr>
<tr>
<td>3</td>
<td>456</td>
<td>481</td>
<td>143</td>
<td>154</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>471.83 ± 12.38</td>
<td>144.67 ± 9.37</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD: Standard Deviation.

The Foramen alare caudale.

The N. facialis appeared from the Foramen stylomastoideum ran dorsocaudally along the lateral recess for approximately 3 to 4 cm. Then they ran between the mandibular and parotid glands. The N. mandibularis appeared from the Foramen lacerum went over the muscular process of an ear bone, ran along the roof of the lateral recess and finally continued with the rostral side of the guttural pouches.

Shape and capacity of guttural pouches

A complete silicon mold of the entire guttural pouches was obtained (Fig. 5a–d). The sulci or depressions on the silicon mold were almost identical to those macroscopically observed. The silicon mold revealed a clear picture of the sulci inside the guttural pouches and provided with the vital information on the major arteries and nerves underlying the mucous membrane. Lymph nodes, scattered on the mucosal surface, appeared as tiny indentations with approximately millet seed size on the silicon surface (Fig. 5c). The average volume of the silicon mold of the guttural pouches was approximately 472 cm³ in adult horses and 145 cm³ in foals (Table 1).

Discussion

Considerable changes in shape, size and location of the guttural pouches during movement of a horse were reported by Baptiste et al. (1996). The pouches become smaller when the neck is bent than when it is extended (Baptiste et al., 1996). Thus, they focused only on changes in size and shape of the pouches. On the other hand, the present silicon mold study revealed the sulci of arteries, nerves, muscles, and bones appeared on the guttural pouches, and the accurate volume of that organ. The dorsal side of the guttural pouches consisted of hard tissues, namely the Os sphenoidale and Os occipitale, and revealed a concavoconvex appearance. Except for the region connected with the Os stylohyoideum, the wall was in contact with soft tissues. The tissues were surrounded by the pharynx, esophagus, and many muscles such as the M. pterygoideus medialis, M. pterygoideus lateralis, M. rectus capitis ventralis, M. longus capitis, occipitomandibular part of M. digastricus, jugular hyoid muscles, M. tensor veli palatini, M. levator veli palatini, M. stylohyoideus, M. styloglossus, and M. occipitohyoideus. The contraction of these muscles may affect the size of the pouches (Baptiste et al., 1996, 1998). Moreover, they also cited that the bending of the neck may reduce the capacity of the guttural pouches. Transient expansion and contraction of the guttural pouches occur when horses neigh or swallow food. The contraction and relaxation of the muscles surrounding the pouches may induce this phenomenon (Baptiste et al., 1996, 1998). As the pouches expand or contract, air moves into or out of the body through the pharyngeal ostium of the auditory tube. This tube is closed except when air is exhausted.

As the guttural pouches of horses have such an intricate shape, it is difficult to portray them in anatomical terms. The x-rays have shown the morphological aspects of the pouches although they are not highly accurate (Trigo et al., 1981; Freeman 1991). Baptiste et al. (1996) succeeded in accurately determining the shape of the guttural pouches by silicon injection. The present study was in well accord with it. These findings enabled us to create a three-dimensional representation of the guttural pouches. The dents and creases appeared on the surface of the molds clearly indicated major blood vessels and nerves running over the mucosa of the guttural pouches. Certainly, the present study will be of great help for endoscopic examination in the field of clinical veterinary medicine, as well as macroscopic anatomy, diagnosis and treatment of that organ.

The capacity of the equine guttural pouches was 472 cm³ in our present study although variation was observed among the investigators (Sisson, 1975). The present study revealed that the value was nearly the same for the left and right pouches. This value in term of capacity was considered in adult thoroughbreds with their head in a normal position. Kubo et al. (1992) reported that the guttural pouches accounted in volume for approximately 4.3% of the entire head in adult horses.

Although a number of studies on the function of the guttural pouches have been carried out (Fish, 1910; Skoda, 1911; Richter, 1923; Rooney, 1997; Baptiste, 1998), sufficient information is not yet available. In addition to occupying a substantial portion of the equine head in terms of capacity, the
guttural pouches are directly associated with major blood vessels and nerves. This suggests that they play a highly important role as an organ. It is well known that, at a high level of motility or vigorous physical exercise, horses exhibit an extremely high body temperature as well as increased heart rate. The guttural pouches are thought to play an important role in cooling down the brain (Baptiste, 1998). Another report claimed that the pouches help the pharynx to swallow food (Skoda, 1911; Rooney, 1997). It will be needed a further research for detailed elaboration on that peculiar organ.

Acknowledgments

We would like to express our deep appreciation for the cooperation from the staff at the Japan Racing Association, the Equine Research Institute, the Clinical Sciences and Pathology Division, and the Epizootic Research Station, Microbiology Division.

References


Explanation of Figures

Plate I

Plate II

Fig. 2. Distribution of muscles around the guttural pouches. A). *M. rectus capitis ventralis*. B). *M. stylohyoideus*. C). *M. styloglossus*. D). *M. digastricus* and *Ostium pharyngeum tubae auditivae*. (opening of the guttural pouch-arrow head. Right lateral view-medial layer)
Plate III

Fig. 3. Distribution of artery & glands associated with the guttural pouches. A). *M. rectus capitis ventralis*. B). *M. longus capitis*. C). *A. carotis communis*. D). *Gl. parotis* and E). *Gl. mandibularis*. (Viewed from behind the head)
Plate IV

Plate V