Original article

Anatomical characteristics of the larynx in giraffe (*Giraffa camelopardalis*)

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Abstract

In the present study, the most outstanding anatomical findings of the larynx of a giraffe are described. The larynx obtained from a male necropsied animal was studied following fixation in a 10% formaldehyde solution. There was no rostral horn in the thyroid cartilage and so cranial thyroid fissure was almost smooth or hardly visible concave structure. Caudal horn was short and caudal thyroid fissure was very depth. Lateral surface of arytenoid cartilage possessed a well-developed oblique arcuate crest between corniculate and vocal processes. On the mucosa of corniculate cartilage, aryepiglottic fold and laryngeal ventricle, there were many macroscopically observable rounded projections in different sizes. There were no cuneiform cartilages in both lateral side of the base of epiglottis. The anatomy of the larynx and its components in the giraffe and horse, showed little differences and overall their laryngeal morphological features were similar.

Keywords: anatomy, Giraffidae, upper respiratory system, wild animals.

1 Introduction

The objective of this article is to describe the most relevant anatomic features of the larynx of a giraffe (*Giraffa camelopardalis*). The giraffe is an African even-toed ungulate mammal, the tallest living terrestrial animal and the largest ruminant. The giraffe is one of only two living species of the family Giraffidae, the other being the okapi (KINGDON, 1988; SKINNER, 2003). It is classified by the International Union for Conservation of Nature as Least Concern, but has been extirpated from many parts of its former range, and some subspecies are classified as endangered. Nevertheless, giraffes are still found in numerous national parks and game reserves (FENNESSY and BROWN, 2010).

Several researches have been performed to accomplish laryngeal anatomy in different mammalians, and most of them have been conducted mostly in domestic mammals (HAST, 1979; BRADLEY, CHEAL and VKIM, 1980; YAMAMOTO, ATOJI, HOBO et al., 2001; GOULDEN, 2002; GUINTARD, 2005). Anatomical characteristics about giraffe larynx described by Harrison (1980) in first time, but this study was focused mostly on physiological peculiarities of the larynx. The numbers of the studies regarding species-specific anatomy in giraffe are significantly fewer than those performed in the mammals. As far as to our literature review, no studies have been available in the morphological structure of the larynx in giraffe, a wild exotic mammal whose number is gradually decreasing. In the present study, we aimed to study the anatomical characteristics of the larynx in giraffe, hoping that current data will help collecting and understanding of anatomical structure of organs of wild mammals in the future.

2 Materials and Methods

The larynx obtained from a male necropsied animal at a local zoo was studied following fixation in a 10% formaldehyde solution. After studying the external conformation and the muscles, the ventral surface of the larynx was cut longitudinally with the aim of studying the internal conformation and the laryngeal cavity. The length and width of laryngeal structures were measured with digital caliper and pictures were taken with a digital camera (Nikon D7000, Nikon Corporation, Tokyo, Japan). The terminology of the NAV (NOMINA…, 2012) was employed.

3 Results

Giraffe larynx was composed of three unpaired cartilages, namely, the cricoid, the thyroid and the epiglottis; and one paired cartilage, namely, the arytenoid. The thyroid, cricoid and arytenoid without corniculate and vocal processes were hyaline cartilage, while epiglottic cartilage, corniculate and vocal process of arytenoid were consisted of elastic cartilage. The total length of the larynx was 117.79 mm from epiglottis to caudal border of the cricoid cartilage. The highest dorsoventral length was 79.27 mm (Figures 1, 2).

The biggest laryngeal cartilage was thyroid cartilage which composed of two convex and irregular quadrilateral shaped fusing in the midline. Thyroid cartilage was situated rostral to cricoid, caudal to epiglottis and lateral to arytenoid cartilages in oblique position of larynx (Figures 1, 3). Both lateral laminas of the thyroid cartilage departed from the conjunction region on both side and form a large part of the lateral wall of the larynx. The length of the thyroid laminas was 100.27 mm from laryngeal prominence to caudal horn. Widths of the thyroid lamina were not constant in all regions, the widths of rostral and caudal portions of the lamina were 44.55 and 30.18 mm, respectively. Bilateral laminas fused in the midline and cranially and formed fairly evident and more developed tubercle (*Prominentia laryngea*) (Figure 3).

It was related dorsally to the base of the epiglottic cartilage, which was attached to laryngeal prominence by thick and strong elastic ligament. There was no rostral horn in the thyroid cartilage and so cranial thyroid fissure was almost smooth or hardly visible concave structure (Figure 3). Caudal horn was short and caudal thyroid fissure was very depth (35.30 mm). Caudal fissure was closed by fairly developed fibrous cricothyroid membrane (Figure 3).

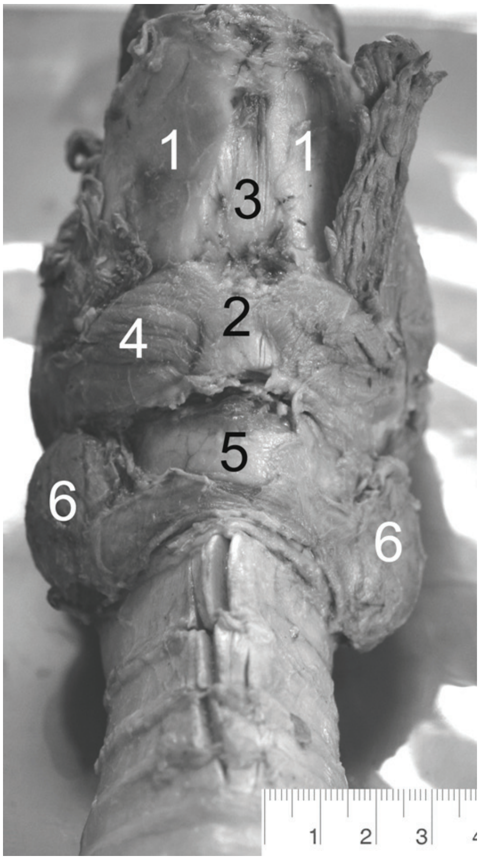

Figure 1. Ventral view of the isolated larynx. 1: Lamina of thyroid cartilage, 2: Cricoid cartilage, 3: Caudal thyroid fissure with cricothyroid ligament, 4: Cricothyroid muscle, 5: first tracheal cartilage, 6: Thyroid gland.

Cricoid cartilage was typically signet ring shaped and was located rostral to the first tracheal cartilaginous ring and medial and caudal to thyroid cartilages. The lamina of the cricoid was a wide irregular quadrilateral surface and this surface had a median and high projection (Figure 4). The length of the lamina was 49.54 mm, and rostral part of the lamina was thicker than the its caudal portion. Thyroid articular surfaces in the caudal face of the lamina were smoother, while arytenoid articular surfaces in the rostral part of the lamina were very concave and oval for articulation with arytenoid cartilage. The caudal border of the cricoid lamina was thinner and had a small incisure in midline (Figure 4). The ventral and lateral parts of the cricoid cartilage were formed by arch which was narrowest ventrally. Cricoid arch was 20.11 and 9.12 mm in width at lateral and ventral parts, respectively. The lateral surfaces of the cricoid arch were grooved for the location of cricothyroid muscles. The rostral margin of the cricoid arch was concave ventrally and gave attachment to the cricothyroid membrane. The caudal margin of the cricoid arch was thinner and jointed with first tracheal ring by cricotracheal ligament. The internal surface was very smooth and covered by respiratory mucosa (Figure 4).

Arytenoid cartilages were irregular pyramidal shaped and situated rostral to cricoid and medial to caudal half of the thyroid cartilages (Figure 5). The inner surfaces, which are covered by respiratory mucosa, of the arytenoid cartilages were almost smooth or slight concave. The concave lateral surface had a hyaline muscular process which elongated caudally, and smaller elastic vocal process cranioventrally (Figure 5). There was an oval and large facet for articulation of cricoarytenoid joint in medial surface of the muscular process. Moreover, lateral surface possessed a well-developed

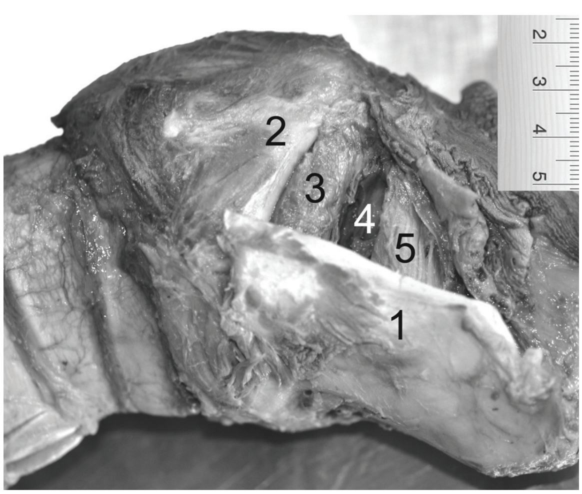

Figure 2. Right lateral view of the larynx with removed part of the lamina of thyroid cartilage. 1: Lamina of thyroid cartilage, 2: Cricoid cartilage, 3: Vocal muscle, 4: Laryngeal ventricle, 5: Vestibular muscle.

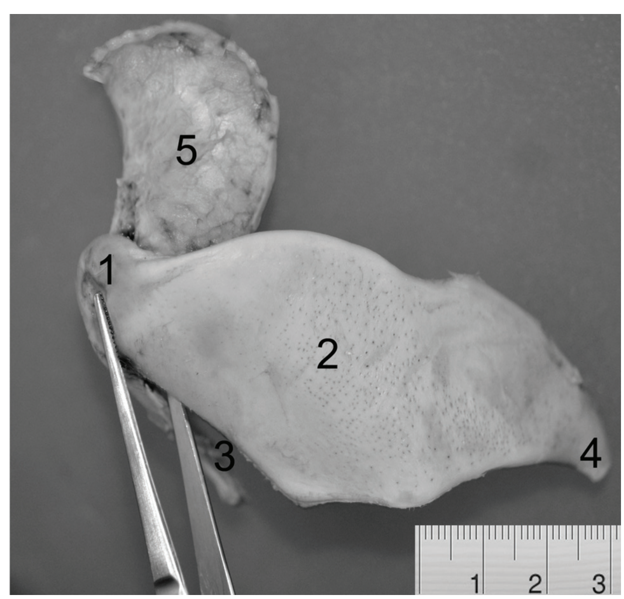

Figure 3. Left ventrolateral view of the epiglottic and thyroid cartilages. 1: Laryngeal prominence, 2: Lamina of thyroid cartilage, 3: Caudal thyroid fissure, 4: Caudal horn of the thyroid cartilage, 5: Epiglottis.

oblique arcuate crest (*Crista arcuata*) between corniculate and vocal processes, and lateral surface of the arytenoid cartilage was divided into cranioventral and caudodorsal regions by arcuate crest (Figure 5). The dorsal region of the arytenoid was composed of elastic corniculate cartilage. The base of each corniculate cartilage was attached to apex of both arytenoid cartilages (Figure 5). The corniculate cartilages had very sharp pointed apex which curved caudoventrally and resembled to eagle bill and were 13.70 mm in thickness. On the mucosa of dorsal and medial surfaces of the arytenoid cartilage, there were many macroscopically observable taste buds or rounded projections in different sizes similar to lingual fungiform papillae. The pigmentation of the mucosa covering the corniculate cartilage was very dominant (Figure 5).

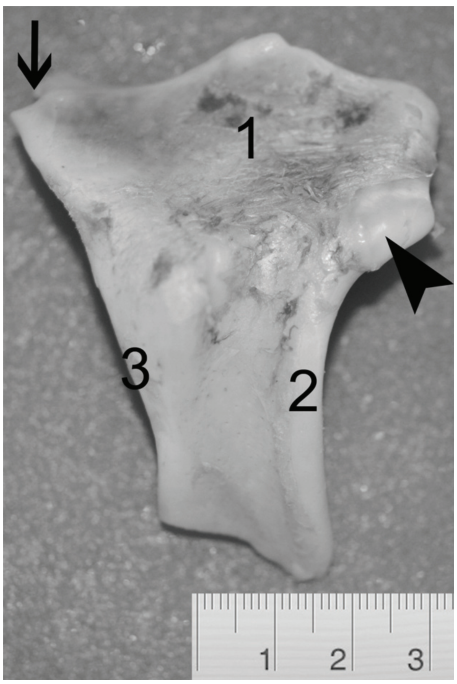

Figure 4. Lateral view of the isolated cricoid cartilage. 1: Lamina of the cricoid cartilage, 2: Rostral margin of arch of the cricoid cartilage, 3: Caudal margin of arch of the cricoid cartilage, arrowhead: articular face of cricoarytenoid joint, arrow: small median incisure of cricoid lamina.

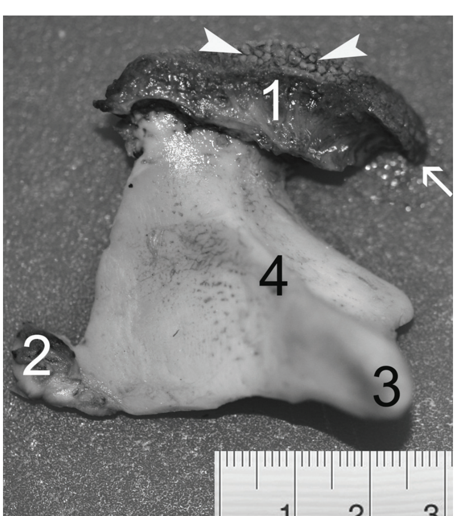

Figure 5. Lateral view of the left isolated arytenoid cartilage. 1: Corniculate process, 2: Elastic vocal process, 3: Muscular process, 4: Arcuate crest, arrow: Apex of the corniculate process.

Epiglottic cartilage was leaf-shaped and situated cranial and medial to thyroid cartilages. It had thick petiolus which resided on the medial surface of the laryngeal prominence of the thyroid cartilage. The lingual surface of epiglottis was concave from apex to base while laryngeal surface was convex from apex to base. There were no cuneiform cartilages in both lateral side of the base of epiglottic cartilage (Figure 3).

The cartilages of the larynx were joined together and to the hyoid bone by two synovial joints and syndesmosis. Synovial joints were the cricothyroid and cricoarytenoid joint. The cricothyroid joint connected the caudal extremity of the thyroid lamina to the corresponding facet of the cricoid lamina. The cricothyroid ligament was a fibro elastic membrane that is upholstered in its dorsal part by the infraglottic mucosa of the larynx and closed the thyroid notch (Figure 1). The cricoarytenoid joint was smaller and joined the articular surface of the base of the arytenoid to the counterparty of the cranial border of the cricoid lamina. The union of the arytenoids to the thyroid was given by the vocal folds. The epiglottis was joined by its base to the rostral border of the thyroid cartilage where a ventral excavated surface where is fixed by the thyroepiglottic ligament.

The intrinsic muscles of the larynx were the cricothyroid, dorsal cricothyroid, lateral cricoarytenoid, transverse arytenoid and thyroarytenoid muscles. The lateral cricoarytenoid and thyroarytenoid muscles were hidden by the laminas of the thyroid cartilage. The thyroarytenoid muscle was divided into two parts, rostral ventricular muscle and other caudal or vocal muscle (Figure 2). Between the two parts appeared one diverticle of the laryngeal cavity, the laryngeal ventricle (Figure 2).

The laryngeal cavity was connected rostrally with laryngeal part of the larynx and caudally with the tracheal cavity. Laryngeal aditus was 35.6 mm and 48.42 mm in width and length, and was limited rostroventrally by epiglottic cartilage, laterally by the aryepiglottic folds and dorsocaudally by the corniculate process of arytenoids cartilage (Figure 6). Aryepiglottic fold was 32.96 and 5.59 mm in length and thickness, respectively. The dorsal and medial surfaces of aryepiglottic fold had also small and bigger projections of taste buds similar to mucosa of corniculate process and laryngeal vestibule, and lateral walls of the vestibule between laryngeal entrance and laryngeal ventricle presented few smaller projections or taste buds (Figure 6).

Among the vestibular and the vocal folds, an elliptical orifice (Figure 2) gave access to a diverticle of the cavity of the larynx: the laryngeal ventricle, which outwardly appeared between the two parts of the thyroarytenoid muscle, hidden by the lamina of thyroid cartilage (Figure 3). The mucosa of the diverticle was surrounded by loose connective tissue. Laryngeal ventricle was 10.48 and 13.39 mm in depth and diameter, and bounded ventrolaterally by the vocal plicae. The length, width and thickness of the vocal plicae were 41.45, 13.05 and 4.26 mm, respectively.

There was a median depression on the floor of the vestibule of the larynx, rostrally to the union of the vocal plicae: the median recess of larynx (Figure 3). Rima glottidis

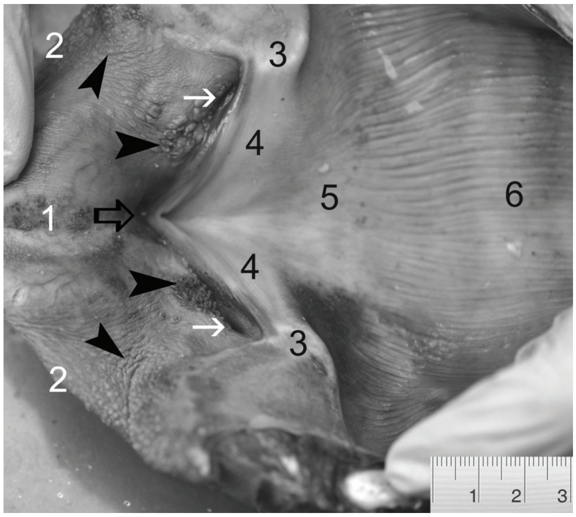

Figure 6. Internal view of the larynx after dorsal incision. 1: Epiglottis, vestibule of the larynx, 2: Aryepiglottic fold, 3: Vocal process of arytenoid cartilage, 4: Vocal plicae 5: Infraglottic cavity of the larynx, 6: Mucosa of the trachea, arrowheads: Projections of the mucosa of laryngeal vestibule, white arrows: Orifices of the laryngeal ventricle, central arrow: Median recess of the larynx.

was very narrow and the distance between two vocal plicae was 4.38 mm. Each rostral border of the laryngeal ventricle was covered by numerous projections and density of these structures was higher in the right ventricle than the left side, and dark pigmentation was very dominant in the laryngeal ventricles and vestibular plicae (Figure 6). Infraglottic cavity of the larynx, which limited by cricoid cartilages in both lateral sides, was caudal and widest compartment of the larynx and had many longitudinal mucosal folds (Figure 6).

4 Discussion

A small number of studies (BISAILLON, 1985; FREY and GEBLER, 2003; FREY, GEBLER and FRITSCH, 2006; FREY, GEBLE, FRITSCH et al., 2007) have been conducted to date that demonstrate the anatomical and physiological aspects of the larynx in the wild animals. These studies, which have been carried out in both wild and domestic animals, have demonstrated the functional characteristics, and most were aimed at revealing the vocalization mechanisms (HARRISON, 1980; FREY and GEBLER, 2003; FREY, GEBLER and FRITSCH, 2006; FREY, GEBLE, FRITSCH et al., 2007) and laryngeal taste buds (BRADLEY, CHEAL and VKIM, 1980; YAMAMOTO, ATOJI, HOBO et al., 2001). Therefore, new and detailed studies of laryngeal cartilages, muscles and internal laryngeal anatomy in giraffe bear importance for the correct interpretation of the results of new researches. To our knowledge, detailed laryngeal anatomy has not been studied before in the giraffe (*Giraffa camelopardalis*).

It was determined that length of the thyroid lamina was higher than its width in the giraffe as reported in muskox (FREY, GEBLER and FRITSCH, 2006). In contrast to many ruminants, it was reported that width of the thyroid cartilage was higher than its length in the one-humped camel (SABER, 1983). There was a great difference between lengths of rostral and caudal horns and caudal horn was 2.5-fold longer than the rostral horn in muskox (FREY, GEBLER and FRITSCH, 2006), and rostral horn was relatively shorter in reindeer (FREY, GEBLE, FRITSCH et al., 2007). The rostrodorsal angle of the lamina was extended to form the short straight rostral horn and thyroid fissure was a deep notch between the rostral horn and the rostral border of the thyroid lamina in cow and sheep (GETTY, 1975) and white tailed deer (BISAILLON, 1985). Whereas, there was no rostral horn and evident cranial thyroid fissure in thyroid cartilage of giraffe. The caudal horn was very simple and smooth in the giraffe and was not sharply curved caudally at its base as in many domestic ruminants (GETTY, 1975), muskox (FREY, GEBLER and FRITSCH, 2006) and reindeer (FREY, GEBLE, FRITSCH et al., 2007). In the white tailed deer (BISAILLON, 1985), the caudal horn was shorter but thicker than its rostral homologue, and was directed caudomedially.

Similar to giraffe, caudal thyroid fissure was encountered in all domestic mammals without pig, and it was reported that cranial thyroid fissure was only present in cattle and humans and absent in other domestic species (GUINTARD, 2005). By contrast to reports of Guintard (2005), many sources (GETTY, 1975; BARONE, 1976; NICKEL, SCHUMMER and SEIFERLE, 1987) reported that cranial thyroid fissure were present on the rostrodorsal angle of the thyroid laminas in domestic mammals such as cow and horse. The general shape of the thyroid laminas of the giraffe was more similar to those of horse (GETTY, 1975; YAMAMOTO, ATOJI, HOBO et al., 2001).

Cricoid cartilage was typically signet ring in many domestic and wild mammals (GETTY, 1975; BARONE, 1976; BISAILLON, 1985; FREY, GEBLER and FRITSCH, 2006; FREY, GEBLE, FRITSCH et al., 2007). In the giraffe, it was seen the same form of the cricoid cartilage. The caudal border of the cricoid lamina of giraffe was thinner and had a small incisure in midline. It was reported that caudal border of the quadrilateral plate of lamina was thin and convex but not mentioned about median incisure in domestic mammals (GETTY, 1975; BARONE, 1976; GUINTARD, 2005). Cranial border of the lamina was thick in giraffe similar to other ruminants (GETTY, 1975; BARONE, 1976; BISAILLON, 1985; GUINTARD, 2005). Dorsal surface of the cricoid lamina presented a well-developed high median ridge or muscular process in our study and other domestic ruminants (GETTY, 1975). In the white tailed deer (BISAILLON, 1985), it was reported that flat dorsal surface of lamina was divided into two halves by a low median crest. The arch of cricoid was laterally compressed and its ventral part was narrow in giraffe and other ruminants (BARONE, 1976; FREY, GEBLER and FRITSCH, 2006; FREY, GEBLE, FRITSCH et al., 2007).

Epiglottic cartilage was leaf-shaped in giraffe. Similarly, it is shaped like an obovate leaf in the sheep and the ox, and like a cordate leaf in the goat (BARONE, 1976). Moreover, there was no cuneiform cartilage of epiglottis in giraffe. Likewise, the absence of caudally directed cuneiform cartilages localized in both lateral side of epiglottis are reported in cat, sheep, goat and cattle (GETTY, 1975; BARONE, 1976; GUINTARD, 2005). On the other hand, cuneiform cartilage is present in the dog, horse (GETTY, 1975; NICKEL, SCHUMMER and SEIFERLE, 1987) and Mongolian gazelle (FREY and GEBLER, 2003).

Arytenoid cartilages were paired and were shaped like a three dimensioned pyramid in giraffe similar to horse (GETTY, 1975; BARONE, 1976; GOULDEN, 2002). The most distinguishing structure on the arytenoid cartilage in giraffe was the presence of evident and thick arcuate crest that separated lateral arytenoid surface into the two different regions for attaching of muscles. In the horse, these regions have been classified into dorsocranial (*Fovea oblongata*) and ventrocaudal (*Fovea triangularis*) for attaching of arytenoid transverse, vocal and lateral cricoarytenoid muscles (BARONE, 1976).

Corniculate cartilages were attached by its base to the apex of the arytenoid cartilages and curved caudoventrally, but this cartilage curved dorsally and medially in ruminant and horse (BARONE, 1976). Moreover, in giraffe, there were numerous macroscopically observable projections consisting of large and small taste buds, locating on the mucosa of dorsal and medial surfaces of the corniculate cartilage as well as aryepiglottic fold, and just rear of the laryngeal ventricles. Papillary projections in different sizes formed by taste buds was reported as well in horse (YAMAMOTO, ATOJI, HOBO et al., 2001). However, the presence of laryngeal projections at the top of the corniculate cartilage and aryepiglottic fold localized laterally at the both sides of the laryngeal vestibule in giraffe was not reported other domestic or wild species studied. Even though no laryngeal projections exists, the basal cell layers of its epiglottic mucosa possessed ovoid collection of cells (taste buds) covered by the superficial epithelium (BRADLEY, CHEAL and VKIM, 1980). Similar to sheep (BRADLEY, CHEAL and VKIM, 1980), intraepithelial laryngeal taste buds have been reported carnivorous (SHIN, NAHM, MAEYAMA et al., 1995; YAMAMOTO, HOSONO, ATOJI et al., 1997), but mucosal projections related to taste buds and free nerve endings of corniculate processes was shown in horse macroscopically (YAMAMOTO, ATOJI, HOBO et al., 2001).

According to Yamamoto, Atoji, Hobo et al. (2001) and Gaughan, Hackett, Ducharme et al. (1990); mucosal projections in the corniculate process of the arytenoid region seems to be sensory structure because of the rich innervations of the epithelium, and tactile stimulation of mucosa causes swallowing and such laryngeal projections may receive mechanical and chemical stimuli from passing bolus for the closure of the laryngeal entrance for protection against aspiration. Similar to horse (GAUGHAN, HACKETT, DUCHARM et al., 1990; YAMAMOTO, HOSONO, ATOJI et al., 1997), we disclosed that gigantic laryngeal projections enveloped laryngeal aditus, and comparatively shorter, these projections were distributed over laryngeal ventricle in giraffe. Therefore, we also think that the projection organizing around laryngeal entrance obstruct escaping of foods into laryngeal cavity and then facilitate the move of nutrients into esophagus by nervous stimulation of laryngeal projections.

The ventricle of the larynx presents variable development according to species. In the giraffe, it was smaller than in the horse. This ventricle is present in human, equine, swine, dog and to a lesser extent in rabbit (BARONE, 1976). Instead there is only a weak depression in domestic ruminants (BARONE, 1976). In the equine and canine larynges, their mucosa insinuates between ventricular and vocal muscles (BARONE, 1976), in the same way as in the giraffe. The laryngeal ventricle is homologous of the laryngeal air-sac (*Saccus laryngis*) of the primates that descends caudally in the neck, even to the axillary region in the orangutan (HAYAMA, 1970).

The joints and muscles of the larynx of the giraffe were similar to those of the horse. Caudal thyroid fissure was similar to the horse, which is a point of surgical access to the cavity of the larynx (BARONE, 1976). The cricothyroid joint was synovial in giraffe, but it is being replaced by a syndesmosis in cattle (BARONE, 1976). The giraffe had two parts of the thyroarytenoid muscle, similar to that described in the equine and canine larynges (BARONE, 1976). Moreover, the depression called median recess of the larynx found in the giraffe is similar to that described in equine and pig among domestic mammals (BARONE, 1976).

5 Conclusion

In conclusion, the anatomy of the larynx and its components in the giraffe and horse, showed little differences and overall their laryngeal morphological features were similar. In the present study, we determined the absence of cranial thyroid horn of thyroid cartilage and cuneiform cartilage of epiglottis, established the organization and topography, general anatomical structure of cartilages, and clarified the location of laryngeal projections spreading on laryngeal entrance and ventricles in detail in giraffe. We noted the presence of well-developed arcuate crest at the lateral surfaces of the arytenoid cartilage and different direction of the apex of corniculate cartilage. We think that a species-specific information and collection of anatomical data about exotic mammals will further influence our understanding of the different anatomy and functional peculiarities of laryngeal structures.

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