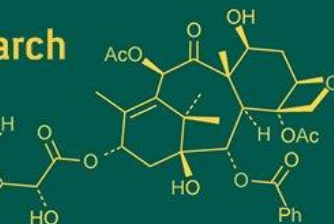
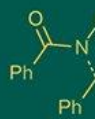


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Gross morphology of laryngeal cavity, ligaments and muscles in Indian goat (*Capra hircus*)

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Abstract

The present study was conducted to describe the detailed gross anatomy of the larynx and its associated structures in goats, with special emphasis on cavity, vocal cords, ligaments, nerves, vessels and intrinsic and extrinsic muscles. The laryngeal cavity extended from the aditus laryngis to the crico-tracheal junction and was divided into vestibule, glottis, and infra-glottic cavity. The aditus laryngis was triangular, bounded by the epiglottis, aryepiglottic folds, and corniculate processes. Vocal cords consisted of the vocal process of the arytenoid cartilage and vocal ligament, while the vocal folds were formed by the thyro-arytenoideus muscle and vocal ligament. Extrinsic ligaments included the hyo-epiglottic and thyro-epiglottic ligaments, while intrinsic structures included the vestibular, vocal, transverse arytenoid, crico-thyroid, crico-tracheal, and dorsal crico-arytenoid ligaments. Morphometric observations of the vocal folds and vocal processes were recorded. Extrinsic muscles identified were sterno-thyroideus, thyro-hyoideus, and hyo-epiglotticus, whereas intrinsic muscles included crico-arytenoideus dorsalis, crico-arytenoideus lateralis, crico-thyroideus, thyro-arytenoideus, and arytenoideus transversus. The recurrent laryngeal nerve supplied all intrinsic muscles except the crico-thyroideus. The thyro-hyoid membrane connected the body of the hyoid bone to the anterior border of the thyroid cartilage and differed from the ligamentous arrangement reported in other species. The study provides comprehensive anatomical information that may be useful for comparative anatomy, veterinary surgery, and clinical interventions involving the caprine larynx.

Keywords: Larynx, muscle, ligament, vocal cord, goat

Introduction

The larynx is a musculo-cartilaginous organ suspended from the hyoid bone in the caudal part of the intermandibular space, situated between the root of the tongue and the trachea (Sisson *et al.*, 1975) ^[12]. It serves as a passage connecting the pharynx and trachea and plays a vital role in respiration, vocalization, and deglutition (Fulton *et al.*, 2012) ^[8]. Structurally, the larynx is a complex tubular organ composed of irregularly shaped hyaline and elastic cartilages that form a protective sphincter at the entrance of the respiratory tract.

The muscles of the larynx are classified into extrinsic and intrinsic groups based on their attachments. In domestic animals, the laryngeal cavity has an hourglass-like appearance, with the glottis representing the narrowest region (Nickel *et al.*, 1979) ^[11]. Detailed knowledge of laryngeal anatomy is essential for planning surgical procedures and conducting clinical investigations involving the larynx. (Thiemann and Bell, 2001s) ^[13].

Materials and Methods

The present study was carried out in the Department of Veterinary Anatomy, College of Veterinary Science, Rajendranagar, Hyderabad. A total of twelve larynges were collected from goats of both sexes, ranging in age from less than one year to more than four years, immediately after slaughter at the Jiyaguda slaughterhouse, Hyderabad, Telangana. The specimens were thoroughly washed with water and preserved in 10% formalin solution. Detailed dissection of the larynges was performed carefully to study and document the gross anatomical features of muscles, ligaments and associated structures. Morphometric parameters including the length, width, and thickness of the vocal cords were measured using digital Vernier calipers according to the method described by Zrunek *et al.* (1988) ^[14].

The obtained measurements were subjected to statistical analysis, and standard error values were calculated.

Results

Cavity of the larynx

Laryngeal cavity of goat extended between the aditus laryngis and caudal extremity of cricoid cartilage and was bound by laryngeal cartilages and adnexa. Aditus laryngis was triangular in shape in cross section with medial union of corniculate tuberculum on its apex and dorsal surface of the epiglottis as its base. It was bounded laterally by the aryepiglottic folds, dorsally by the corniculate process and anteriorly by the epiglottis. Cartilaginous and membranous parts of vocal cords divided the cavity into two parts on its cranial and caudal ends viz., vestibule and infra glottic cavity respectively (Fig.1). Aryepiglottic fold connected the lateral border of the base of epiglottis to the caudal, lateral and dorsal aspects of the corniculate process which extended medially onto dorsal surface of the arytenoid and dorsal surface of cricoid cartilage. Vestibule was located between the aditus laryngis and glottis and its caudal end extended on to the cranial part of the laryngeal sac (Fig. 2 A). Vestibule was a triangular cavity bounded ventrally by epiglottis and thyroid cartilage, part of corniculate process and anterior border of proximal part of arytenoid cartilages. Glottis was enclosed between the medial surfaces of the arytenoid cartilages and bounded laterally by the part of arytenoid cartilages and vocal cords from proximal to distal extremity. It was diamond shaped between the vocal processes. Glottic cleft was between the pars inter membranacea where the vocal folds were close to each other with a narrow gap (Fig.2 B). Infra-glottic cavity extended between the caudal ends of the glottis to crico tracheal junction and was bounded by cricoid cartilage and partly by the thyroid cartilage.

Vocal cords

Vocal cords consisted of the vocal process of arytenoid cartilage and vocal ligament. Vocal fold comprised of thyro-arytenoideus muscle and vocal ligament (Fig. 3). It was directed obliquely downwards and forwards. Mean length of vocal tract was 20.61 ± 1.97 mm while mean width and thickness of vocal process were 8.50 ± 0.83 and 7.01 ± 0.67 mm respectively. Mean length, width and thickness of vocal fold were 14.14 ± 1.78 mm, 6.25 ± 0.74 mm and 5.13 ± 0.67 mm respectively.

Muscles of Larynx

Sterno-thyroideus, thyro-hyoideus and hyoepiglotticus were extrinsic muscles of larynx of which the first two were paired while the third was unpaired. Sterno-thyroideus muscle extended between the sternum and larynx. It was inserted laterally to the caudal border of thyroid cartilage and related anteriorly, dorsally and caudally to thyro-hyoideus, thyro-pharyngeus and crico-thyroideus muscles respectively (Fig. 4A). Thyro hyoideus muscle was located on ventro-lateral aspect of the thyroid cartilage extending between it and the hyoid bone and was related to omohyoideus muscle ventrally in the anterior one third portion located ventrally to the origin of thyro-pharyngeus muscle. It originated from thyroid cornua and body of the hyoid bone and was inserted to an oblique line on lateral surface of the thyroid lamina (Fig. 4B). Hyo-epiglotticus muscle originated from the body and kerato hyoid of hyoid bone

and was inserted to the lingual surface of epiglottic base (Fig.5A). Intrinsic muscles of larynx were cricoarytenoideus dorsalis, cricoarytenoideus lateralis, crico-thyroideus, thyroarytenoideus and arytenoideus transversus.

Crico-arytenoideus dorsalis muscle was located in the shallow depressions on the dorsal surface of the cricoid lamina, where it was originated and was inserted to the muscular process of the arytenoid cartilage. It was dorsally related to the oesophagus and some of the muscle fibres blended with the ventral wall of the esophagus, resulted in the formation of crico-esophageal muscle. (Fig.5B). Crico arytenoideus lateralis muscle was medial to lamina of thyroid cartilage and crico thyroideus muscle. It was related dorsally to crico arytenoideus dorsalis and ventrally to thyroarytenoideus. The muscle was originated from the anterior border of lateral cricoid arch and was inserted to the muscular process of arytenoid on ventro lateral aspect, to the crico-thyroid membrane i.e., ventro-laterally from the base of the epiglottis, dorsal surface of the thyroepiglottic ligament, medial surface of the thyroid lamina and cricothyroid membrane (Fig. 6A). It was inserted to the muscular and the vocal processes of the arytenoid cartilage. The muscle was related medially to the ventricular and vocal ligament, laterally to the thyroid lamina. Arytenoideus transversus muscle arose from the muscular process of the arytenoid cartilage and inserted to the arytenoid of other side (Fig.6B).

Crico-thyroideus muscle originated from the lateral surface and cranial border of the cricoid arch and was inserted to the caudal fissures and lateral surface of posterior part of the thyroid cartilage. It was roughly rectangular in shape with muscle fibres directed obliquely forwards and upwards. It was laterally related to the terminal part of the sterno-thyroideus muscle and medially to the cricothyroid ligament (Figs. 6A).

Anterior laryngeal nerve entered the anterior thyroid foramen (Fig. 7A), whereas recurrent laryngeal nerve (Fig. 7B) supplied all intrinsic muscles of larynx except crico-thyroideus. Laryngeal artery (Fig. 7A) passed through the secondary thyroid foramen which entered the mucosa of larynx between the cricoid and thyroid cartilages on ventral aspect. The artery and nerve were found beneath the fascia of cricoid whose course was along the shape of cricoid cartilage. It divided into branches on ventral surface of dorsal cricoid lamina.

Ligaments and Membranes

The adnexa larynx was mainly the muscles and membranes. In the present study the thyro-hyoid membrane was extrinsic and connecting the body of hyoid to anterior border of thyroid cartilage (Fig.6B). Hyo-epiglottic ligament was extrinsic ligament, found between the lingual surface of epiglottic base and body of hyoid. Thyro-epiglottic ligament was between the dorsal surface of thyroid and lingual surface of epiglottic base (Fig. 6B). Crico-thyroid membrane connected the caudal border of thyroid lamina with cranial border of lateral and ventral arches further extending onto the internal surface of thyroid lamina. Transverse arytenoid ligament connected the dorsomedial aspects of two arytenoid cartilages (Fig. 3B). Crico-tracheal membrane connected the caudal aspect of cricoid with cranial border of first tracheal ring and dorsal crico-arytenoid ligament extended from dorsal aspect of arytenoid to ventral surface of dorsal cricoid lamina (Fig.6B). Vocal

ligament was found between the vocal process of arytenoid and deep sulcus on dorsal surface of thyroid cartilage. Vestibular ligament extended from the base of epiglottis to thyroid cartilage and further onto the lateral surface of arytenoid cartilage (Fig. 3A).



Fig 1: Dorsal view of larynx showing Aditus laryngis (Arrow), Corniculate tuberculum (bold)

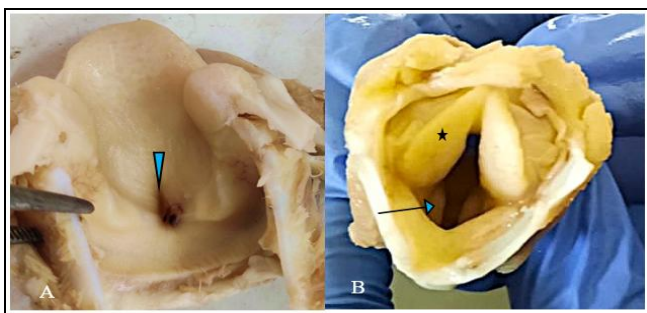


Fig 2: Posterior view of larynx showing Laryngeal cavity (A) Horizontal section of larynx (B): Cartilaginous (*) and membranous parts (arrow) of vocal cords Laryngeal sac (arrow head)

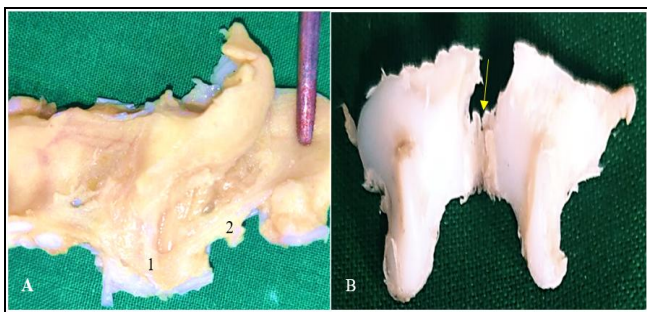


Fig 3: Photograph of sagittal section of larynx (1.0-1.5 years) indicating Vocal ligament (1) and Vestibular ligament (2) Arytenoid cartilage showing transverse arytenoid ligament (yellow arrow)

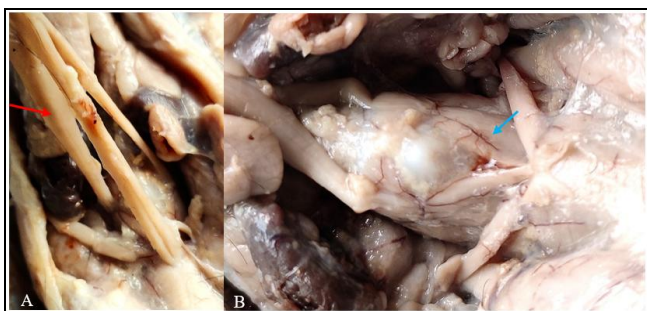


Fig 4: Photograph showing ventral view of in situ larynx of 9 months goat (A) and 2 years old goat (B), Sternothyroid muscle (Red arrow), Thyrohyoid muscle (Blue arrow)

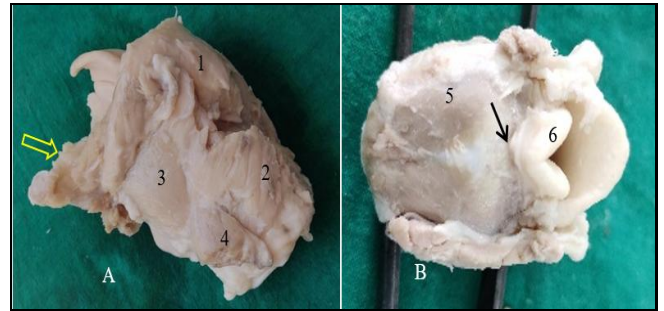


Fig 5: Photograph showing lateral view of 3-4 years goat larynx (A) Dorsal view of 2.5-3years goat larynx (B) indicating chondropharyngeus (1), Crico pharyngeus (2), Thyro-hyoideus (3), Sterno-thyroideus (4), Crico-arytenoideus dorsalis (5), Tuberculum corniculatum (6) and Transverse arytenoideus muscle (Arrow), Hyo-piglottic muscle (Yellow muscle).

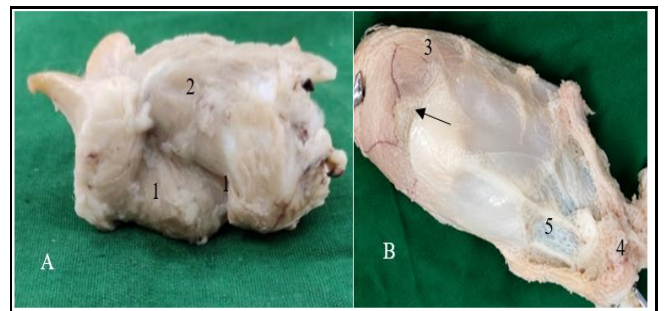


Fig 6: Photograph of 3-4 years goat Larynx-Lateral view without thyroid cartilage (A) Ventral View of 1.5-years goat Larynx (B) Thyroarytenoideus (1), Cricothyroideus (3), Body of hyoid (4), Thyro hyoid membrane (5) and Cricothyroid membrane (arrow).

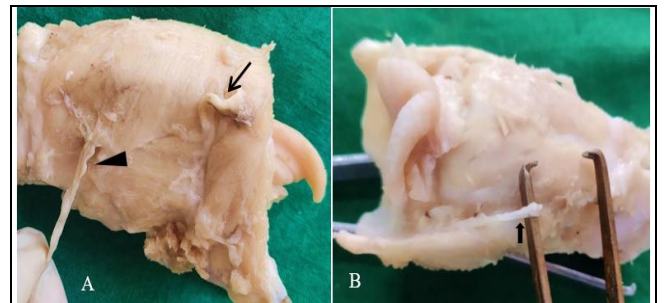


Fig 7: Photograph showing lateral view of 3-4 years goat larynx (A) and Dorsal view of 1-1.5 years old goat larynx (B) indicating Cranial laryngeal nerve (arrow), Recurrent laryngeal nerve (Bold arrow) and Cranial laryngeal artery (arrow head).

Discussion

Aditus laryngis of goat was bounded laterally by the aryepiglottic folds, dorsally by the corniculate process and anteriorly by the epiglottis. Cartilaginous and membranous part of vocal cords divided the laryngeal cavity into cranial vestibule and caudal infraglottic cavity. The above findings in goat were akin with the findings of Nickel *et al.* (1979) [11] in domestic animals.

Thiemann and Bell (2001) [13] and Metwally *et al.* (2018) [5] observed a broad lateral ventricle with laryngeal saccules in donkey which was absent in goat larynx. Ventral diverticulum was in the form of a recess, similar to Musk Ox (Frey *et al.*, 2006) [7]. Thyro-arytenoideus muscle of goat was not divided into ventricularis and vocalis muscles unlike in dogs (Nickel *et al.*, 1979) [11], in donkeys (Lindsay and Clayton, 1986 and Metwally *et al.*, 2018) [10, 5] and in

Mangolian Gazelle. FEP (Fibro elastic pad) was in place of vocal ligament in Mangolian gazelle (Frey and Gebler, 2003) ^[6]. Transformation of vocal ligament to fat pad in old animals was not true in the present work but, fat deposition increased with age, which was partially in accordance to the reports of Frey *et al.* (2006) ^[7] in Musk Ox. With the above observations it was inferred that dimensions of vocal fold were almost similar to those in Gaddi goat (Aishwarya *et al.* (2018) and Mangolian Gazelle (Frey and Gebler, 2003) ^[6] respectively.

Sterno-thyroideus muscle extended between the sternum and caudal border of thyroid cartilage, analogous to buffaloes (Eshra *et al.*, 2016) ^[4]. Thyro hyoideus muscle was located on ventro-lateral aspect of the thyroid cartilage. It originated from thyroid cornua and body of the hyoid bone as reported by Sisson *et al.* (1975) ^[12] in domestic animals. Hyo-epiglotticus muscle fibres originated from body and keratohyoid of hyoid bone, as observed in canines (Tobias and Johnston, 2017) ^[9].

Arytenoideus transversus was an unpaired muscle that extended between the muscular processes on either side, as reported in sheep (ALSadi, 2006) ^[2], but was not attached to dorsomedial angle of arytenoid cartilage as seen in white tailed deer (Bisaillon, 1985) ^[3].

Crico-arytenoideus dorsalis muscle fibres blended with the ventral wall of esophagus, resulted in the formation of crico-esophageal muscle. Similar observations were seen in buffalos and donkeys (Metwally *et al.*, 2018) ^[5]. In contrary to white-tailed deer (Bisaillon, 1985) ^[3], buffalo and donkey (Metwally *et al.*, 2018) ^[5], crico arytenoideus lateralis muscle of goat was inserted to vocal process (ALSadi, 2006) ^[2]. Thyro-arytenoideus of goat was undivided unlike in Musk Ox (Frey *et al.*, 2006) ^[7] and donkey (Lindsay and Clayton, 1986 ^[10] and Thiemann and Bell, 2001) ^[13] which was divided into vestibularis and vocalis muscles. Crico-thyroideus was a roughly rectangular muscle which originated from cricoid arch and was inserted to the thyroid cartilage, similar to the reports of Metwally *et al.* (2018) ^[5] in buffaloes, donkeys and camel.

But, the thyro-hyoid membrane was not in the form of ligament in goats as mentioned by ALSadi (2006) ^[2]. Crico-thyroid membrane connected the caudal border of thyroid lamina with cranial border of ventral arch, similar to the larynx in canines (Tobias and Johnston, 2017) ^[9]. Vestibular ligament was not involved in the formation of vestibular fold which was in accordance with the report of Nickel *et al.* (1979) ^[11] in domestic animals.

Conclusion

The present study provides a comprehensive account of the gross anatomy of the larynx and its associated structures in goats. Detailed observations on the laryngeal cavity, vocal cords, vocal folds, ligaments, muscles, nerves, and blood vessels revealed species-specific anatomical features of the caprine larynx. The arrangement of the intrinsic and extrinsic muscles, along with the pattern of innervation by the recurrent laryngeal nerve, highlights the functional organization of the laryngeal apparatus in goats. The presence of a thyro-hyoid membrane connecting the hyoid body to the thyroid cartilage, differing from the arrangement reported in other species, indicates notable anatomical variation. Morphometric data recorded for the vocal folds and vocal processes further enrich the anatomical database of small ruminants. Overall, the findings of this study serve

as a valuable reference for comparative anatomy, veterinary surgery, anesthesia, and clinical management of laryngeal disorders in goats.

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