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Original Article

# Morphological Variations of the Human Interarytenoid Muscle

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**Abstract** : This study investigated morphological variations of the transverse and oblique bellies of the interarytenoid muscle and their microstructures in humans. Forty-seven larynges from 50 formalin-embalmed cadavers were dissected to expose the arrangement of muscle fibers of the interarytenoid muscle. Histological sections of the laryngeal frame including the arytenoid cartilage and adjacent connective tissues were observed in three larynges. Forty larynges (85%) showed the typical morphology with superficial oblique and deep transverse bellies of the interarytenoid muscle. The boundaries of the oblique and transverse bellies of the interarytenoid muscle were atypical in the other seven cases (15%). In one case, a muscle belly originated from the cricoid cartilage medial to the posterior cricoarytenoid muscle and caused a height discrepancy of the arytenoid cartilage. Histological observations revealed that most of the muscle bellies of the transverse arytenoid muscle inserted to the muscular process of the arytenoid cartilage, whereas some muscle fascicles dispersed into the connective tissues of the lateral laryngeal frame. Occasionally, accessory muscle bellies vertically arose deep to the transverse arytenoid muscle. The results of this study will contribute to advance relevant anatomical knowledge for accurate diagnosis and treatment planning of laryngeal disorder such as dysphonia.

**Keywords** : Anatomy, Histology, Laryngeal muscle, Vocal cords

## INTRODUCTION

Knowledge of the morphological characteristics of the laryngeal structure is essential given that clinical procedures for diagnosing and treating of laryngeal disorders are becoming increasingly precise and sophisticated [1]. The transverse belly (tAM) and oblique belly (oAM) of the interarytenoid muscle (AM) have been alternative targets for the treatment of adductor paralysis and vocal cord granuloma, compensating for the side effect of the thyroarytenoid or lateral cricoarytenoid muscle being involved in conditions such as coarse voice and dysphagia [2-5].

As a target for partial laryngeal surgery or laryngeal reinnervation related to neurological voice disorders, many studies have investigated laryngeal innervation [6-12]. With implications for laryngeal neuroanatomic descriptions, the musculatures involved in the arytenoid cartilage (AC) could be the cause of the asymmetry therein preoperatively, which is a predictive factor for unilateral vocal cord paralysis and impaired posterior glottic closure [5,13-18]. Com-

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pared with the situation for other laryngeal muscles related to the AC, there have been insufficient studies focused on the AM. We therefore investigated the AM morphology by correlating the attachment to the laryngeal frame and their underling microstructures.

## MATERIALS AND METHODS

Fifty larynges from 50 formalin-embalmed cadavers (28 male and 22 females aged 70.4±12.1 years [mean±SD] at death) were collected after applying exclusion criteria of esophageal and thyroidal malignancies. We obtained the appropriate consent to use cadavers that had been legally donated to Dong-A University College of Medicine in Busan, South Korea from 2019 to 2021. Before they died, each donor signed documents agreeing to their participation in the body donation program of the medical school and to the use of their body in clinical studies. Considering the collection period of research data, this study does not require approval from the Institutional Review Board. This study conformed with the World Medical Association Declaration of Helsinki from June 1964 and its subsequent amendments.

The thyroid cartilages and entire mucosa were removed, and then the underlying connective tissues were dissected under 3× loupe magnification to expose the muscle fibers of the AM and posterior cricoarytenoid muscle of 47 specimens. Three laryngeal frames with intact mucosa were decalcified and underwent routine histological processing. Ten micron-thick sections were cut in the sagittal and transverse directions and then stained using Masson's trichrome. The stained sections were scanned and analyzed using a virtual slide scanner and slide viewer software (PANNORAMIC MIDI, 3DHISTECH, Budapest, Hungary) at the Neuroscience Translational Research Solution Center (Busan, South Korea).

## RESULTS

### 1. Muscle bellies of the interarytenoid muscle

Muscle fibers of the oAM passed upward to the anterolateral surface of the AC, and the tAM passed backward to the AC laterally under the oAM. The direction, number, and attachment of muscle bellies of the AM showed distinguishable variations. As the typical morphology, 40 larynges (85%) were found to have a separated configu-

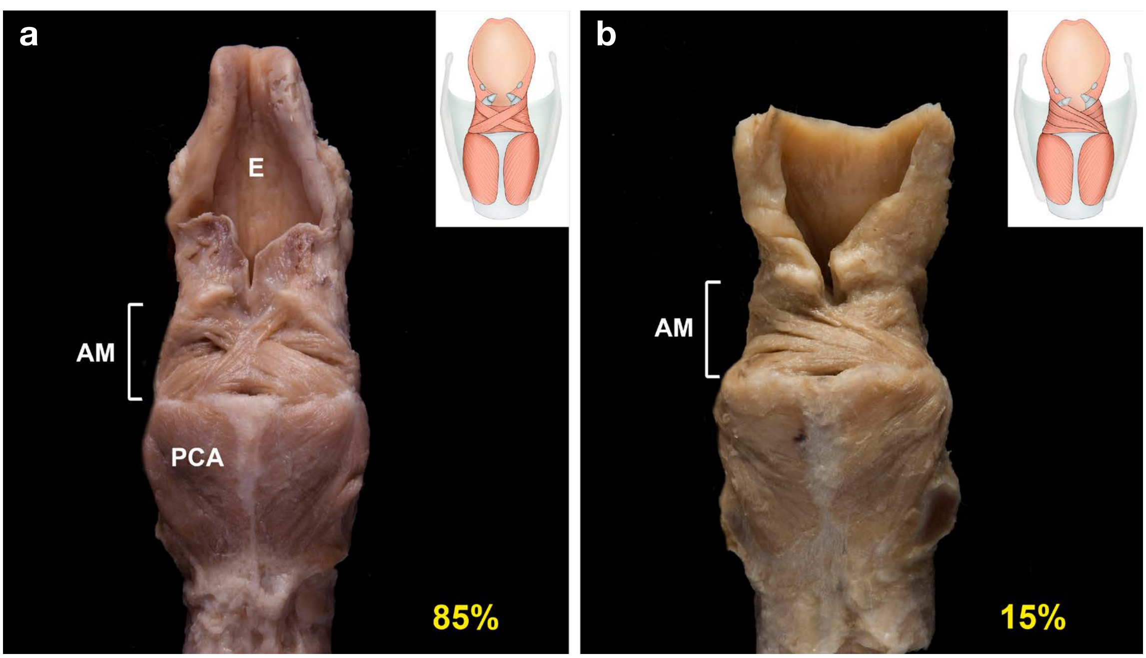


**Fig. 1.** Posterior view of the interarytenoid muscle (AM) with the pharyngeal mucosa removed. (a) The typical morphology with the distinct transverse belly (tAM) and the oblique belly (oAM) of the AM in an 'X' shape. (b) Asymmetrical triangular arrangement of the tAM and oAM. E, epiglottis; PCA, posterior cricoarytenoid muscle.

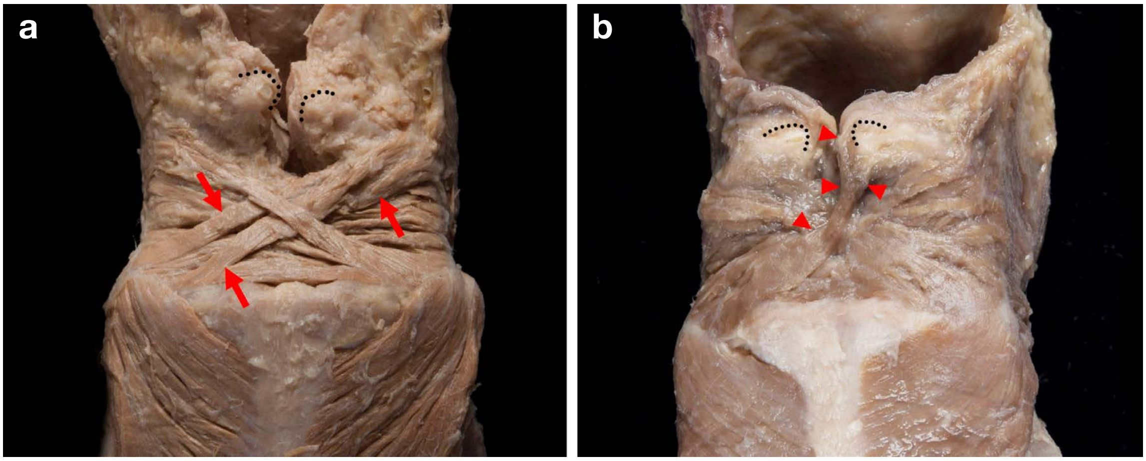


**Fig. 2.** Asymmetrical morphology of the oAM. (a) Dominant muscle bellies of the oAM (arrows) and asymmetrical positions of the corniculate cartilage and arytenoid cartilage (AC) (dotted lines). (b) A muscle belly (arrowheads) inserting to the apex of the corniculate cartilage and AC.

ration with the oAM and tAM in an 'X' shape (Fig. 1a). In the remaining 15% of cases, the territory between the oAM and tAM was indistinct, resulted in an asymmetrical arrangement of the muscle fibers in a triangular shape (Fig. 1b). Morphological diversity of the oAM was observed among the typical type in terms of the dominancy of muscle bellies (Fig. 2a) and their insertion to the apex of the AC and corniculate cartilage (Fig. 2b).

In one case, a thick muscle belly originating from the cricoid cartilage (CC) medial to the posterior cricoarytenoid muscle inserted to the AC (Fig. 3). This accessory belly intruded under the tAM and resulted in a downward AC compared with the contralateral AC. The contralateral aryepiglottic muscle originated from the middle of the superior rim of the CC. Other muscle bellies were also disarranged to lose the typical configuration between the oAM and tAM.

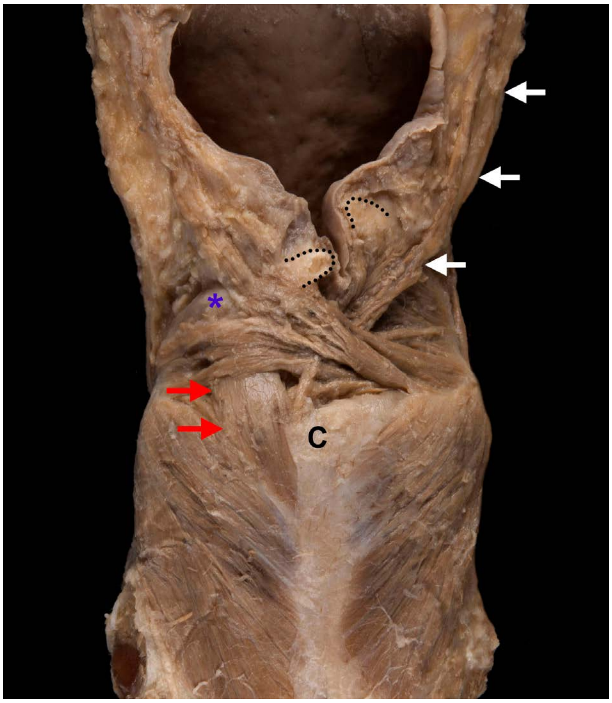


**Fig. 3.** An unusual muscle belly (red arrows) originating from the cricoid cartilage (CC) and inserting to the AC (blue asterisk). Note the severe height discrepancy of the corniculate cartilage (dotted lines) and the AC protruding unilaterally between the interarytenoid and aryepiglottic muscles. The right aryepiglottic muscle (white arrows) arose from the superior rime of the CC deep to the AM.

### 2. Histological observations of the interarytenoid muscle

Microstructural correlations with muscle fibers, laryngeal cartilages, and overlying connective tissues were investigated. In sagittal sections of the lateral laryngeal frame, the perimysium of the tAM originated directly from the perichondrium of the AC (Fig. 4a). The nerve fibers from the laryngeal plexus ran in the submucosal layer. Medially adjacent to the vocal process of the AC, the nerve fibers passed under the fascia of the oAM and intruded into the muscle fascicles of the tAM (Fig. 4b). In transverse sections of all specimens, the arrangement of the two parts of the AM commonly appeared as a superficial oAM and a deep

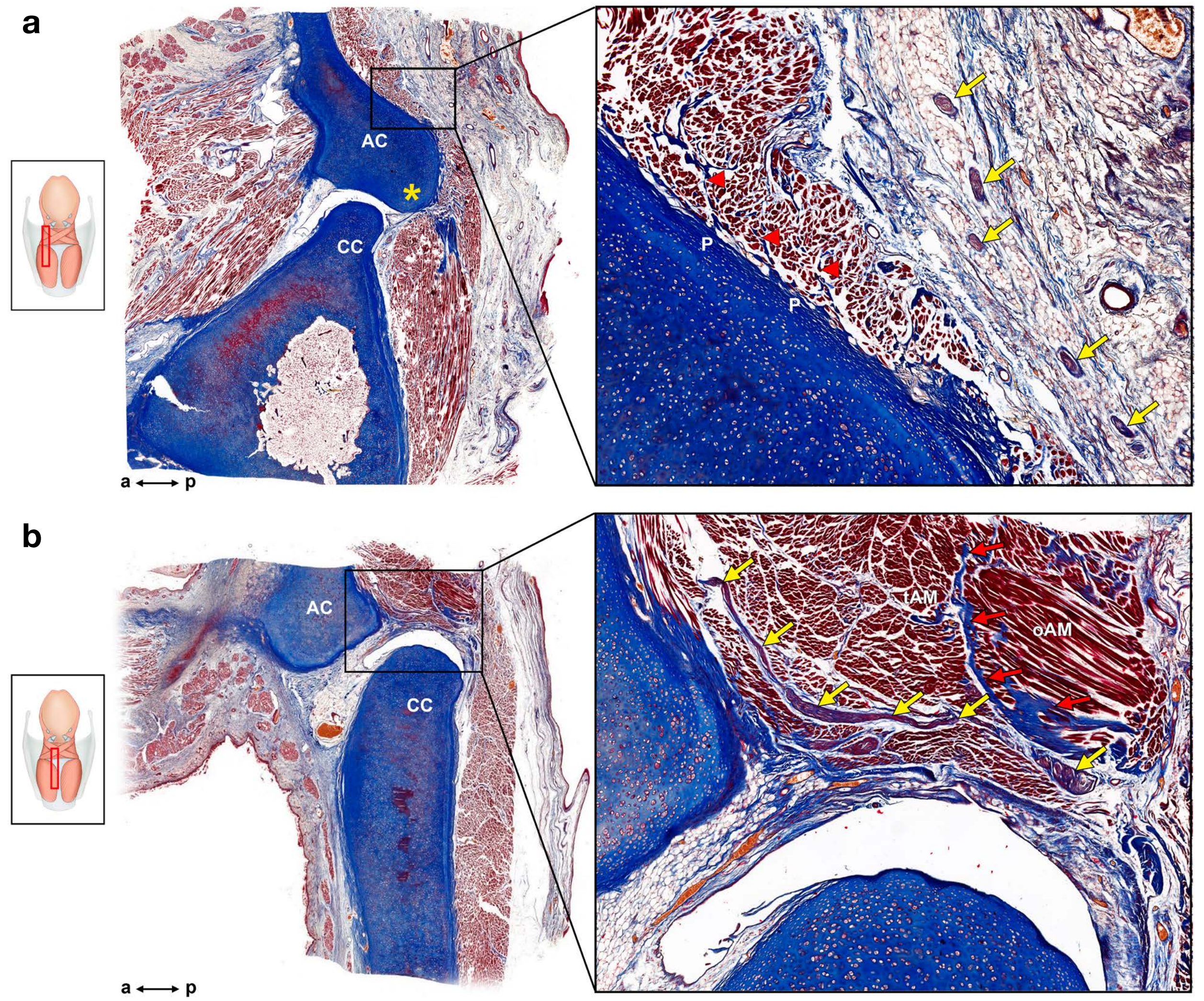


**Fig. 4.** Sagittal sections of the laryngeal frame. Right-side images are magnifications of the boxed areas on the left side. (a) The perimysium (red arrowheads) of the tAM was connected to the perichondrium (P) of the AC. The nerve fibers (yellow arrows) in the submucosa ran vertically above the AM. (b) The nerve fibers passed under the oAM and penetrated the tAM. a, anterior; p, posterior; red arrows, fascia of the oAM; yellow asterisk, muscular process of the AC; yellow arrows, nerve fibers.

tAM (Fig. 5a). Submucosal glands were distributed in connective tissues posterior to the AM and in broad areas anterior to the AC. The thyroarytenoid muscle and the tAM attached to the muscular process of the AC without a clear boundary (Fig. 5b). More medially near to the posterior glottic gap, longitudinal muscle bellies were found deep to the tAM (Fig. 5c).

In one specimen, the tAM consisted of multiple layers: a superficial layer, ending in the muscular process of the AC within the posterior laryngeal frame; an intermediate layer, dispersing to the connective tissues of the lateral laryngeal frame; and a deep layer, directly inserting to the muscular process of the AC (Fig. 6a). Glandular tissues with mucous and serous acini in the submucosa intruded into the niche between the oAM and tAM (Fig. 6b). Anterior to the AC, lobulated glands dominant in the serous acinus were well developed and their ducts opened to the posterior glottic gap (Fig. 6c).

## DISCUSSION

We have revealed morphological variations of the human AM using both macroscopic and microscopic observations.

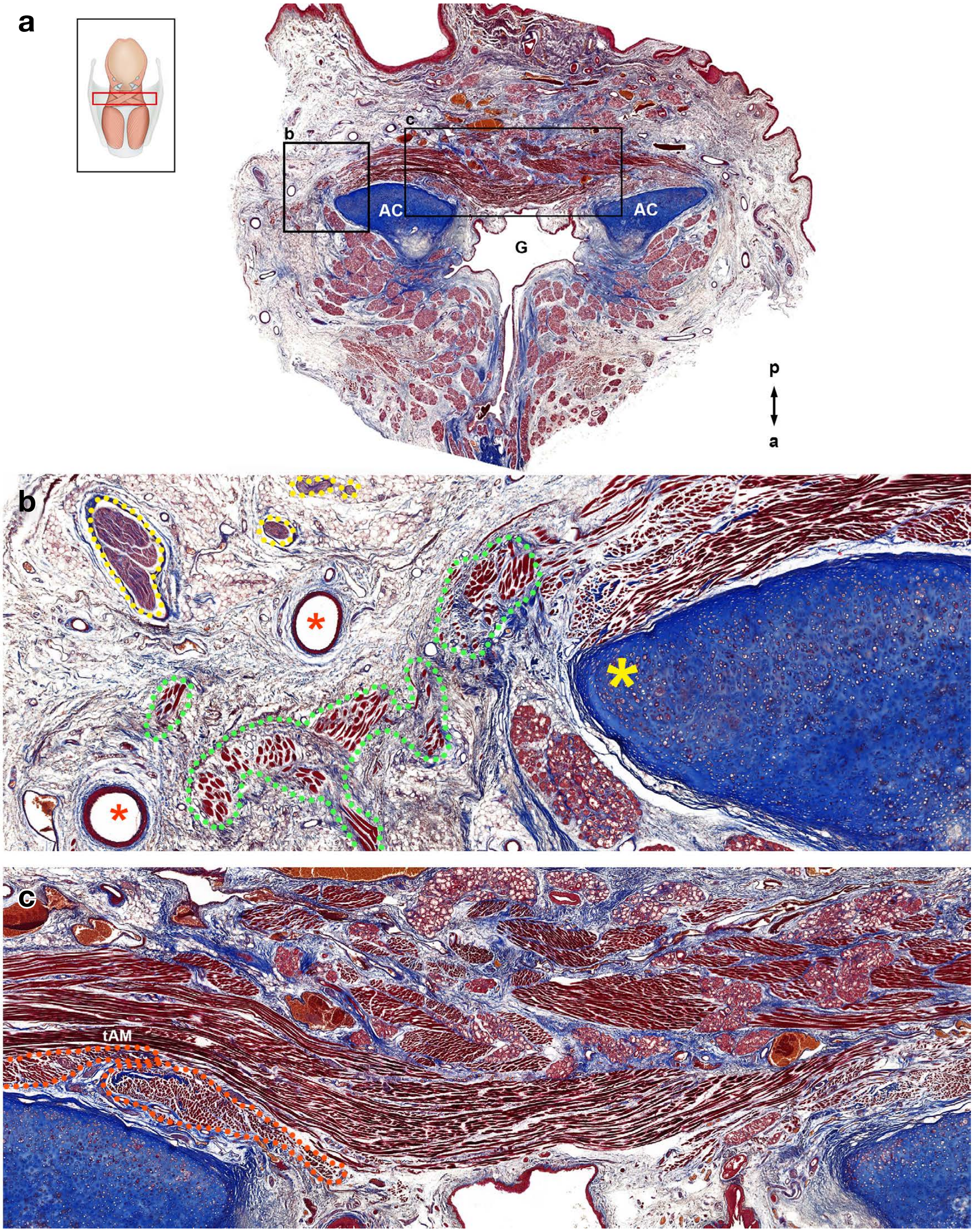


**Fig. 5.** Cross section of the AM and magnified areas. (a) Common features of a superficial oAM and a deep tAM. (b) The lateral part of the AM attached to the AC near to the thyroarytenoid muscle (green dotted lines). (c) Longitudinal muscle bellies (red dotted lines) located between the tAM and the AC. G, posterior glottic gap; red asterisks, arteries; yellow asterisk, muscular process of the AC; yellow dotted lines, nerve fibers.

The typical morphology in most (85%) cases was a superficial oAM and a deep tAM. The oAM could be indistinguishable from the tAM and exhibited diverse attachment patterns to the laryngeal cartilages. The tAM consisted of sublayers attaching to the muscular process of the AC, vertical accessory bellies in the deep layer, or the muscle

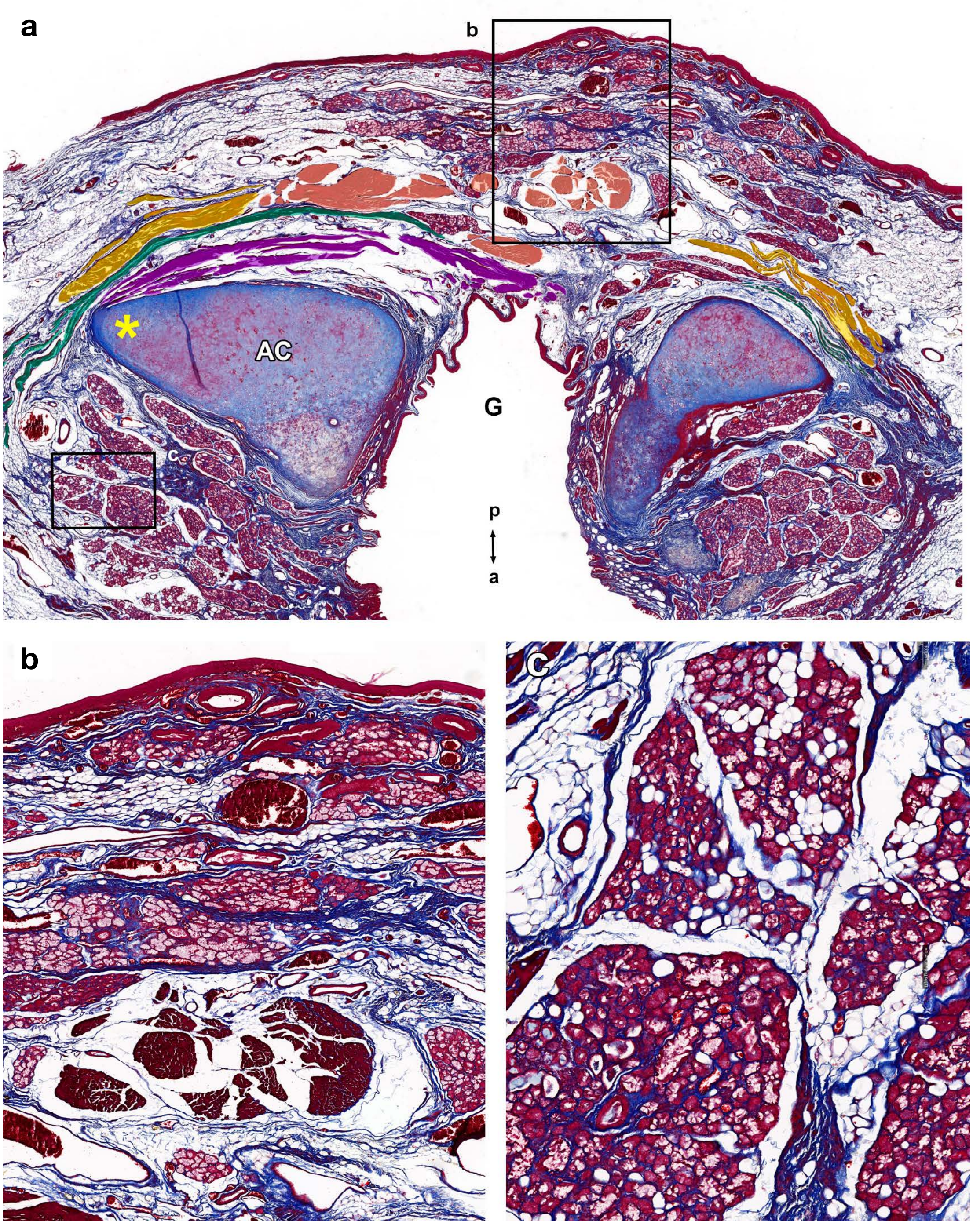


**Fig. 6.** Cross section of the AM in another specimen. (a) The intermediate layer of the tAM (colored green) between superficial (yellow) and deep (purple) layers diffused into the connective tissues of the lateral laryngeal frame. (b) Scattered glandular tissues localized between muscle bellies of the AM. (c) Lobulated submucosal glands anterior to the AC. Yellow asterisk, muscular process of the AC.

fascicle diffusing into the connective tissues.

Accurate knowledge of the anatomy can be helpful when surgically repositioning of the vocal cords in attempts to correct dysphonia. Laryngeal framework surgery involves planned changes in the length, tension, and mass of the vocal cords, whose optimal position is determined by muscle activity as constrained by movement of the cartilaginous joints of the laryngeal cartilages [16,19]. The technically challenging adduction surgery of the AC remains a treatment option for vocal cord paralysis because adduction of the AC plays an important role in posterior glottic closure [17,18]. AC dislocation can cause hoarseness, breathy voice, and dysphagia [20], while height asymmetry of the AC can play a significant role in voice quality [21]. Together these observations indicate that insufficient AC movement results in deleterious posterior glottic closure by the vocal cords. This study observed on case of severe AC asymmetry due to unusual musculature of the AM (Fig. 3), in which an unknown thick muscle belly originated from the middle of the CC, ascended under the tAM, and inserted to the AC. This means that an unilateral downward AC caused by unusual musculature of the AM would result in height asymmetry of the AC. Height mismatch of the AC could contribute to impaired vocal cord apposition that is related to poor voice restoration. Further studies are needed to characterize the correlations between asymmetry in the vocal cord positions and muscular variations of the AM.

The microstructures of the muscle fibers correlated with the AC and overlying connective tissues are also important for procedures that improve apposition of the vocal cords. The muscle bellies of the AM comprise the superficial oAM and deep tAM, and they insert to the muscular process of the AC. Our histological observations indicated that the tAM consists of multiple layers with an intermediate layer dispersing to the connective tissues on the lateral side, and others containing accessory bellies that ran vertically under the tAM. There was no clear boundary between the thyroarytenoid muscle and tAM in the muscular process of the AC. Submucosal glands were abundant in loose connective tissues of the posterior laryngeal frame and broad areas between the AC and the posterior glottic gap. The compositions of the mucous and serous acini differed between the pharyngeal mucosa covering the posterior laryngeal frame and the mucosa of the posterior glottic gap. Submucosal glands opening to the posterior glottic gap were dominant in the serous acinus compared with the pharyngeal mucosa. Secretions from this glandular tissue might be facilitated by AC adduction and lubricate the vocal cords.

In conclusion, the human AM showed morphological variations in musculature both macroscopically and microscopically. Diversity of the AC movement caused by an atypical AM attachment could influence posterior glottic closure by the vocal cords. More investigations on other laryngeal muscles related to the AC movement are needed to fully understand how the vocal cords are controlled. The results of this study will contribute to advance relevant anatomical knowledge for accurate diagnosis and treatment planning of laryngeal disorder such as dysphonia.

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