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Morphologic Characteristics of Palatopharyngeal Muscle

Abstract

In an effort to clarify the morphologic characteristics of the palatopharyngeal muscle, we examined the origin, insertion and positional relationship with other muscles. The origin of the palatopharyngeal muscle was both the oral and nasal sides of the soft palate, being also attached to both the palatal aponeurosis and soft palate median. However, in some cases, the muscle originated on the nasal side. When the palatopharyngeal muscle originated from both the oral and nasal sides, it traveled through its insertion via the levator muscle of the palatine velum. This insertion was seen in a wide area and could be divided into three parts; the pharynx anterior, central and posterior walls. In the central pharyngeal wall, insertion into the pharyngeal aponeurosis, inferior constrictor pharyngeal muscle and esophagus were observed. The present results suggest that the palatopharyngeal muscle has a close positional relationship with the levator and tensor muscles of the palatine velum, the pharyngeal constrictor muscles and the esophagus.

Key Words: Palatopharyngeal muscle, palatal muscles, soft palate, swallowing, pharynx, levator muscle of palatine velum, tensor muscle of palatine velum

I. Introduction

Swallowing results from the carefully coordinated movement of muscle groups in various many organs, including the oral cavity, soft palate, pharynx and esophagus. To better understand swallowing function, it is important to understand the morphologic characteristics of the muscle groups linking the oral cavity, pharynx and esophagus.

In current reports on the morphologic characteristics of the muscles from the pharynx through esophagus, variations in pharyngeal constrictor muscles have been noted. Many of these reports are related to the continuity of the buccal muscle and pharyngeal raphe variations[1, 2]. Bosma et al. reported that pharyngeal raphe tissue at the junction of hypopharynx and upper esophagus is replaced with loose connective tissue[3]. Hollinshed also reported that the upper esophageal aponeurosis is attached to cricoid cartilage [4]. These reports clearly indicate a close morphologic relationship between the oral cavity, pharynx and esophagus. However, the relationships between these organs and the soft palate largely remain unknown.

With regard to the morphologic characteristics of the muscle groups comprising the soft palate, Kuehn et al. [5,6] reported muscle bundle arrangements from a functional perspective. However, the relationship at the insertion site of the pharynx has not yet been elucidated. Furthermore, although there are histopathological reports on the bundle arrangements for the muscle groups comprising the soft palate [5,6], no studies have focused on the muscle bundles facing the important palatopharyngeal muscle insertion.

Although functional coordination between the soft palate and pharynx is necessary during swallowing, swallowing disturbance has been reported due to shifts in the timing of muscle motions [7,8]. Therefore, detailed

morphologic observation of running directions and insertion conditions of the palatopharyngeal muscle fibers from the soft palate through the pharynx is essential for understanding swallowing function. We thus performed morphologic observation of the palatopharyngeal muscle fibers with regard to running, origin and insertion attachment patterns, and relationships with surrounding muscles.

II. Materials and methods

1. Observation materials

A total of twenty Japanese adult cadavers (10 males and 10 females; age range, 49-90 years) fixed with neutral buffered 10% formalin solution and provided for anatomical practice to the Department of Anatomy at Tokyo Dental College were used. Medical records of the cadavers were not available. However, on gross inspection, oropharyngeal structures appeared to be normal.

2. Dissection of palatopharyngeal muscle

After performing sagittal section of the head and neck, the masseter muscle, zygomatic arch, part of the mandibular ramus, temporal muscle, lateral pterygoid muscle and medial pterygoid muscle were removed. Cervical vertebrae localized in the posterior pharynx were also removed. With regarding to the soft palate, the palatoglossal muscle was removed and the palatopharyngeal muscle was exposed for observation from the oral and nasal sides.

3. Observation region

1) Origin of palatopharyngeal muscle

We investigated the presence of the palatopharyngeal muscle origin

through the oral and nasal directions. The locus relationship between the palatopharyngeal muscle and the levator muscle of palatine velum was also observed through the oral and nasal directions. Classification was performed based on the oral side locus relationship, followed by observation of the nasal side locus relationship of each part.

2) Insertion of palatopharyngeal muscle

Confluence of the palatopharyngeal muscle with the salpingopharyngeus muscle is already known [9]. Moreover, some reports have considered the salpingopharyngeus muscle to be part of the palatopharyngeal muscle [10]. This makes distinction of the two muscles difficult [11]. Therefore, we excluded cases having a salpingopharyngeus muscle.

As insertion of the palatopharyngeal muscle covers a large area of the hypopharynx, morphologic observation was performed by dividing the palatopharyngeal muscle into 3 regions; anterior, posterior and central.

III. Results

1) Origin of palatopharyngeal muscle

(1) Observation from oral side

Two regions of the palatopharyngeal muscle origin were seen on the oral side. Origin from the posterior of the palatine aponeurosis (Oral Tendineus (OT); 20 out of 20 cases) was observed, and origin with interlacing fibers at the median portion of the soft palate from the contralateral palatopharyngeal muscle were seen (Oral Median (OM); 20 out of 20 cases). On the oral side, OT and OM were seen in all cases (Fig. 1).

(2) Observation from nasal side

Two regions of the palatopharyngeal muscle origin were seen on the nasal

side. Origin from the posterior of the palatine aponeurosis (Nasal Tendineus (NT); 14 out of 20 cases) and at the median portion of the soft palate, and origin with interlacing fibers from the contralateral palatopharyngeal muscle (Nasal Median (NM); 17 out of 20 cases) were observed.

NT did was not seen the posterior palatine aponeurosis area. Rather, it was observed in a narrow area of the palatine aponeurosis medial to the vertical section of the levator muscle of the palatine velum (vertical muscle bundles running from the temporal bone to the soft palate) (Fig. 2). Moreover, insertion from the posterior palatine aponeurosis near the hamulus pterygoideus lateral to the vertical section of the levator muscle of palatine velum was observed (Fig. 3)

2) Positional relationship with levator muscle of palatine velum

(1) Observation from oral side

The palatopharyngeal muscle at the oral side (MOP) originated at the posterior (OT) and median (OM) parts of the palatine aponeurosis. From the positional relationship of MOP with the levator muscle of the palatine velum, two types were observed:

Type 1: MOP running through the anterior part of the oral side of the levator muscle of the palatine velum (17 out of 20 cases).

Type 2: MOP covering all the levator muscle of the palatine velum on the oral side (3 out of 20 cases) (Fig. 4).

(2) Observation from nasal side

The palatopharyngeal muscle at the nasal side (MNP) originated at the posterior (NT) and median (NM) palatine aponeurosis.

The two types (O1 and O2) classified on observation of the oral side were also examined from the nasal side.

Observation of O1 from the nasal side (MOP running through the anterior part of the oral side of the levator muscle of the palatine velum) revealed two subtypes according to the positional relationship of MNP with the levator muscle of the palatine velum. These are:

N1a type; MNP running through the nasal side of the levator muscle of the palatine velum (12 out of 17 cases).

N1b type; MNP interlacing with the levator muscle of the palatine velum (5 out of 17 cases) (Fig. 5).

Nasal side observation of O2 (muscle bundle MOP covering all the levator muscle of palatine velum) revealed depletion of MNP (Fig. 6)

3) Insertion of palatopharyngeal muscle

Because the palatopharyngeal and salpingopharyngeus muscles run vertically to the hypopharynx after merging at the lower portion of the palatopharyngeal arch, distinction between the two parts is difficult. Thus, we observed the insertion of the palatopharyngeal muscle in cases with depletion of the salpingopharyngeus muscle (15 out of 20 cases) (Fig. 7).

On observation from the intrapharyngeal side, the palatopharyngeal muscle comprising the palatopharyngeal arch, the muscle bundle originating from the oral side of the soft palate (MOP) and the muscle bundle originating from the nasal side of the soft palate (MNP) interlaced, merged and extended like a fan running downward, and finally inserted into a wide area in the pharynx wall. These muscles exhibited 2 layers; a superficial layer (luminal side) mainly composed of MNP, and a deep layer (outer wall side) composed of MOP (Fig. 8).

(1) Insertion observation of anterior part

In the anterior part of the pharynx, both the palatopharyngeal muscle

and the stylopharyngeus muscle were observed. The stylopharyngeus muscle ran in the anteroinferior direction of the deep layer of the palatopharyngeal muscle. However, in some cases, the distinction between the palatopharyngeal muscle and the stylopharyngeus muscle was clear (5 out of 15 cases), while in other cases, the distinction between the palatopharyngeal muscle and the stylopharyngeus muscle was not clear due to confluence of the two muscles (10 out of 15 cases).

With regard to the 5 cases in which distinction between the palatopharyngeal muscle and the stylopharyngeus muscle was possible, insertion of the palatopharyngeal muscle into the piriform fossa and into the posterior border of the thyroid cartilage was seen in 2 cases, while insertion into the posterior border of the thyroid cartilage was seen in 3 cases (Fig. 9). However, in all 10 cases showing confluence of the palatopharyngeal muscle with the stylopharyngeus muscle, insertion into the posterior border of the thyroid cartilage was seen (Fig. 10). Insertion into the piriform fossa was not clearly observed due to the difficulty in distinguishing the palatopharyngeal muscle from the stylopharyngeus muscle. When the palatopharyngeal muscle inserted into the anterior part, the muscle bundle (MOP) tended to originate on the oral side.

(2) Insertion observation of posterior part

In the posterior pharynx, the palatopharyngeal muscle inserted into the pharyngeal raphe.

The muscle bundle originating on the oral side (MOP) inserted at a higher point than the muscle bundle originating on the nasal side (MNP) (Fig. 8).

The muscle bundle originating from the posterior palatine aponeurosis of

the hamulus pterygoideus origin on the nasal side (NP; Fig. 3), part of the muscle bundle within the soft palate, merged with MOP and ran along the pharyngeal wall outer surface in the posterior direction. This muscle bundle inserted into the superior part of the pharyngeal raphe (pharyngeal luminal side) located in the superficial layer (Fig. 11).

(3) Insertion observation of central part

The palatopharyngeal muscle inserted into the central pharynx had 3 types.

Type 1: Muscle bundle inserted into the pharyngeal aponeurosis (10 out of 15 cases; Fig. 12).

Type 2: Muscle bundle inserted into the pharyngeal aponeurosis and interlaced with the horizontal running inferior constrictor pharyngeal muscle (4 out of 15 cases; Fig. 13).

Type 3: Muscle bundle inserted into the pharyngeal aponeurosis and ran horizontally through the esophageal inner circular muscle layer of the luminal side (1 out of 15 cases; Fig. 14).

However, all tissues at the superior part of the esophagus were dissected. As a result, the fibers in the esophagus could be examined, but the insertion conditions could not be observed. The muscle bundle originating from the oral side (MOP) and the muscle bundle originating from the nasal side (MNP) could not be distinguished due to the confluence and interlacing.

IV. Discussion

Although classical textbooks describe the origin of the palatopharyngeal muscle as being in the hard palate and palatine aponeurosis [9), 12-14)], the present study found the muscle to originate in the

palatine aponeurosis, but not in the hard palate. The palatopharyngeal muscle originated from the palatine aponeurosis and the median part of soft palate on both the oral and nasal side. The palatine aponeurosis is reported to comprise the anterior part of the soft palate through reciprocal merging of the contralateral tensor muscle of palatine velum with the ipsilateral tensor muscle of palatine velum after its tendon turns around the hamulus pterygoideus [15].

Although depletion of the palatine aponeurosis origin and the soft palate median region was not seen on the oral side, unilateral or bilateral sparseness of the origin was observed on the nasal side, thus suggesting a developmental difference from the oral side. The palatopharyngeal muscle originates from the surface of the palatine aponeurosis on oral and nasal sides, and exhibits a morphologic origin, for example, holding the posterior part of the palatine aponeurosis from both the oral and nasal sides. Our results suggest that joining of the insertion of the palatine velum tensor muscle with the palatopharyngeal muscle originating from the palatine aponeurosis occurs in the sequential function of mastication and swallowing movements.

With regard to the positional relationship between the palatopharyngeal muscle and the levator muscle of the palatine velum, Shimokawa et al. reported that the levator muscle of palatine velum was held by the palatopharyngeal muscle [16]. However, the detailed positional relationship of the two muscles has not yet been reported. In the present research, muscle bundles originating from the oral and nasal sides of the palatopharyngeal muscle passed along the oral and nasal sides of the levator muscle of the palatine velum. In cases with a depleted nasal side origin and

palatopharyngeal muscle, the origin of the median part on the oral side exhibited an attachment hiding the levator muscle of the palatine velum. Thus, the palatopharyngeal muscle held the levator muscle of the palatine velum, and despite the deficient bundle on the nasal side, it merges with the levator muscle of palatine velum in the oral side. Thus, movement of the soft palate, such as elevation and descending is performed smoothly. Moreover, the palatopharyngeal muscle originated from a limited region of the posterior palatine aponeurosis, and inserted into the pharyngeal raphe after posteriorly passing the superficial layer of the superior constrictor pharyngeal muscle. The palatine aponeurosis was localized laterally to the horizontal section of the levator muscle of palatine velum observed on the nasal side of the soft palate.

Whillis reported that part of the superior constrictor pharyngeal muscle was located in the soft palate and described this as the palatopharyngeal sphincter [17]. However, our results showed that part of the muscle bundle of the transverse section of the palatopharyngeal muscle merged with the muscle bundle on the oral side and ran inferiorly along the pharynx luminal wall. The distinction between the palatopharyngeal muscle and the superior constrictor pharyngeal muscle in the vicinity of the hamulus pterygoideus was largely clear. The transverse part of the palatopharyngeal muscle passed from the soft palate through the pharyngeal raphe and superficial layer of the superior constrictor pharyngeal muscle. This suggests that it participates in forming Passavant's ridge in the superior pharynx during nasopharyngeal closure[11]. The palatopharyngeal muscle also participates in closure of the nasopharynx by supporting the elevation of the soft palate by the palatine velum levator muscle, and

antero-posterior protrusion of the posterior pharynx wall by the superior constrictor pharyngeal muscle[11].

Classical textbooks mention that the palatopharyngeal muscle inserts into the thyroid cartilage, the pharynx lateral wall and the pharyngeal raphe [9, 12-14]. It has also been reported that part of the muscle bundle inserts into the piriform fossa [18] or the esophagus [14]. However, Cassel et al.[19] revised the classical description by separating vertically running fibers from the soft palate to the larynx and inferior pharynx as the palatothyroideus, and horizontal muscle fibers running from the soft palate laterally and posteriorly into the superior pharynx as the true palatopharyngeal muscle. Thus, there are different opinions regarding the insertion of the palatopharyngeal muscle.

In the present study, the palatopharyngeal muscle originating from the oral side mainly inserted into the posterior border of the thyroid cartilage (part also inserted into the piriform fossa) and into a wide area from superior to inferior region of the pharyngeal raphe. The muscle bundles originating from the nasal side inserted into the pharyngeal aponeurosis (part also inserted into posterior border of the thyroid cartilage) and into a narrow area from the middle to inferior region of the pharyngeal raphe. This suggests that even when the palatopharyngeal muscle originating from the nasal side is depleted, the palatopharyngeal muscle originating from the oral side inserts into a wide area to compensate for this deficiency, thereby maintaining normal swallowing function. Moreover, insertion into the pharyngeal raphe in the median pharynx, interlacing of the palatopharyngeal muscle bundle with the inferior pharyngeal constrictor muscle, and its longitudinal running down the luminal side of the esophageal

inner circular muscle layer all suggest that the palatopharyngeal muscle supports the sequential swallowing process from the pharyngeal phase to esophageal phase.

The results of the present study suggest that the palatopharyngeal muscle has a close topographic relationship with the levator muscle of the palatine velum, the tensor muscle of the palatine velum, the pharyngeal constrictor muscles and the esophagus, and that it is involved in sequential swallowing function during the pharyngeal stage, as well as the oral and esophageal stages.

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Figure legends

Fig. 1. Origin on oral side.

Oral Tendineus (OT): Origin of the palatal aponeurosis posterior border on the oral side, Oral Median (OM): Origin of the soft palate median part, PB: Palatal bone, PA: Palatal aponeurosis, LVP: Levator muscle of the palatine velum (crossing internal part of the soft palate), UV: Uvula, SPC: Superior pharyngeal constrictor muscle, MOP: Palatopharyngeal muscle originating on the oral side, MNP: Palatopharyngeal muscle originating on the nasal side.

Fig. 2. Origin on nasal side.

Nasal Tendineus (NT): Origin of the palatal aponeurosis on the nasal side, Nasal Median (NM): Origin of soft palate median part, LVP: Levator muscle of the palatine velum (longitudinal fibers lying from origin to soft palate), UV: Uvula, SPC: Superior pharyngeal constrictor muscle, TVP: Tensor muscle of palatine velum, PA: Palatal aponeurosis, MOP: Palatopharyngeal muscle originating on oral side, MNP: Palatopharyngeal muscle originating on nasal side. To observe origin of NM median part on the nasal side, part of the musculus uvulae, which is localized superficially, was removed.

Fig. 3. Origin was posterior of the palatal aponeurosis near the hamulus pterygoideus (NP).

Part of the NP muscle bundle merged with the MOP within the soft palate. Asterisks: Palatopharyngeal muscle originating from NP, Arrows: Hamulus pterygoideus, PB: Palatine bone, LVP (1): Levator muscle of the palatine velum (longitudinal fibers lying from temporal bone to soft palate), LVP (2): Levator muscle of palatine velum (crossing fibers into soft palate), UV: Uvula,

TVP: Tensor muscle of palatine velum PA: Palatine aponeurosis, MOP: Palatopharyngeal muscle originating on oral side, MNP: Palatopharyngeal muscle originating on nasal side, SPC: Superior pharyngeal constrictor muscle.

Fig. 4. Positional relationship of palatopharyngeal muscle with levator muscle of the palatine velum on oral side.

O1 type: MOP passes anterior of the levator muscle of palatine velum, O2 type: MOP covers the levator muscle of palatine velum, MOP: Palatopharyngeal muscle originating on oral side, LVP: Levator muscle of the palatine velum, MNP: Palatopharyngeal muscle originating on nasal side.

Fig. 5. Observation of O1 type on nasal side.

N1a: Palatopharyngeal muscle on the nasal side (MNP) passes through the nasal side of the levator muscle of palatine velum, N1b: Palatopharyngeal muscle on the nasal side (MNP) interlaces with the levator muscle of palatine velum, Dotted line: Path of levator muscle of the palatine velum on nasal side, Black arrow: Interlacing with levator muscle of the palatine velum, MNP: Palatopharyngeal muscle originating on nasal side, LVP: Levator muscle of the palatine velum, ATC: Auditory tube cartilage, UV: Uvula, T: Tongue.

Fig. 6. Observation of O2 type on nasal side.

The palatopharyngeal muscle on the nasal side (MNP) was deficient.

MOP: Palatopharyngeal muscle originating on oral side, LVP: Levator

muscle of the palatine velum, ATC: Auditory tube cartilage, UV: Uvula, T: Tongue.

Fig. 7. Relationship between palatopharyngeal muscle and salpingopharyngeal muscle.

A: Merged with salpingopharyngeal muscle (5 out of 20 cases), B: Salpingopharyngeal muscle is deficient (15 out of 20 cases), PP: Palatopharyngeal muscle, SP: Salpingopharyngeal muscle, ATC: Auditory tube cartilage, LVP: Levator muscle of the palatine velum, UV: Uvula, T: Tongue.

Fig. 8. Distribution of palatopharyngeal muscle originating on oral side (MOP) and palatopharyngeal muscle originating on nasal side (MNP).

MOP runs in a deeper layer than MNP.

Dark gray area: MNP, Light gray and dark gray areas: MOP, ST: Stylopharyngeal muscle (runs in a deeper layer than MOP), SPC: Superior pharyngeal constrictor muscle (runs in a deeper layer than MOP), ATC: Auditory tube cartilage, LVP: Levator muscle of the palatine velum, TVP: Tensor muscle of the palatine velum, TC: Thyroid cartilage, PA: Pharyngeal aponeurosis, EP: Epiglottis, LA: Larynx, PR: Pharyngeal raphe.

Fig. 9. Cases in which distinction between the palatopharyngeal and stylopharyngeal muscles was possible.

A: Palatopharyngeal muscle inserts into the piriform fossa and posterior border of the thyroid cartilage (2 out of 5 cases), B: Cases with insertion into the posterior border of the thyroid cartilage (3 out of 5 cases), PP:

Palatopharyngeal muscle, ST: Stylopharyngeal muscle (runs in a deeper layer than the palatopharyngeal muscle), T: Tongue, EP: Epiglottis, TC: Thyroid cartilage.

Fig. 10. Confluence of palatopharyngeal muscle with stylopharyngeal muscle.

PP: Palatopharyngeal muscle, ST: Stylopharyngeal muscle (runs in a deeper layer than the palatopharyngeal muscle), T: Tongue, EP: Epiglottis, LA: Larynx, TC: Thyroid cartilage.

Fig. 11. Traveling and insertion of muscle bundle originating from NP.

White arrows: Muscle bundle from OP crosses, Dotted line: Pharyngeal raphe, PA: Palatine aponeurosis, LVP: Levator muscle of the palatine velum (longitudinal fibers from origin into soft palate), MNP: Palatopharyngeal muscle originating on nasal side, PPA: Palatopharyngeal arch, UV: Uvula, T: Tongue.

Fig. 12. Type I (Palatopharyngeal muscle bundle inserts into pharyngeal aponeurosis).

PP: Palatopharyngeal muscle, TC: Thyroid cartilage, PA: Pharyngeal aponeurosis, EP: Epiglottis, LA: Larynx, PR: Pharyngeal raphe, TR: Trachea, ES: Esophagus.

Fig. 13. Type II (Palatopharyngeal muscle inserts after interlacing with the inferior pharyngeal constrictor muscle).

Black arrow: Palatopharyngeal muscle crosses into the inferior pharyngeal

constrictor muscle, IPC: Inferior pharyngeal constrictor muscle, PP: Palatopharyngeal muscle, EP: Epiglottis, LA: Larynx, TC: Thyroid cartilage.

Fig. 14. Type III (Palatopharyngeal muscle passes through the surface of the esophagus inner circular muscle).

PP: Palatopharyngeal muscle, ES: Esophagus, EP: Epiglottis, LA: Larynx, TC: Thyroid cartilage, TR: Trachea.

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Figure

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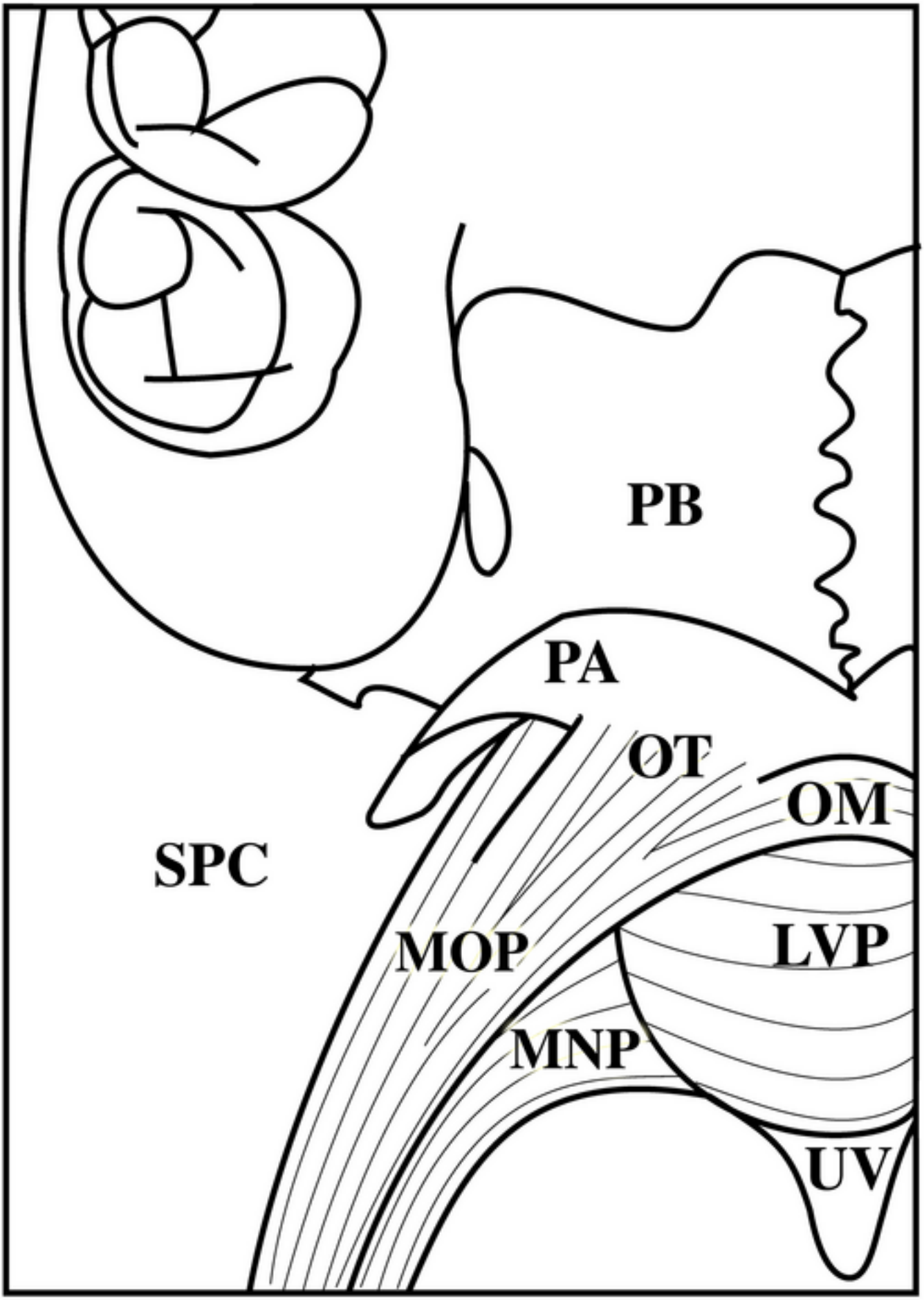

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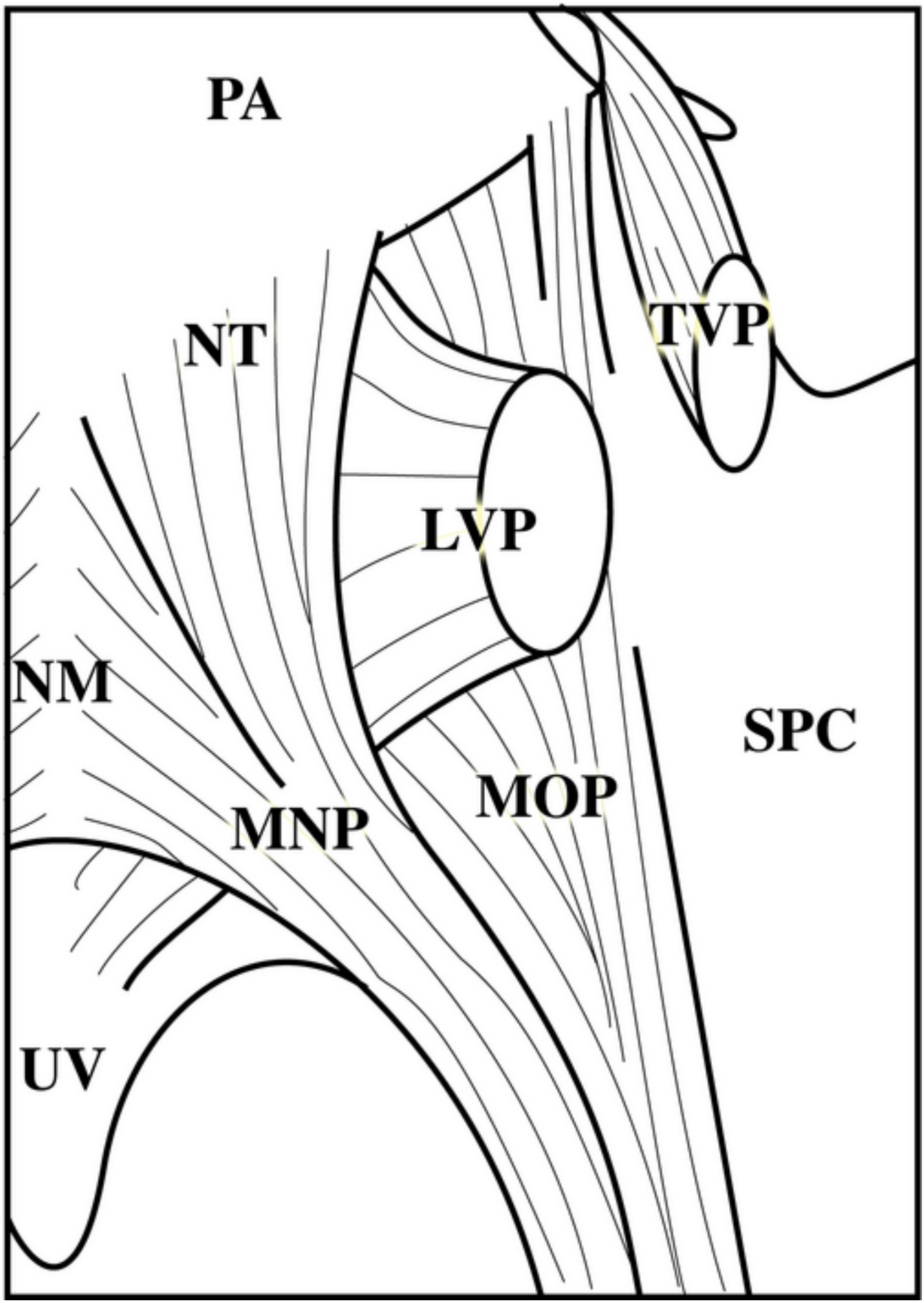

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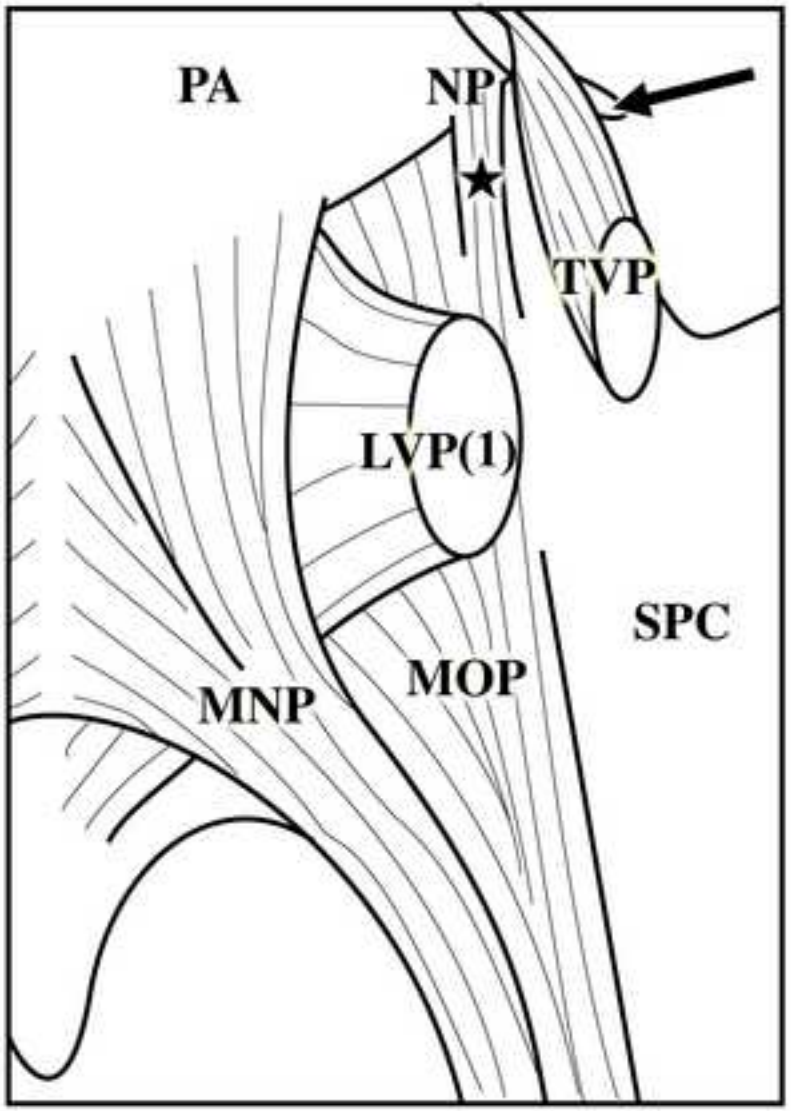

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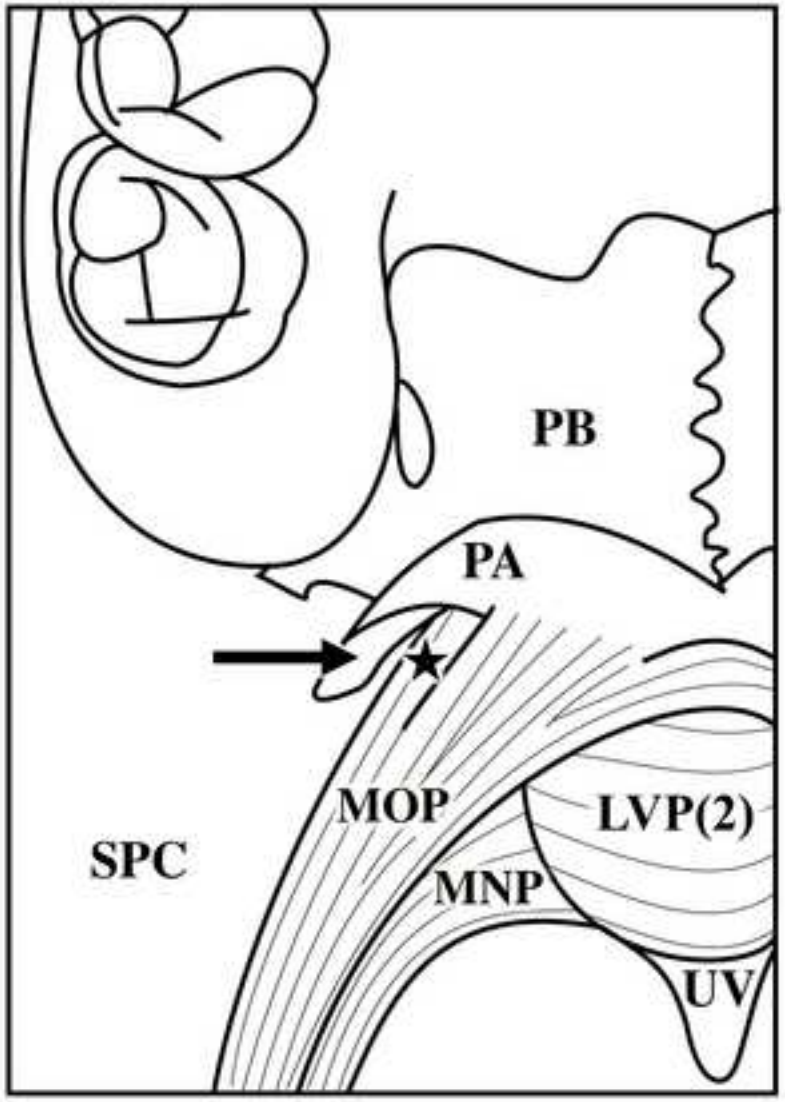

Oral side

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O1 type

O2 type

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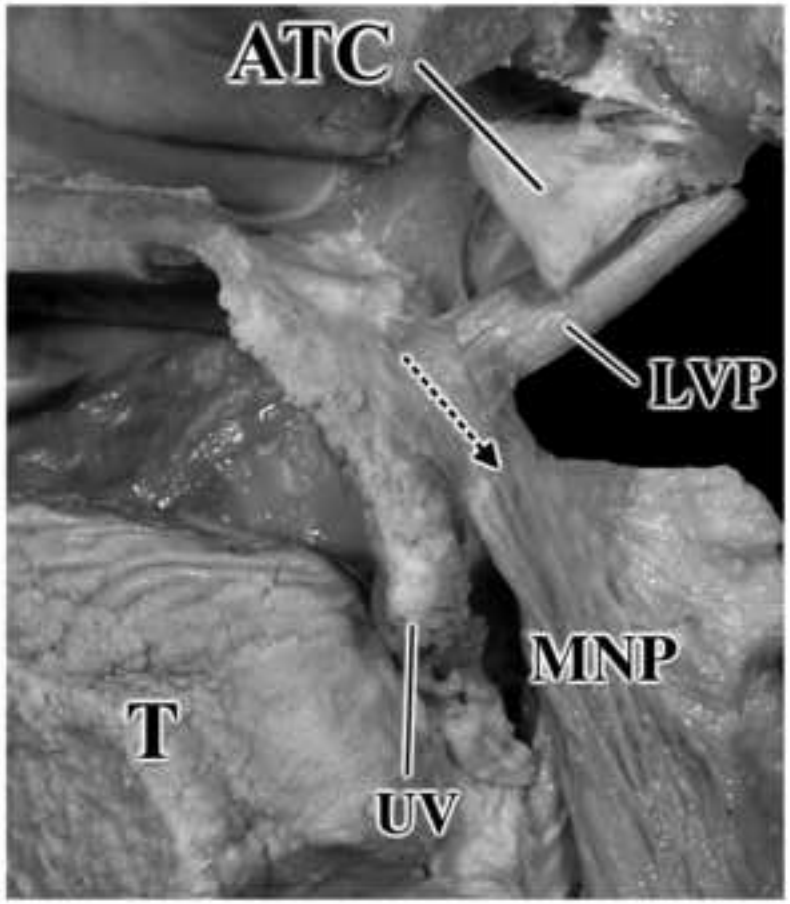
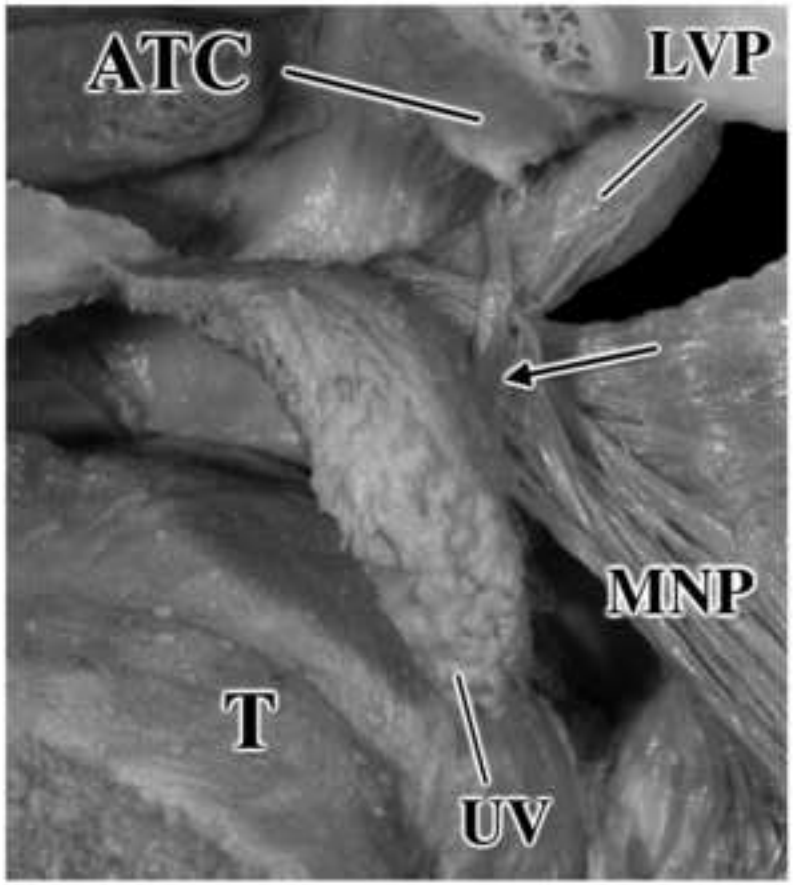


N1a type



N1b type

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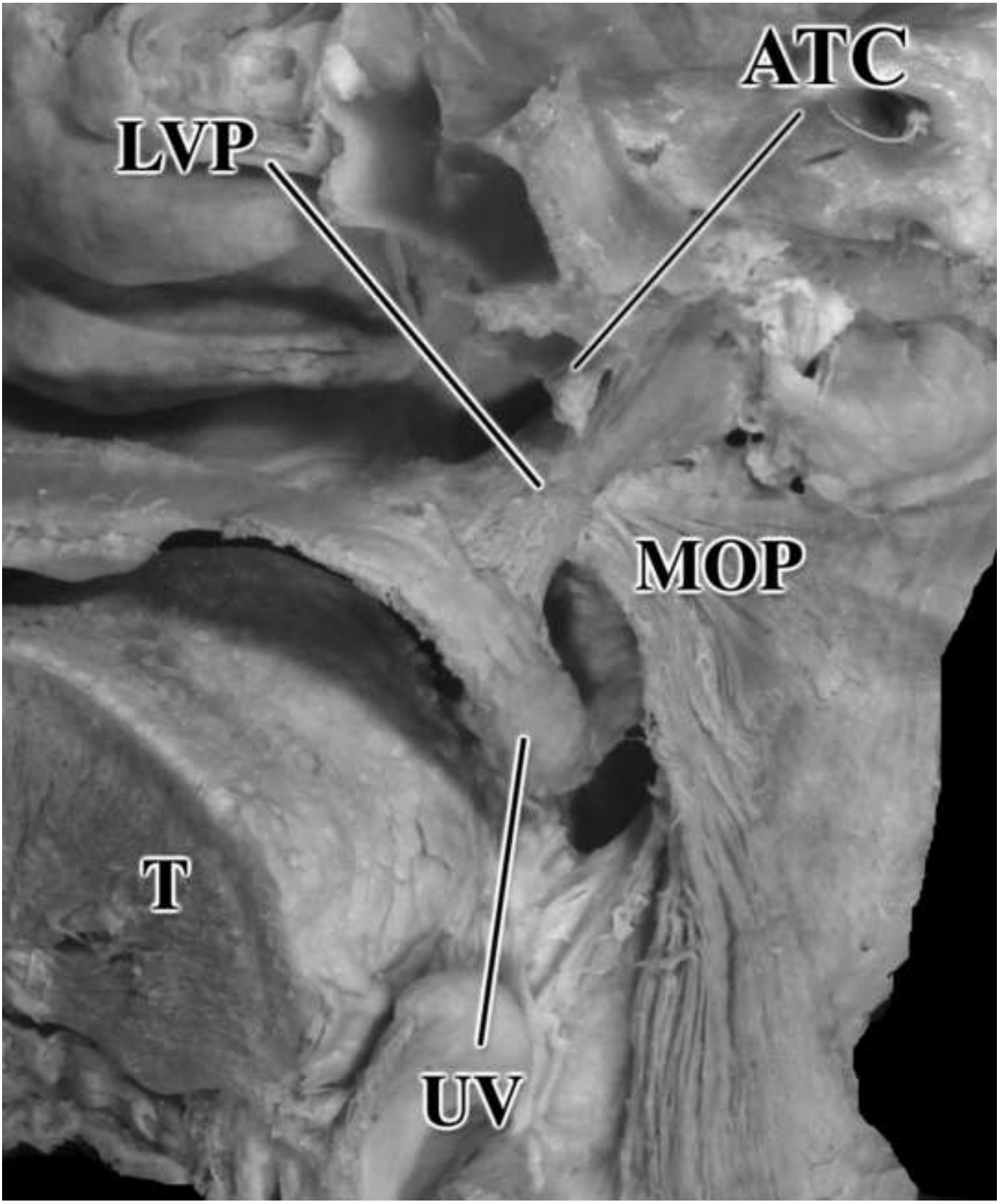

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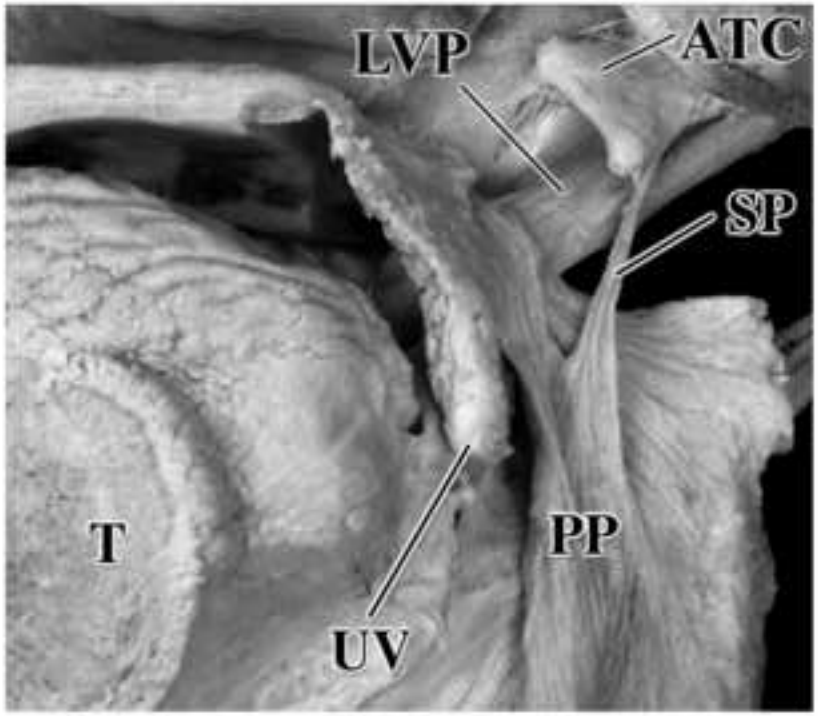

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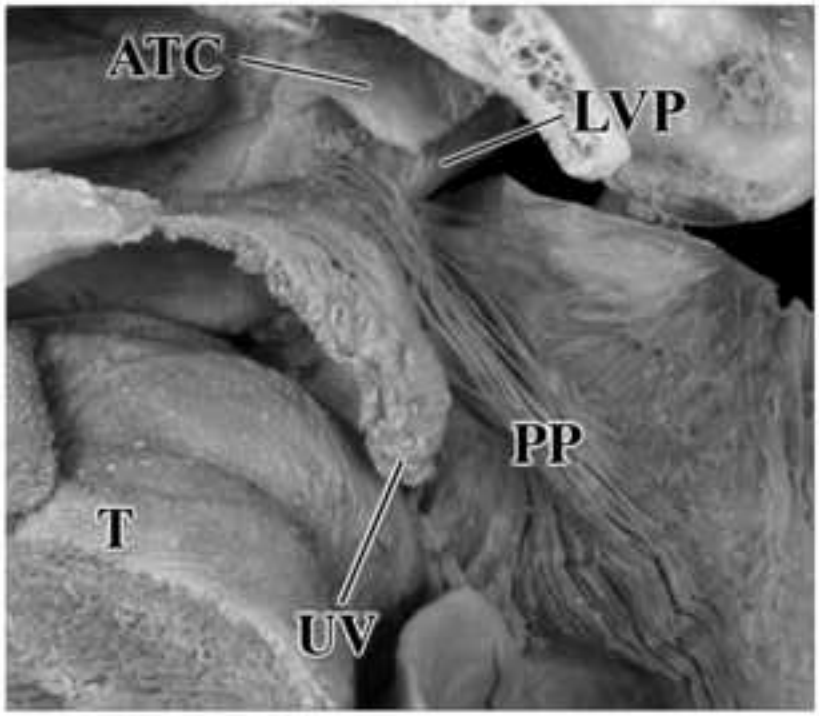

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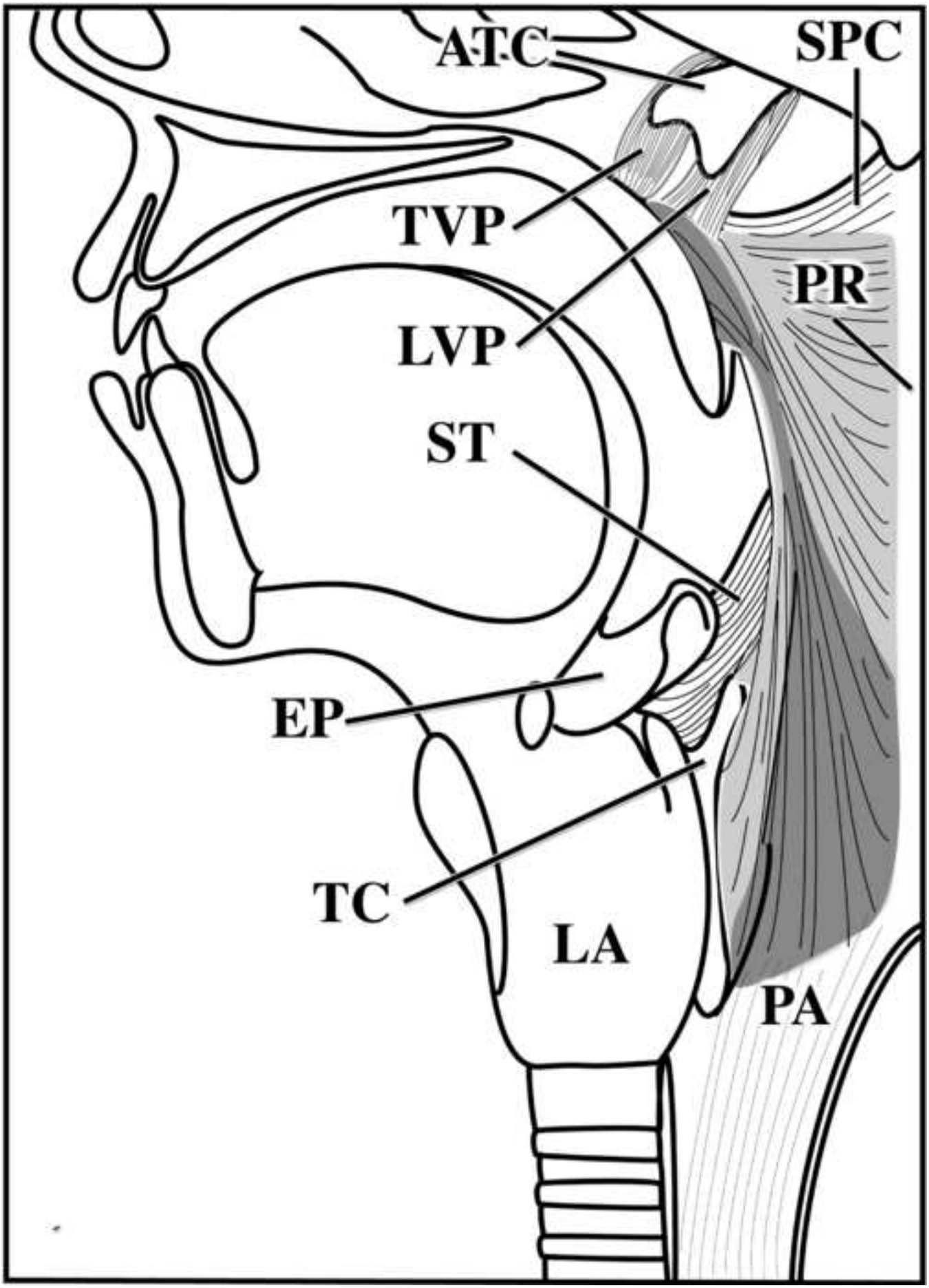

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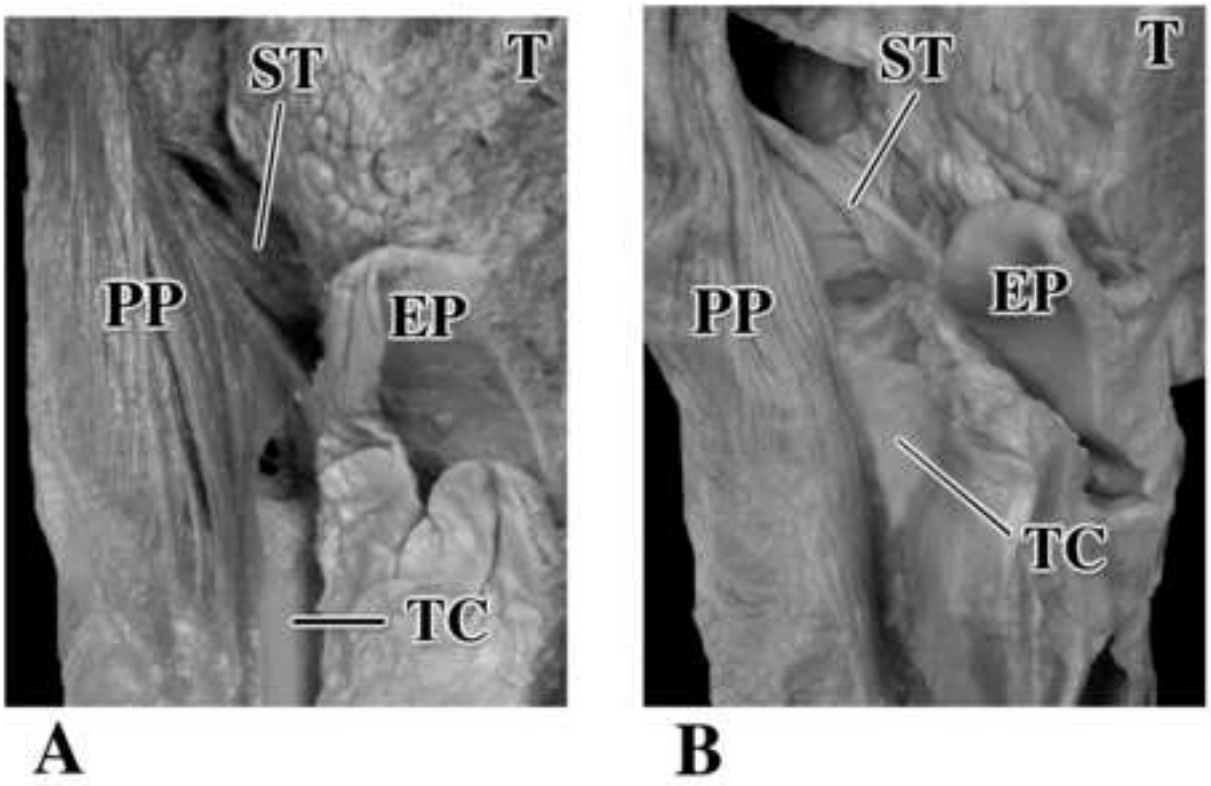

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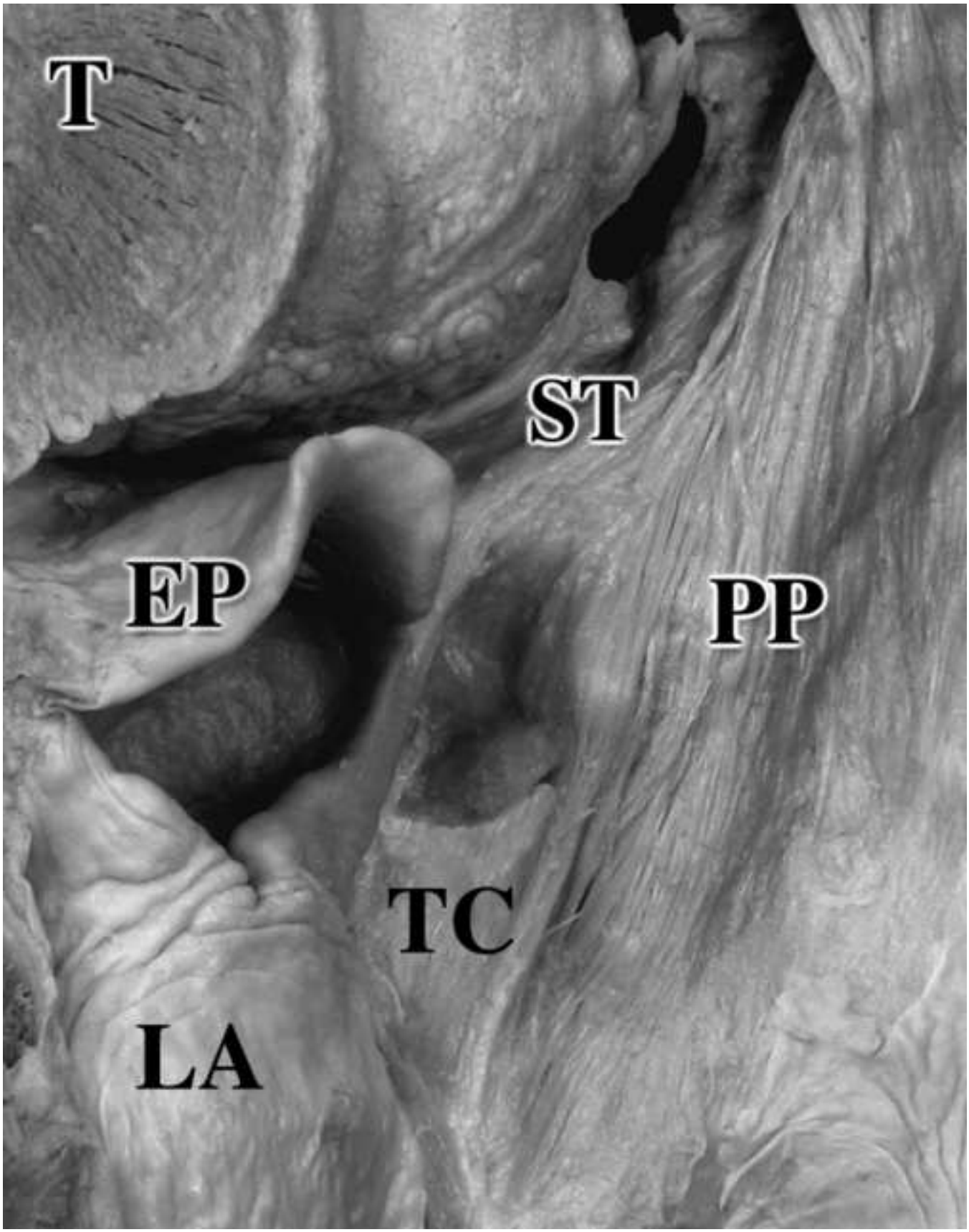

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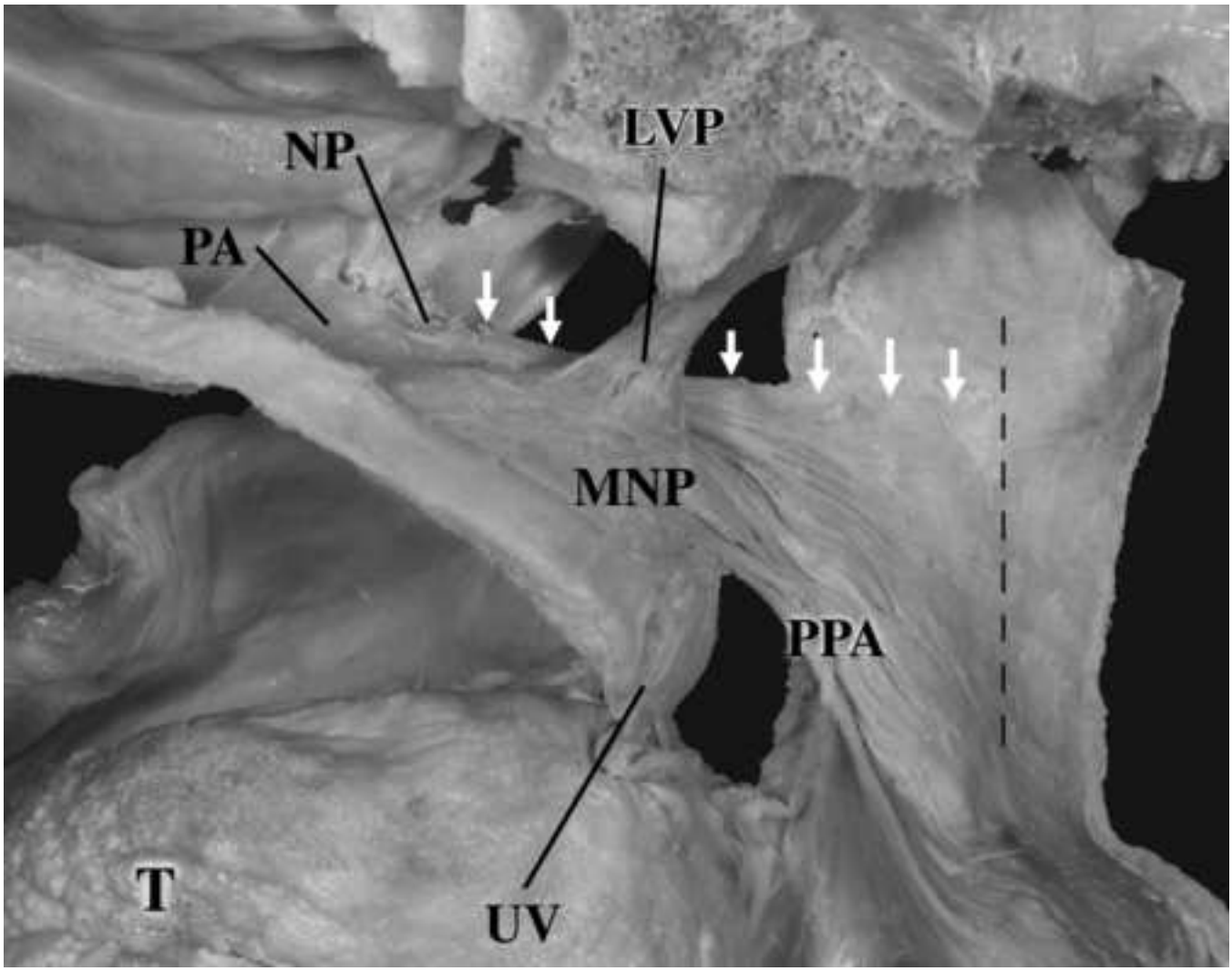

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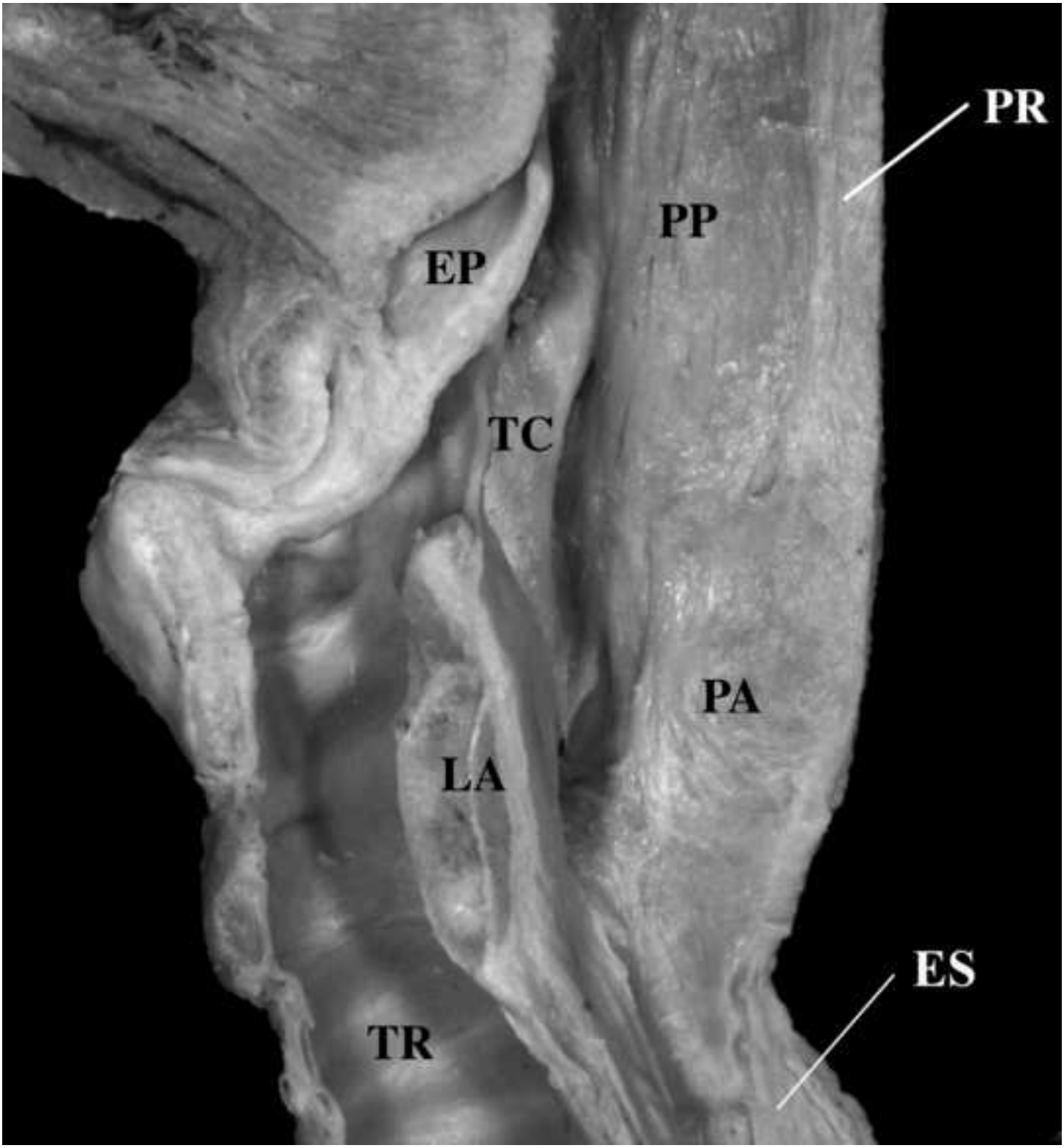

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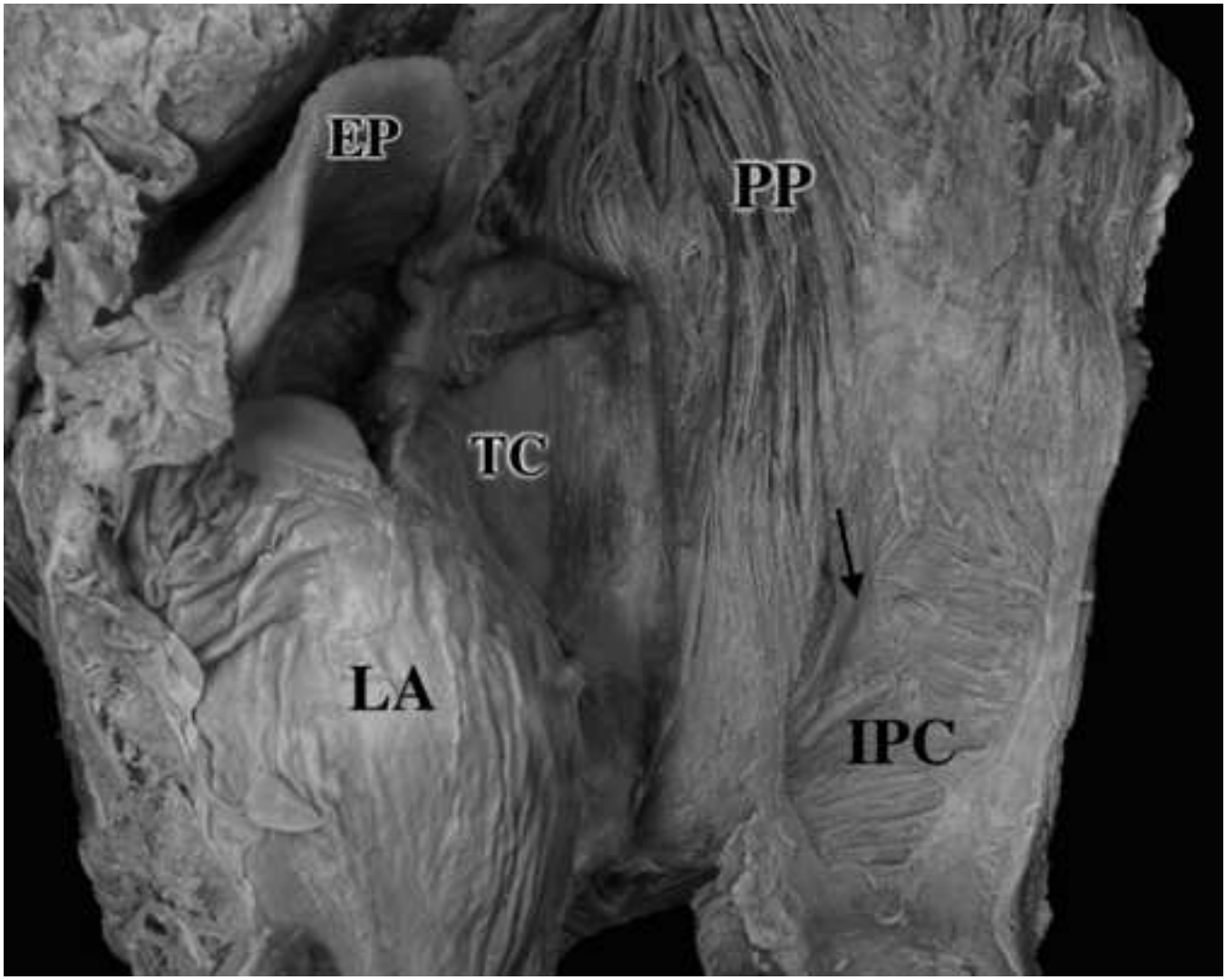

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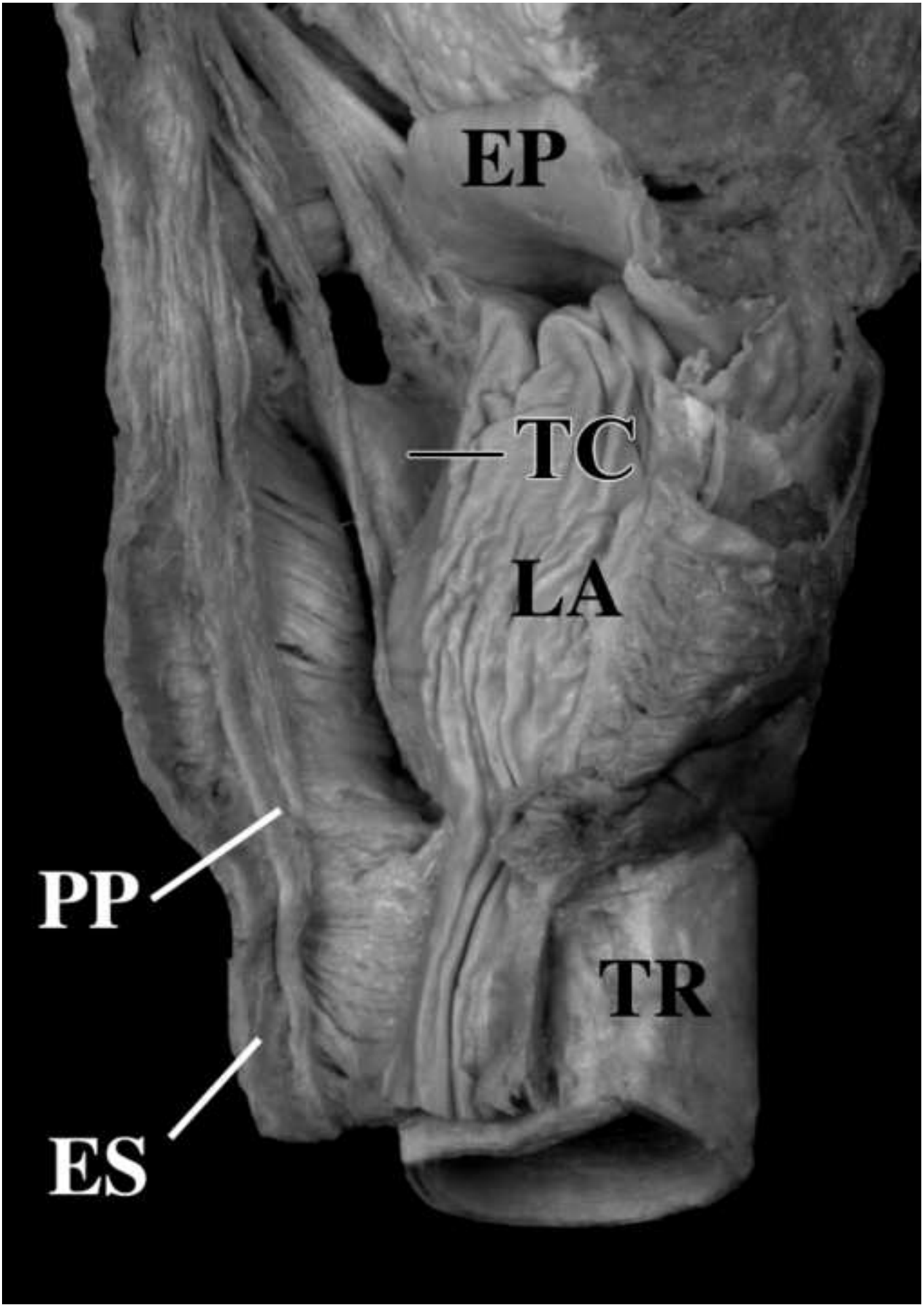

Morphologic Characteristics of Palatopharyngeal Muscle

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*** Response to Reviewer Comments (must not contain author information)**

September 25, 2007
Bronwyn Jones
Editor-in-Chief
Dysphagia

Dear Professor Bronwyn Jones

Re: Dysphagia - Decision on Manuscript "Morphologic Characteristics of Palatopharyngeal Muscle during Swallowing Function"

Thank you very much for reviewing our manuscript. I am sending herewith the english-check revisions to our manuscript.

With kind regards,

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