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ORIGINAL ARTICLE

Prestyloid compartment of the parapharyngeal space: a histological study using late-stage human fetuses

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Abstract
Purpose Although the prestyloid space is well known, its definition still remains unclear.
Methods Using semiserial sagittal sections of 15 late-stage human fetal heads, we studied details of the topographical anatomy.
Results A definite posterior marginal fascia of the space was seen along the anterior aspect of the stylopharyngeus and styloglossus muscles. Inferiorly, the prestyloid space faced the bucallis and medial pterygoid muscles and the submandibular gland. The external carotid artery ran along the posterolateral side of the space. The tensor veli palatini fascia did not contribute to the posterior marginal fascia. A major supplying artery of the space was the ascending palatine artery.
Conclusions The prestyloid compartment of the parapharyngeal space (hereafter, the prestyloid space) seems to correspond to a border between the first and second pharyngeal arch derivatives. This concept may provide a better understanding of prestyloid space.

Keywords Parapharyngeal space · Prestyloid space · Levator veli palatini fascia · Submandibular gland · Human fetuses

Introduction

According to Ichimura et al. [5], the parapharyngeal space has traditionally been divided by the styloid process and

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the tensor veli palatini fascia (nasopharyngeal level) or the stylopharyngeus muscle fascia (oropharyngeal level) into two compartments: the prestyloid and poststyloid compartments. The prestyloid compartment exclusively contains fat tissue, which is demonstrated as an area of absorption on CT films and as a high-density area on MRI. Previous descriptions have led researchers to consider that the posterior margin of the prestyloid space varies depending on the supero-inferior level. Based on this anatomical understanding, Tomita et al. [18] considered that tumors arising in the prestyloid (or poststyloid) compartment of the parapharyngeal space are of salivary gland origin (or schwannoma or paraganglioma). They concluded that surgery should be automatically indicated for the former tumors because the surgical risk is lower than the risk of inaction. Such understanding of the anatomy and pathology seems to have been maintained in recent studies [1, 6].

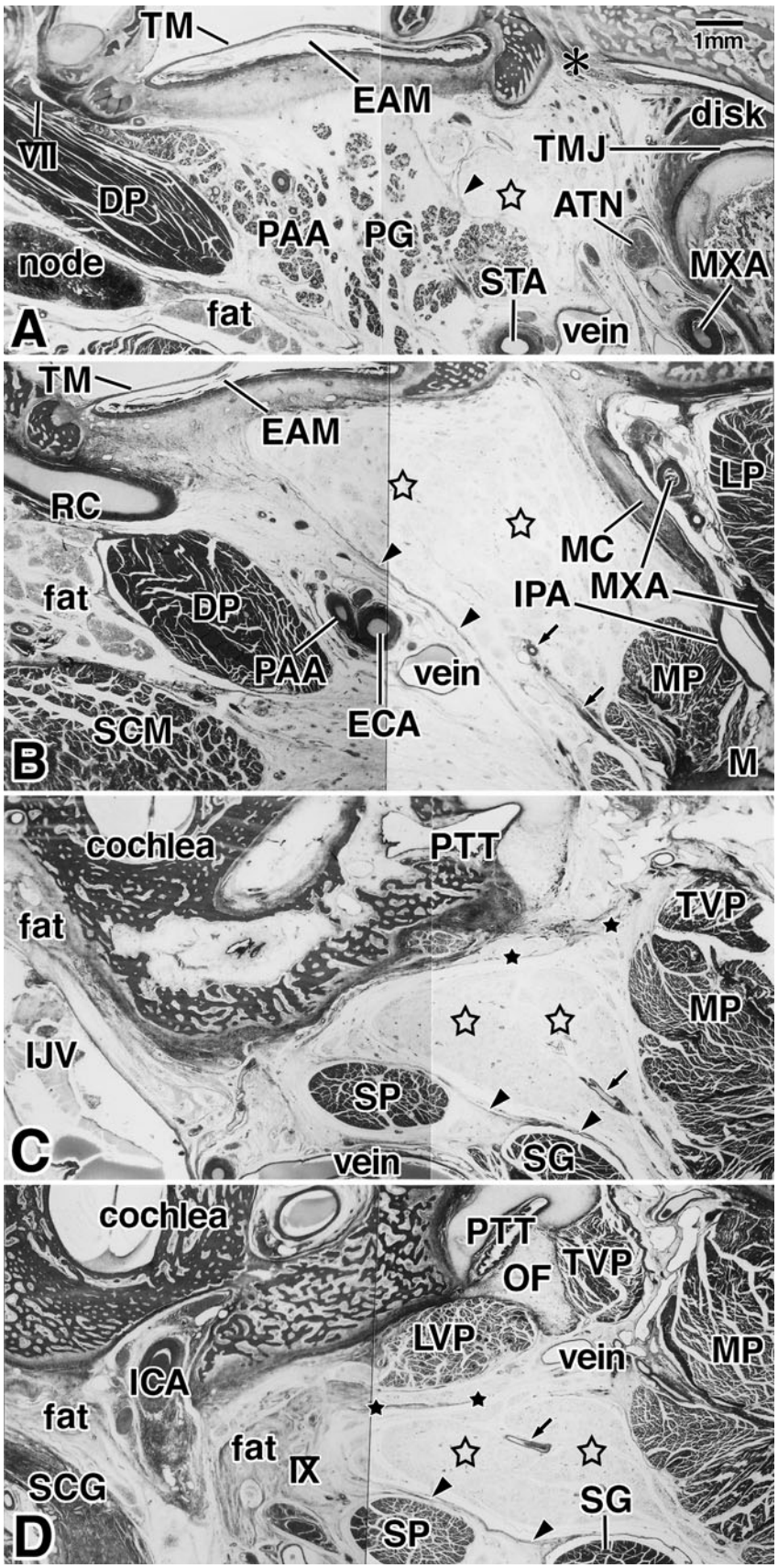
Shin et al. [17] defined the "tensor-vascular-styloid fascia" (or TVS fascia) as the posterior margin of the prestyloid space on the basis of MRI observations. The same fascia was called simply "the tensor veli palatini fascia" by Curtin on the basis of a dissection study [2]. Also according to dissection observations, Maheshwar et al. [10] considered that the tensor veli palatini fascia divides the upper part of the prestyloid space into (1) an anterolateral compartment containing fat and a deep part of the parotid gland and (2) a posteromedial compartment containing the cartilaginous part of the Eustachian tube, internal carotid artery, internal jugular vein and lower cranial nerves. However, the tensor veli palatini muscle is located much anteriorly to the styloid process, and between these structures there should be the middle ear, the external auditory meatus, and the pharyngotympanic tube. Therefore, we suspect that if the tensor veli palatini fascia is a fascia covering the muscle, it would be difficult for it to extend posteriorly to the styloid process. In the above studies, the supero-inferior extension of the TVS fascia might have been confused with the antero-posterior extension.

To clarify these issues, the aim of the present study was to obtain the details of the fascial configuration at and around the styloid process and the tensor veli palatini muscle in late-stage human fetuses. Our recent studies have shown that the embryology provides a clear-cut viewpoint of fascial configurations, for example demonstrating that the alar fascia in the cervical deep fasciae corresponds to a kind of the intermediate tendon between the bilateral longus colli muscles [11, 15]. We used sagittal sections to identify supero-inferior extensions of the related fasciae. The posterior margin of our target area corresponds to the digastricus muscle posterior belly, the internal jugular vein, the internal carotid artery, the superior cervical ganglion and the nodosa ganglion, whereas the anterior margin was found in the temporomandibular joint, the medial pterygoid muscle and the buccalis muscle. The submandibular gland should be also included in the inferior margin of the sections because Wolfram-Gabel et al. [19] stated that the prestyloid space continues to the submandibular space according to their observations of the macro slices of cadavers. This large area should include the TVS fascia as well as the prestyloid space with sufficient margins.

Fig. 1 Prestyloid space extending between the Meckel and Reichert cartilages in a 35-week fetus. HE staining. Sagittal sections. The right-hand side of each panel corresponds to the anterior side of the body. **a** (or **d**) The most lateral (or medial) in the figure. Intervals between panels are 2.6 mm (**a**, **b**), 3.0 mm (**b**, **c**), 1.6 mm (**c**, **d**). Laterally, the prestyloid space (*clear stars*) is adjacent to the parotid gland (*PG*; **a**). This space is demarcated posteriorly by a definite fascia (*arrowheads*) connecting between the temporal bone including Reichert cartilage (*RC*) and the styloglossus muscle (*SG*; **c**, **d**). The anterior margin of the space corresponds to a Meckel cartilage-related ligament (*IPA*) and the medial pterygoid muscle (*MP*; **b**–**d**). The prestyloid space is supplied by an artery approaching from the inferomedial aspect (*arrows* in **b**–**d**). Ostmann's fat (*OF*) of the pharyngotympanic tube (*PTT*) is separated from the prestyloid space by the levator veli palatini muscle (*LVP*) (*black stars*) along the muscle. No clear fascia is seen along the posterior margin of the medial pterygoid muscle. The medial part of the discomalleolar ligament (*asterisk* in **a**) is evident between the disk of the temporomandibular joint (*TMJ*) and the middle ear node, developing lymph nodes. All panels are prepared at the same magnification (*scale bar* in **a**). *APA* ascending pharyngeal artery, *ATN* auriculotemporal nerve, *CPS* constrictor pharyngis superior muscle, *DP* digastricus muscle posterior belly, *EAM* external auditory meatus, *ECA* external carotid artery, *FA* facial artery, *HG* hyoglossus muscle, *HB* hyoid bone, *ICA* internal carotid artery, *IJV* internal jugular vein, *IPA* interpterygoid aponeurosis (one of the Meckel cartilage-related ligaments in the text), *LA* lingual artery, *LN* lingual nerve, *GGL* submandibular ganglion, *LP* lateral pterygoid muscle, *M* mandible, *MC* Meckel cartilage, *MH* mylohyoideus muscle, *MP* medial pterygoid muscle, *MXA* maxillary artery, *NG* nodosa or inferior vagal ganglion, *OF* Ostmann's fat, *PAA* posterior auricular artery, *PG* parotid gland, *PP* pterygoid process of the sphenoid bone, *RC* Reichert cartilage, *SCG* superior cervical ganglion of the sympathetic nerve trunk, *SCM* sternocleidomastoideus muscle, *SG* styloglossus muscle, *SH* stylohyoideus muscle, *SMG* submandibular gland, *SML* sphenomandibular ligament (one of the Meckel cartilage-related ligaments in the text), *SP* stylopharyngeus muscle, *STA* superficial temporal artery, *STHA* superior thyroid artery, *TC* thyroid cartilage, *TH* thyrohyoideus muscle, *TVP* tensor veli palatini muscle, *V* mandibular nerve and its branches, *VII* facial nerve, *X* vagus nerve, *IX* glossopharyngeal nerve, *XII* hypoglossal nerve

Materials and methods

The study was performed in accordance with the provisions of the Declaration of Helsinki 1995 (as revised in Edinburgh 2000). We examined paraffin-embedded sagittal sections of 12 late-stage human fetuses [28–37 weeks of gestation; crown-rump length (CRL) 220–320 mm].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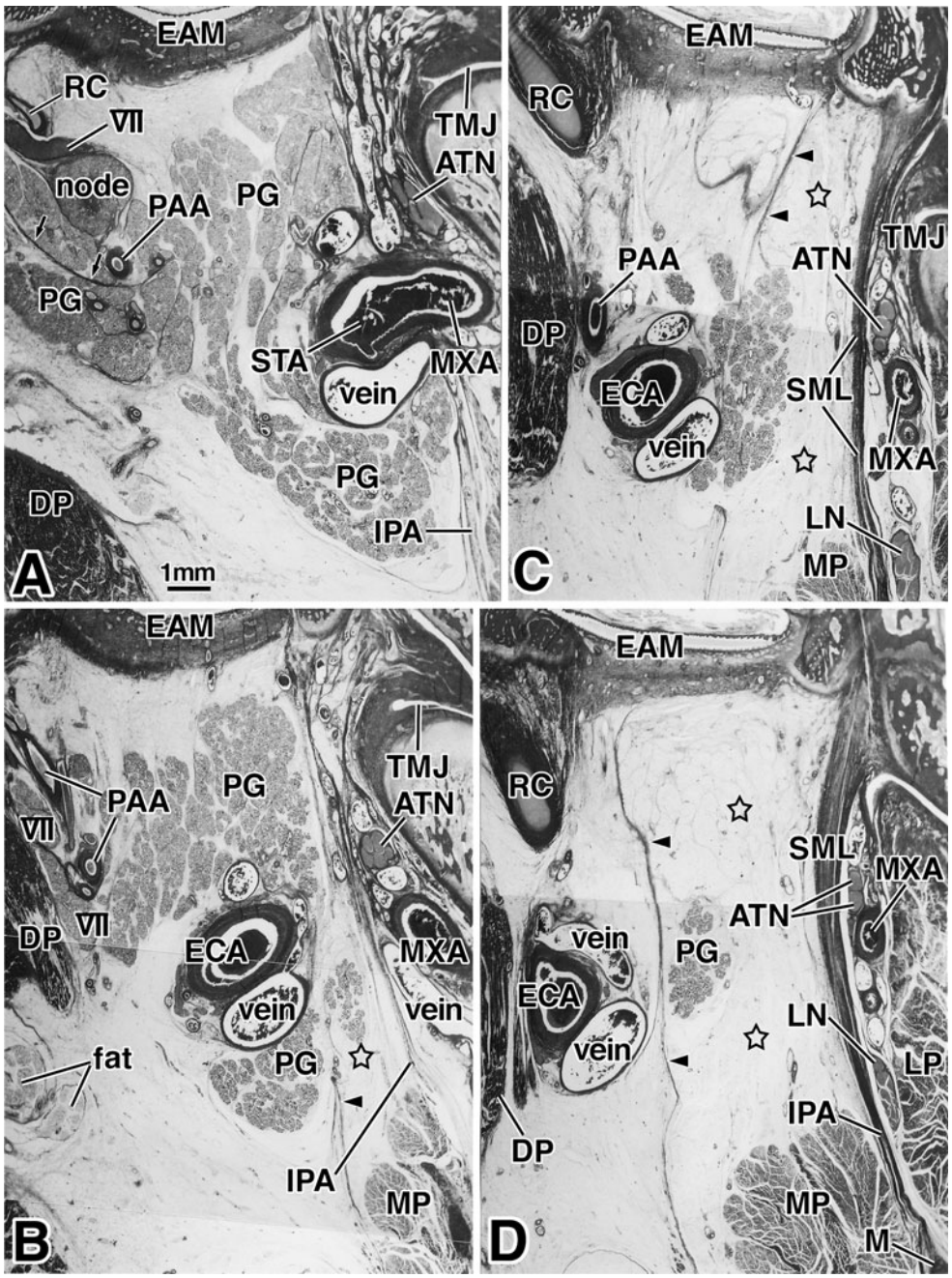


All specimens were part of the large collection kept at the Embryology Institute of the Universidad Complutense, Madrid, being the products of urgent abortion, miscarriages or ectopic pregnancies managed at the Department of Obstetrics of the University. The donated fetuses had been fixed in 10 % v/v formalin solution and stocked in the same solution for more than 3 months. After trimming of the tissue mass, the left or right side of the head was decalcified in 5 % v/v nitric acid. In the sections, we tried to include a large area extending from the internal jugular vein (posterior) to the medial pterygoid and buccalis muscles (medial) as well as the area from the middle ear and Eustachian tube (superior) to the submandibular gland (inferior). From one side of the head, we prepared 50–150 sections with a thickness of 10 μm at intervals of 0.5 mm. Most sections were stained with hematoxylin and eosin (HE), while some were subjected to silver impregnation or Masson trichrome

◀ **Fig. 2** Outer wall of the external auditory meatus providing superior attachments for the prestyloid space posterior fascia in a 33-week fetus. HE staining. Sagittal sections. The right-hand side of each panel corresponds to the anterior side of the body. **a** (or **d**) The most lateral (or medial) in the figure. Intervals between panels are 1.2 mm (**a**, **b**), 1.2 mm (**b**, **c**), 0.8 mm (**c**, **d**). **a** The bifurcation of the external carotid artery (*EAC*) into the superficial temporal artery (*STA*) and the maxillary artery (*MXA*). The ECA runs along the posterolateral side of the posterior fascia (*arrowheads*) of the prestyloid space (*clear stars*). *Arrows* in **a** indicate a septum in the parotid gland (*PG*) that is different from the posterior fascia. As the PG decreases in size from the lateral to the medial side (**b**–**d**), the posterior fascia changes its superior attachment posteriorly along the outer wall of the external auditory meatus (*EAM*). Meckel cartilage-related ligaments (*IPA*, *SML*) pass between the medial and lateral pterygoid muscles (*MP*, *LP*). No clear fascia is evident along the posterior margin of the medial pterygoid muscle node, developing lymph nodes. All panels are prepared at the same magnification (*scale bar* in **a**). *APA* ascending pharyngeal artery, *ATN* auriculotemporal nerve, *CPS* constrictor pharyngis superior muscle, *DP* digastricus muscle posterior belly, *FA* facial artery, *HG* hyoglossus muscle, *HB* hyoid bone, *ICA* internal carotid artery, *IJV* internal jugular vein, *IPA* interpterygoid aponeurosis (one of the Meckel cartilage-related ligaments in the text), *LA* lingual artery, *LN* lingual nerve, *GGL* submandibular ganglion, *LVP* levator veli palatini muscle, *M* mandible, *MC* Meckel cartilage, *MH* mylohyoideus muscle, *NG* nodosa or inferior vagal ganglion, *OF* Ostmann's fat, *PAA* posterior auricular artery, *PP* pterygoid process of the sphenoid bone, *PTT* pharyngotympanic tube, *RC* Reichert cartilage, *SCG* superior cervical ganglion of the sympathetic nerve trunk, *SCM* sternocleidomastoideus muscle, *SG* styloglossus muscle, *SH* stylohyoideus muscle, *SMG* submandibular gland, *SML* sphenomandibular ligament (one of the Meckel cartilage-related ligaments in the text), *SP* stylopharyngeus muscle, *STHA* superior thyroid artery, *TC* thyroid cartilage, *TH* thyrohyoideus muscle, *TVP* tensor veli palatini muscle, *V* mandibular nerve and its branches, *VII* facial nerve, *X* vagus nerve, *IX* glossopharyngeal nerve, *XII* hypoglossal nerve

staining. Approval for the study was granted by the ethics committee of the university.

Identification of fetal structures around the Meckel and Reichert cartilages was based on our recent studies of the areas overlapping those investigated in the present study [3, 4, 7, 8, 16]. To convenience, the discomalleolar ligament, the sphenomandibular ligaments and the interpterygoid aponeurosis are referred to as "Meckel cartilage-related ligaments" hereafter. In addition, the Eustachian tube will be termed the pharyngotympanic tube in accordance with the usual embryological terminology.

Results

The fascial configuration was almost the same among the specimens examined, although the CRL of the fetuses varied between 220 and 320 mm. A mass of loose connective tissue or a definite fascial space consistently extended inferiorly from the roof, which (from the anterior to the posterior side) was composed of the pharyngotympanic tube and its associated muscles and Ostmann's fat, the middle ear, or the external auditory meatus (Figs. 1, 2, 3, 4, 5). Thus, the covering fascia of the tensor veli palatini muscle (i.e., the tensor veli palatini fascia) did not represent the posterior margin, but formed part of the roof and the anterior margin of the space (Figs. 1c, d, 4c, 5d). A covering fascia of the levator veli palatini muscle (i.e., the levator veli palatini fascia) also made a roof of the space (Figs. 1d, 5d). The inferior aspect of the wall of the external auditory meatus was not covered by a definite fascia (Figs. 1a, 2b, 4a, 5a, b). Thus, the levator veli palatini fascia as well as the tensor veli palatini fascia did not extend posteriorly toward the primitive styloid process (Reichert cartilage). In all figures, the right-hand side of each panel corresponds to the anterior side of the body, and each panel is arranged from the lateral side to the medial side. We tentatively called this space the "prestyloid space". Figure 1 provides a good representation of the anterior and posterior margins of the space. Figure 2 shows the details of the lateral border of the prestyloid space facing the parotid gland, while Fig. 3 shows the details of the relationship between the posterior marginal fascia and the styloglossus muscle. Figure 4 shows the continuation of the prestyloid space to a space around the pharynx, while Fig. 5 shows the topographical anatomy including the oral cavity and sublingual triangle. The bifurcation of the common carotid artery is included in Figs. 3 and 5.

The anterior margin of the prestyloid space corresponded to Meckel cartilage and the Meckel cartilage-related ligaments (the definition, see the "Materials and methods") on the superior side (Figs. 1a, b, 2c, d, 3a, 4a, b) and to the medial pterygoid muscle on the inferior side (Figs. 1c, d, 2d, 3a, 4a, 5c). No clear fascia was evident along the posterior margin of the medial pterygoid muscle. The former ligaments passed through a space between the medial and lateral pterygoid muscles. At the most medial position, the prestyloid space extended anteromedially to face the buccalis muscle (Fig. 5d). Thus, the prestyloid space was located adjacent to the posterolateral aspect of the walls of the oral cavity. Laterally, the prestyloid space was located adjacent to the parotid gland (Figs. 1a, 2). The space was demarcated posteriorly by a definite fascia (arrowheads in Figs. 1, 2, 3, 4, 5) connecting between the temporal bone, including the Reichert cartilage or the primitive styloid process, and the stylopharyngeus and styloglossus muscles. Instead of the TVS, we tentatively termed this fascia the "posterior fascia of the prestyloid space" because the tensor veli palatini muscle made no contribution to the fascia (see above). At the lateral margin, the parotid gland disturbed the fascial configuration to divide the posterior fascia into several parts (Fig. 2). In relation to the medial invasion of the

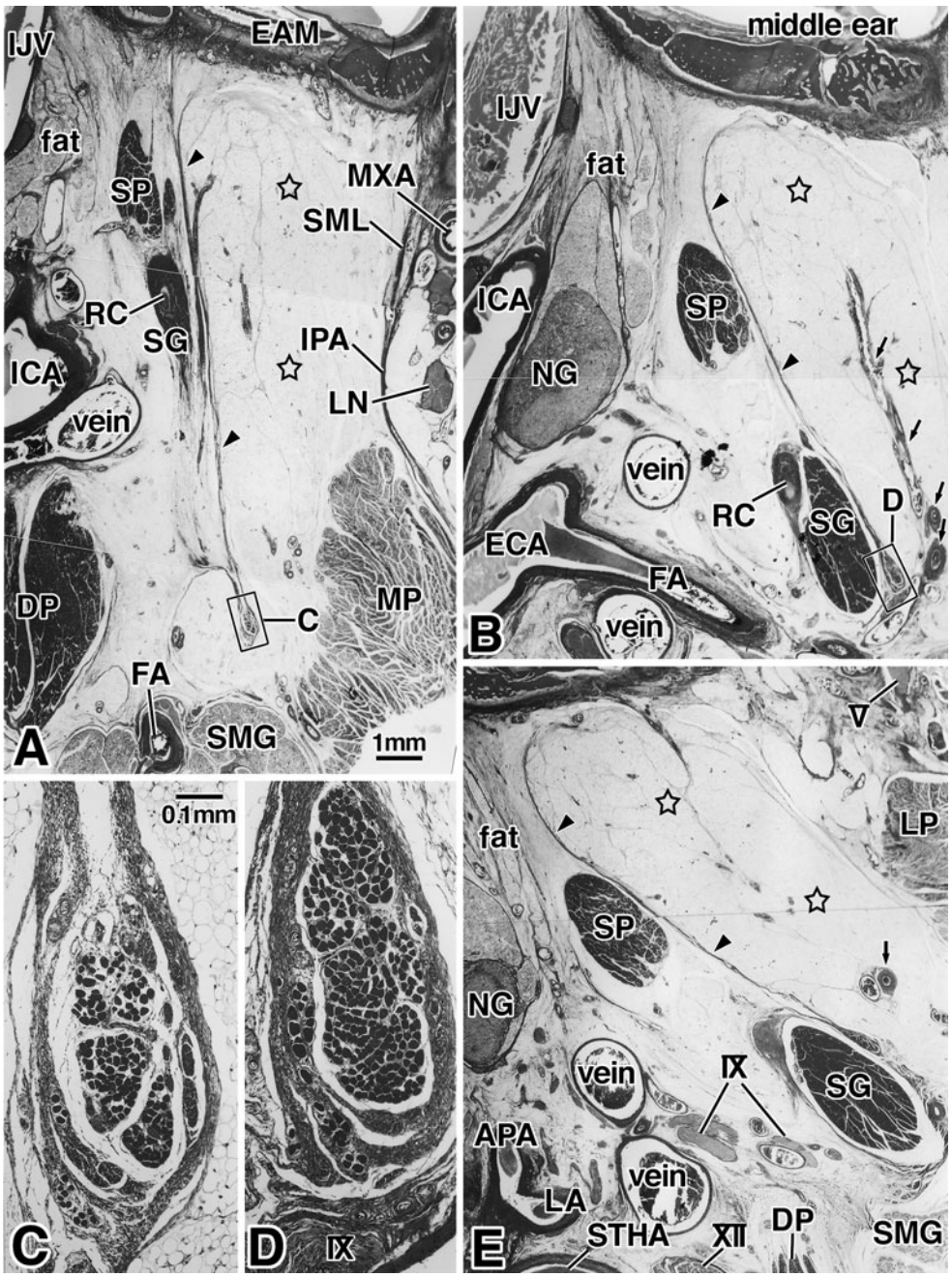
parotid gland, the posterior fascia changed its superior attachment posteriorly along the outer wall of the external auditory meatus (Fig. 2).

Along the anterior aspects of the stylopharyngeus and styloglossus muscles, the posterior fascia extended inferomedially to the outer surface of the constrictor pharyngis superior muscle and the tonsillar bed (Fig. 4). Thus, the prestyloid space continued inferiorly to the peripharyngeal space immediately outside the pharyngeal wall. The fascia did not attach or extend toward any parts of the hyoid bone, but extended more anteriorly (Fig. 5d). Thus, the fascia did not follow the initial course of the Reichert cartilage. Near the pharynx, the posterior fascia was separated from the tensor veli palatini fascia covering the inferior part of the muscle (Fig. 4b, c). At the inferior border, the prestyloid space was adjacent to the submandibular gland (Figs. 3e, 5c, d) and pharyngeal wall (see above). The inferior parts of the stylopharyngeus and styloglossus muscles also contributed to the inferior margin of the space (Figs. 4, 5d). In two specimens (at 30 and 33 weeks), a variant slip of the styloglossus muscle formed the inferior end of the posterior fascia of the prestyloid space on the lateral side where the styloglossus was still located superiorly (Fig. 3a, b). This muscle slip accompanied the glossopharyngeal nerve (Fig. 3d).

The major content of the prestyloid space was loose undifferentiated mesenchymal tissue. Fatty tissue had differentiated in the fascial space in a limited number of specimens (3 of 12; Fig. 5): whether this fatty tissue had developed or not did not depend on fetal size, because these three specimens included the smallest fetus (28 weeks, CRL 220 mm). The fatty tissue was evident on the posterior side of the digastricus muscle posterior belly and along the internal carotid artery (Figs. 1b, 2b, 3b). The external carotid artery ran along the posterior side of the posterior fascia of the prestyloid space (Figs. 1b, 2d, 5a, b) and bifurcated into the maxillary and superficial temporal arteries at the lateral and anterior margin of the prestyloid space (Fig. 2a). Thus, these thick arteries did not pass through the space. Instead, the prestyloid space was supplied by an ascending branch of the facial artery (arrows in Figs. 1, 3, 4, 5) and was drained by the concomitant veins. Notably, this artery was located in the center of the fatty tissue mass of the prestyloid space (Fig. 3b, e). The facial artery showed a reverse U-shaped course at the inferomedial aspect of the prestyloid space or above the submandibular gland, and at the superior point it issued an ascending branch (Figs. 3b, 5c). Thus, we identified this branch as the ascending palatine artery, which then took a curved course to wind along the styloglossus muscle (Fig. 3b). The posterior auricular artery, including the stylomastoid artery, as well as the ascending pharyngeal artery, was located on the posterior or lateral side of the posterior fascia. The facial nerve was located on the posterolateral side of the posterior fascia (Figs. 1a, 2a, b), while the glossopharyngeal nerve was located on the postero-inferior side (Figs. 3d, e, 5c, d). All of the mandibular nerve branches were located on the anterior side of the Meckel cartilage-related ligaments. Thus, the prestyloid space contained no distinct nerve, nor lymph nodes; these developed on the posterior side of the parotid gland or the digastricus muscle posterior belly (Figs. 1a, 2a).

Consequently, the prestyloid space was demarcated (1) posteriorly, by the definite posterior fascia extending along the stylopharyngeus and styloglossus muscles; (2) anteriorly, by the Meckel cartilage-related ligaments and the medial pterygoid muscle; (3) laterally, by the parotid gland; (4) medially, by the pharyngeal wall and buccalis muscle; (5) superiorly, by the middle ear, external auditory

Fig. 3 A major supplying artery of the prestyloid space originating from the facial artery and a variant muscle at the inferior end of the posterior fascia in a 33-week fetus. HE staining. Sagittal sections. The right-hand side of each panel corresponds to the anterior side of the body. The same specimen as that shown in Fig. 2: **a** located 1.8 mm medial to Fig. 2d. **a** (or **e**) The most lateral (or medial) in the figure. **c** (or **d**) A higher magnification view of the square in **a** (or **b**). Interval between panels is 1.6 mm (**a**, **b**) or 0.8 mm (**b**–**e**). No clear fascia is evident along the posterior margin of the medial pterygoid muscle (**a**). A major supplying artery (*arrows*) of the prestyloid space (*clear stars*) corresponds to a thick ascending branch of the facial artery (*FA*; **b**). The prestyloid space posterior fascia (*arrowheads* in **a**, **b**, **e**) extends along the anterior aspects of the stylopharyngeus and styloglossus muscles (*SP*, *SG*) and ends at a variant slip of the latter muscle (**c**, **d**). The submandibular gland (*SMG* in **e**) is seen on the posterior side of the medial pterygoid muscle. **a**, **b**, **e** Prepared at the same magnification (*scale bar* in **a**). *APA* ascending pharyngeal artery, *ATN* auriculotemporal nerve, *CPS* constrictor pharyngis superior muscle, *DP* digastricus muscle posterior belly, *EAM* external auditory meatus, *ECA* external carotid artery, *HG* hyoglossus muscle, *HB* hyoid bone, *ICA* internal carotid artery, *IJV* internal jugular vein, *IPA* interpterygoid aponeurosis (one of the Meckel cartilage-related ligaments in the text), *LA* lingual artery, *LN* lingual nerve, *GGL* submandibular ganglion, *LP* lateral pterygoid muscle, *LVP* levator veli palatini muscle, *M* mandible, *MC* Meckel cartilage, *MH* mylohyoideus muscle, *MP* medial pterygoid muscle, *MXA* maxillary artery, *NG* nodosa or inferior vagal ganglion, *OF* Ostmann's fat, *PAA* posterior auricular artery, *PG* parotid gland, *PP* pterygoid process of the sphenoid bone, *PTT* pharyngotympanic tube, *RC* Reichert cartilage, *SCG* superior cervical ganglion of the sympathetic nerve trunk, *SCM* sternocleidomastoideus muscle, *SH* stylohyoideus muscle, *SML* sphenomandibular ligament (one of the Meckel cartilage-related ligaments in the text), *STA* superficial temporal artery, *STHA* superior thyroid artery, *TC* thyroid cartilage, *TH* thyrohyoideus muscle, *TVP* tensor veli palatini muscle, *V* mandibular nerve and its branches, *VII* facial nerve, *X* vagus nerve, *IX* glossopharyngeal nerve, *XII* hypoglossal nerve



meatus and levator veli palatini fascia; and (6) inferiorly, by the inferior parts of the stylopharyngeus and styloglossus muscles as well as the submandibular gland. Although we tried to draw the fascial configuration, because of our poor skill, the posterior fascia is divided into two aspects of the prestyloid space (Fig. 6). However, the proposed pyramid-like model of the space appears be helpful for the better understanding of the topography and embryology. In Fig. 6, instead of the Meckel cartilage-related ligaments, Meckel cartilage itself is drawn in the anterior aspect of the prestyloid space; it is a symbol to suggest a position of the space between the first and second pharyngeal arches.

Discussion

The present study demonstrated the prestyloid space with clear demarcations. The posterior fascia of the space seemed to develop in close relation to the development of the stylopharyngeus and styloglossus muscles (derived from the second pharyngeal arch). As a variant muscle slip

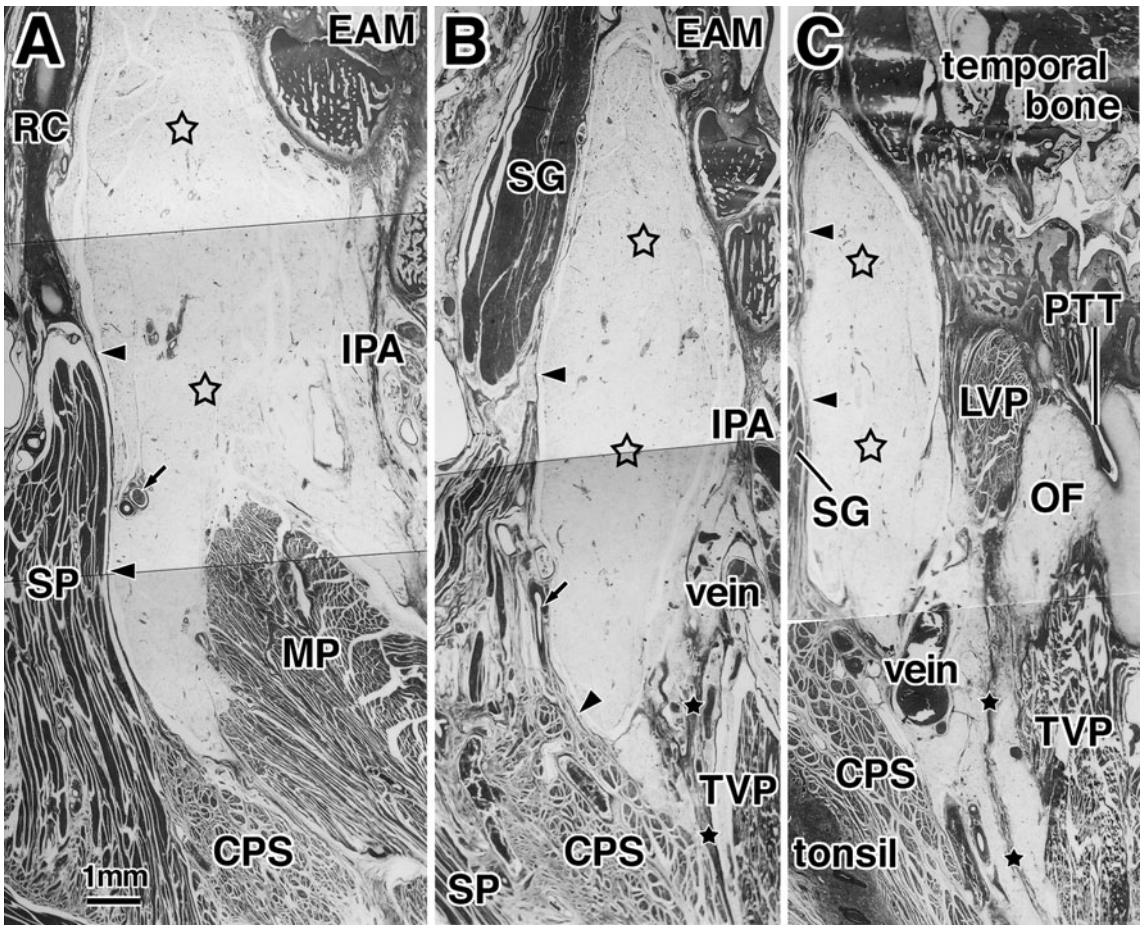


Fig. 4 Longitudinal sections of the stylopharyngeus and styloglossus muscles showing the inferior extension of the prestyloid space in a 41-week fetus. HE staining. Sagittal sections. The right-hand side of each panel corresponds to the anterior side of the body. **a** (or **c**) The most lateral (or medial) in the figure. Interval between panels is 1.0 mm (**a**, **b**) or 1.8 mm (**b**,**c**). Panel A displays the insertion of the stylopharyngeus muscle (*SP*), while panel C that of the styloglossus muscle (*SG*) near the palatine tonsil (tonsil). The prestyloid space (*clear stars*) extends inferomedially to continue to a space surrounding the constrictor pharyngis superior muscle (CPS in **c**). The prestyloid space posterior fascia (*arrowheads* in **a**–**c**) extends along the medial aspects of these two muscles. No clear fascia is seen along the posterior margin of the medial pterygoid muscle (MP in **a**). *Arrow* indicates the feeding artery of the space (a branch of the facial artery). *Black stars* in **b**, **c** indicate the most inferior part of the tensor veli palatini fascia. All panels are prepared at the same magnification (*scale bar* in **a**). *APA* ascending pharyngeal artery, *ATN* auriculotemporal nerve, *DP* digastricus muscle posterior belly, *EAM* external auditory meatus, *ECA* external carotid artery, *FA* facial artery, *HG* hyoglossus muscle, *HB* hyoid bone, *ICA* internal carotid artery, *IJV* internal jugular vein, *IPA* interpterygoid aponeurosis (one of the Meckel cartilage-related ligaments in the text), *LA* lingual artery, *LN* lingual nerve, *GGL* submandibular ganglion, *LP* lateral pterygoid muscle, *LVP* levator veli palatini muscle, *M* mandible, *MC* Meckel cartilage, *MH* mylohyoideus muscle, *MXA* maxillary artery, *NG* nodosa or inferior vagal ganglion, *OF* Ostmann's fat, *PAA* posterior auricular artery, *PG* parotid gland, *PP* pterygoid process of the sphenoid bone, *PTT* pharyngotympanic tube, *RC* Reichert cartilage, *SCG* superior cervical ganglion of the sympathetic nerve trunk, *SCM* sternocleidomastoideus muscle, *SH* stylohyoideus muscle, *SMG* submandibular gland, *SML* sphenomandibular ligament (one of the Meckel cartilage-related ligaments in the text), *STA* superficial temporal artery, *STHA* superior thyroid artery, *TC* thyroid cartilage, *TH* thyrohyoideus muscle, *TVP* tensor veli palatini muscle, *V* mandibular nerve and its branches, *VII* facial nerve, *X* vagus nerve, *IX* glossopharyngeal nerve, *XII* hypoglossal nerve

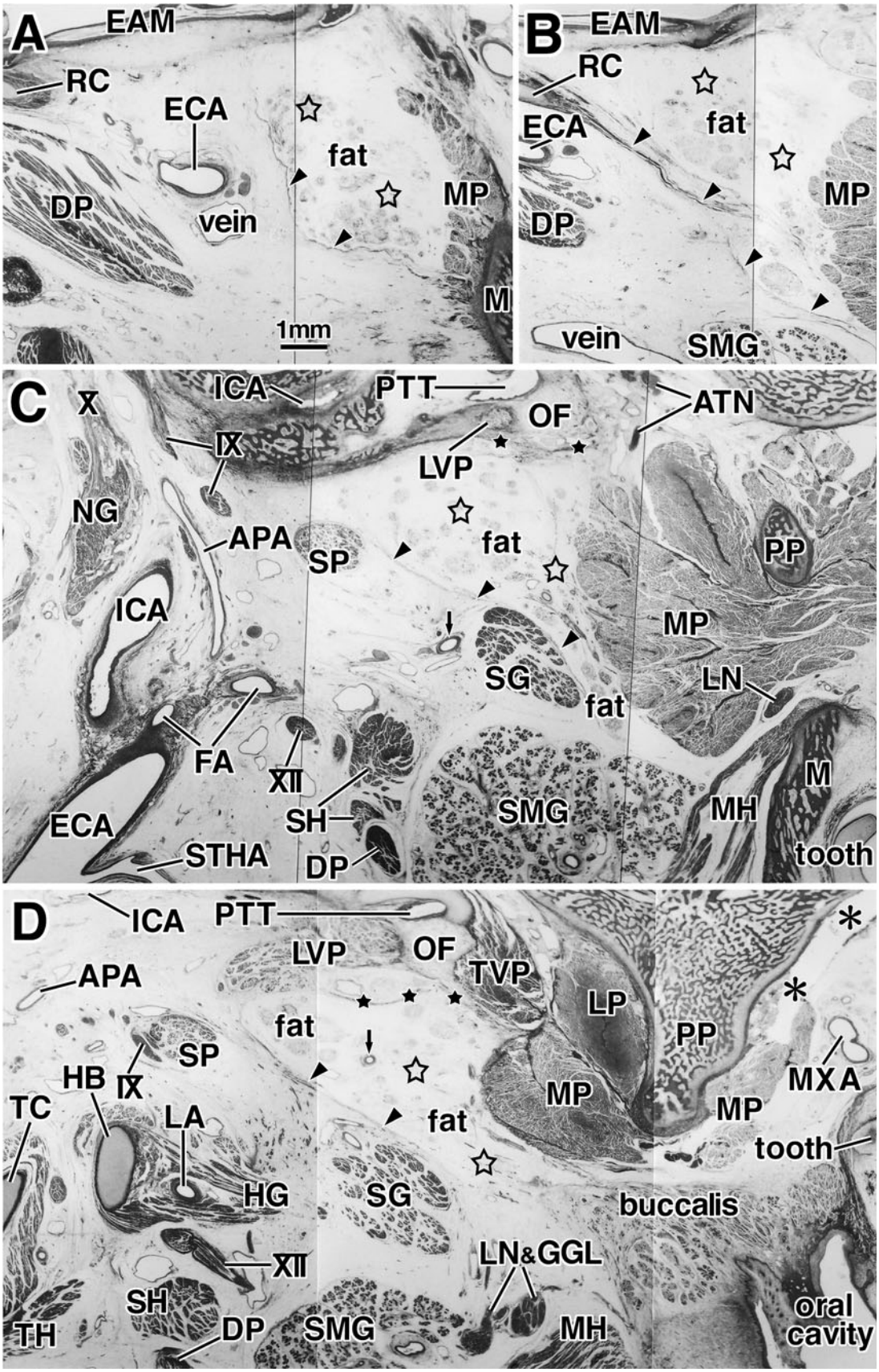
of the styloglossus provided the inferior end of the posterior fascia, a critical role of the muscle in extending the fascia inferiorly was suggested. Visceral insertions of these two muscles, passing through or intermingling with the pharyngeal wall, led the prestyloid space inferiorly to continue to the peripharyngeal space (a space surrounding the lateral pharyngeal wall). The second pharyngeal cartilage or the Reichert cartilage itself appeared not to contribute to fascia formation, although at the initial stage of this study, we speculated that a missing intermediate portion of the Reichert cartilage corresponded to the posterior fascia of the prestyloid space. In contrast to Reichert cartilage, the first pharyngeal arch cartilage or Meckel cartilage is likely to become reduced in both

thickness and area, showing a change in the morphology at the late stage of fetal development and during the postnatal period and, to form the sphenomandibular ligament with an aid of the interpterygoid aponeurosis (reviewed by Rodríguez-Vázquez et al. [16]). Thus, instead of these Meckel cartilage-related ligaments, the medial pterygoid muscle seems to become important for anterior demarcation of the prestyloid space. The fascia of this muscle may be established prenatally because we found no definite fascia. Consequently, the prestyloid space seems to be well defined, not only in terms of topographical anatomy but also embryologically as a space between the pharyngeal arches (Fig. 6).

The present posterior fascia of the prestyloid space is similar to, and most likely corresponds to a fascia that has been described radiologically (see "Introduction"). However, the present findings were clearly different from those described previously: the tensor veli palatini fascia was distant from the posterior fascia. Shin et al. [17] postulated a relationship between the fascia and a vascular sheath of the external carotid artery, but the sheath was located on the posterior side of the posterior fascia and attached to the latter at the lateral border of the prestyloid space. Instead of the present fascia, on the basis of dissection of 10 adult specimens, Maheshwar et al. reported that the roof of the parapharyngeal space was divided by the tensor veli palatini fascia into (1) an anterolateral compartment containing fat and a deep part of the parotid gland and (2) a posteromedial compartment containing the cartilaginous part of the Eustachian tube, internal carotid artery, internal jugular vein and the lower cranial nerves. They measured each of these compartments. The present study demonstrated the "levator" veli palatini fascia separating the tube and Ostmann's fat from the prestyloid space. However, Maheshwar et al. did not identify the present posterior fascia of the prestyloid space; one of the reasons might have been a suspected postnatal change in the fascia. Nevertheless, the stylopharyngeus and styloglossus muscles appear to form the posterior margin even in adults. Maheshwar et al. [10] considered the medial pterygoid fascia, the tensor veli palatini fascia and the pharyngobasilar fascia to be three important fasciae in the roof of the parapharyngeal space. However, it is unclear why they chose the medial pterygoid fascia for the roof, and not for the floor or anterior demarcation. In a dissection study, Curtin described the medial pterygoid fascia as extending between the muscle and skull base as well as the tensor veli palatini fascia extending between the muscle and the styloid process. His medial pterygoid fascia appeared to include Meckel cartilage-related ligaments, while his tensor veli palatini fascia corresponded to the present posterior fascia of the prestyloid space.

It seems to be widely known that the parapharyngeal space continues to a space around the oral and pharyngeal wall [4]. The anteromedial extension of the prestyloid space toward the oral and pharyngeal walls was better described in classical studies than in recent studies because abscess spread was a major problem at that time. According to a textbook by Hollinshead [4], Hall appeared to first divide the lateral pharyngeal space (parapharyngeal space) into the prestyloid and poststyloid portions [3]. Because of the specific supply of the ascending palatine artery to the prestyloid space, selective radiography of the facial artery, if conducted, would demonstrate the prestyloid space clearly even in adults. The present results suggested that the posterior auricular artery, including the stylomastoid artery, as well as the ascending pharyngeal artery, was located on the posterior or lateral side of the prestyloid space posterior fascia, although these arteries were considered to supply the space. However, the marginal inferior part of the space can receive their branches. Likewise, because the retrodiskal area is supplied by the anterior tympanic artery [12–14], it is also likely to supply the superolateral part of the prestyloid space. According to Chinese visible human project, Li et al. [9] considered the supplying artery of the prestyloid space as the ascending pharyngeal artery. However, the present study denied the possibility. We identified the ascending pharyngeal artery as an artery going to the jugular foramen: such an artery did not issue a branch to the prestyloid space.

Overall, our observations of the fetal prestyloid space, especially those about space margins as well as about the feeding artery, were quite different from previous descriptions according to dissection or radiology. Thus, the famous parapharyngeal space seemed to still contain anatomically unknown parts. We suspected that, in the previous studies, there might be (1) confusion between the tensor and levetor veli palatini muscles and/or (2) misunderstanding of the stylopharyngeus and styloglossus muscles. The fact that the external carotid artery ran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◀ **Fig. 5** Prestyloid space extending anteriorly to reach the lateral oral wall or the buccalis muscle in a 25-week fetus. HE staining. Sagittal sections. The right-hand side of each panel corresponds to the anterior side of the body. **a** (or **d**) The most lateral (or medial) in the figure. Intervals between panels are 1.6 mm (**a**, **b**), 2.6 mm (**b**,**c**) and 1.4 mm (**c**,**d**), respectively. The prestyloid space (*clear stars*) extends anteriorly to reach the lateral wall of the oral cavity or the buccalis muscle (buccalis). The posterior fascia (*arrowheads* in all panels) is not so clear, possibly due to postmortem change in the tissues, but superiorly it ends at the Reichert cartilage (*RC* in **b**). **c** A major branching site of the external carotid artery (*ECA*), while **d** the lateral parts of the sublingual triangle. In this specimen, in contrast to the other figures, fatty tissue differentiation (*fat*) is restricted to the prestyloid space. *Arrow* indicates the feeding artery of the space (a branch of the facial artery). *Black stars* **b**, **c** indicate the levator veli palatini fascia. Asterisks in **d** indicate an artifactual space created during the histological procedure. All panels are prepared at the same magnification (*scale bar* in **a**). *APA* ascending pharyngeal artery, *ATN* auriculotemporal nerve, *CPS* constrictor pharyngis superior muscle, *DP* digastricus muscle posterior belly, *EAM* external auditory meatus, *FA* facial artery, *HG* hyoglossus muscle, *HB* hyoid bone, *ICA* internal carotid artery, *IJV* internal jugular vein, *IPA* interpterygoid aponeurosis (one of the Meckel cartilage-related ligaments in the text), *LA* lingual artery, *LN* lingual nerve, *GGL* submandibular ganglion, *LP* lateral pterygoid muscle, *LVP* levator veli palatini muscle, *M* mandible, *MC* Meckel cartilage, *MH* mylohyoideus muscle, *MP* medial pterygoid muscle, *MXA* maxillary artery, *NG* nodosa or inferior vagal ganglion, *OF* Ostmann's fat, *PAA* posterior auricular artery, *PG* parotid gland, *PP* pterygoid process of the sphenoid bone, *PTT* pharyngotympanic tube, *SCG* superior cervical ganglion of the sympathetic nerve trunk, *SCM* sternocleidomastoideus muscle, *SG* styloglossus muscle, *SH* stylohyoideus muscle, *SMG* submandibular gland, *SML* sphenomandibular ligament (one of the Meckel cartilage-related ligaments in the text), *SP* stylopharyngeus muscle, *STA* superficial temporal artery, *STHA* superior thyroid artery, *TC* thyroid cartilage, *TH* thyrohyoideus muscle, *TVP* tensor veli palatini muscle, *V* mandibular nerve and its branches, *VII* facial nerve, *X* vagus nerve, *IX* glossopharyngeal nerve, *XII* hypoglossal nerve

along the posterolateral aspect of the prestyloid space would also help in the identification of the adult anatomy. A fatty tissue mass of the prestyloid space was clearly separated from surrounding tissues and carried independent and proper feeding vessels. Thus, we hypothesized that this tissue is a remnant of a space between pharyngeal arches. Actually, the marginal structures of the fatty tissue mass seemed to be classified into either of the two origins: Meckel's cartilage derivatives or Reichert's cartilage derivatives. However, according to reports of clinical pathology (see the "Introduction"), tumors from the prestyloid space is most likely to originate from salivary gland tissues those secondarily invade into the proper fatty tissue.

Conflict of interest The authors have no financial conflicts of interests.

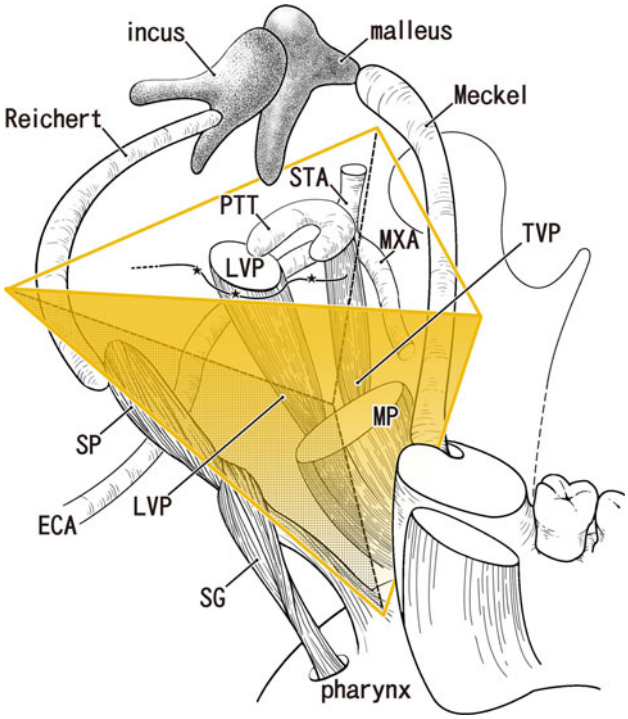

Fig. 6 A schematic representation of the prestyloid space. To simplify, the prestyloid space is represented by a pyramid-like space tilted at a right angle: the apex attaches to Reichert cartilage or the primitive styloid process (Reichert); the upper aspect is made by the temporal bone containing the middle and inner ear as well as the pharyngotympanic tube (*PTT*); the medial aspect faces the medial pterygoid muscle (*MP*), the tensor veli palatini muscle (*TVP*) and Meckel cartilage-related structures (Meckel); the lateral aspect is invaded by the parotid gland (not drawn); the inferior and anterior aspects are provide by the posterior fascia of the prestyloid space (*yellow*). This posterior marginal fascia extends along the stylopharyngeus and styloglossus muscles (*SP*, *SG*). The external carotid artery (*ECA*) runs along the inferior aspect (*dotted area*), turns to the lateral aspect and, divides into the superficial temporal artery (*STA*) and maxillary artery (MXA) at a margin of the pyramid. A fascia (*black stars*) of the levator veli palatini muscle (*LVP*) makes a part of the upper aspect. *APA* ascending pharyngeal artery, *ATN* auriculotemporal nerve, *CPS* constrictor pharyngis superior muscle, *DP* digastricus muscle posterior belly, *EAM* external auditory meatus, *FA* facial artery, *HG* hyoglossus muscle, *HB* hyoid bone, *ICA* internal carotid artery, *IJV* internal jugular vein, *IPA* interpterygoid aponeurosis (one of the Meckel cartilage-related ligaments in the text), *LA* lingual artery, *LN* lingual nerve, *GGL* submandibular ganglion, *LP* lateral pterygoid muscle, *M* mandible, *MC* Meckel cartilage, *MH* mylohyoideus muscle, *NG* nodosa or inferior vagal ganglion, *OF* Ostmann's fat, *PAA* posterior auricular artery, *PG* parotid gland, *PP* pterygoid process of the sphenoid bone, *RC* Reichert cartilage, *SCG* superior cervical ganglion of the sympathetic nerve trunk, *SCM* sternocleidomastoideus muscle, *SH* stylohyoideus muscle, *SMG* submandibular gland, *SML* sphenomandibular ligament (one of the Meckel cartilage-related ligaments in the text), *STHA* superior thyroid artery, *TC* thyroid cartilage, *TH* thyrohyoideus muscle, *V* mandibular nerve and its branches, *VII* facial nerve, *X* vagus nerve, *IX* glossopharyngeal nerve, *XII* hypoglossal nerve (color figure online)

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