A Comparative Analysis of Endoscopic-Assisted Transoral and Transnasal Approaches to Parapharyngeal Space: A Cadaveric Study

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J Neurol Surg B 2018;79:229–240.

Abstract

Background Surgical resection of parapharyngeal space (PPS) tumors is very challenging. An endoscopic-assisted surgical approach to this region requires detailed and precise anatomic knowledge. The main purpose of this study is to describe and compare the detailed anatomy of the PPS via transnasal transpterygoid (TP) and endoscopic-assisted transoral (TO) approaches.

Materials and Methods Six fresh injected cadaver heads (12 sides) were prepared for dissection of the PPS via TP and TO approaches. Computed tomography (CT) with image-based navigation (Navigation System II; Stryker, Kalamazoo, Michigan, United States) was used to identify bony structures around the PPS.

Results TP and TO approaches could both expose the detailed anatomical structures in the PPS. The TP approach can provide a direct route to the upper PPS, but it is limited inferiorly by the hard palate and laterally by the medial and lateral pterygoid muscles. However, the TO approach can provide a direct route to the lower PPS, but it is difficult to expose the area around the Eustachian tube. The styloglossus and stylopharyngeus muscles could be considered as the safe anterior boundary of the parapharyngeal internal carotid artery (ICA) with the TO approach. Dissection between the stylopharyngeus muscle and the superior pharyngeal constrictor muscle provides direct access to the parapharyngeal ICA.

Conclusion The TP and TO approaches provide new strategies to manage lesions in the PPS. The important neurovascular structures of the PPS could be identified with these approaches. The endoscopic-assisted TO approach can provide direct access to the parapharyngeal ICA.

Keywords

- anatomy
- endoscopic surgery
- parapharyngeal space
- transoral approach
- transpterygoid approach

* Xicai Sun and Bo Yan contributed equally to this work.

Introduction

The parapharyngeal space (PPS) is a potential deep space in the head and the neck, which is located between the pterygoid musculature and the lateral pharyngeal wall. Generally, the PPS is described as an inverted pyramid with its apex at the greater cornu of the hyoid bone and the base at the skull base. The anterior boundary is the pterygomandibular raphe and interpterygoid fascia. The medial boundary is the superior constrictor, tensor, and levator veli palatini muscles. The lateral boundary of the PPS is the medial pterygoid muscle, the ramus of the mandible, and the deep lobe of the parotid gland. The posterior boundary is limited by the prevertebral fascia and muscle.¹ The fascia that extends from the inferior border of the tensor veli palatini muscle to the styloid process divides the PPS into prestyloid and poststyloid compartments.² The prestyloid compartment mainly contains fatty tissue, part of the deep lobe of the parotid gland, lymph nodes, the styloglossus muscle, the stylopharyngeus muscle, the internal maxillary artery, the ascending palatine artery, and the posterior division of mandibular nerve (the inferior alveolar, lingual, and auriculotemporal nerves). However, the poststyloid compartment contains the internal carotid artery (ICA), internal jugular vein, lower cranial nerves IX to XII, cervical sympathetic chain, and lymph nodes.³

Tumors of the PPS are rare, accounting for 0.5% of all head and neck tumors, and most of these tumors are benign.^{4–6} Because of its deep location and the complex anatomy, resection of PPS tumors is challenging by any route. Traditionally, it can be managed by transcervical, transoral (TO), transmandibular, transparotid, and various combined approaches.^{3,6,7} These external approaches provide limited surgical exposure and have high risk of morbidity and longer hospitalization time. Recently, endoscope-assisted TO (with or without surgical robotic system) and transnasal transpterygoid (TP) approaches have been used to remove benign lesions of the PPS with reduced surgical complications and cosmetic deformity relative to traditional external approaches.^{8–11} Because of anatomical complexity with important neurovascular structures in the PPS, minimally invasive approaches to this region require detailed and precise anatomic knowledge. Although many operative procedures and endoscopic anatomy of the PPS have been reported, the target area in these investigations is only focused on upper or lower PPS.^{12–15} Therefore, the purpose of this study was to compare the surgical anatomy of the PPS via the transnasal TP approach with the endoscopic-assisted TO approach with the goal of defining the limitations of each approach and the advantage of a combined approach.

Materials and Methods

Six fresh cadaver heads (12 sides) were prepared for endoscopic dissection at the Surgical Neuroanatomy Laboratory of the Center for Cranial Base Surgery within the Department of Neurological Surgery at the University of Pittsburgh School of Medicine. The common carotid arteries, vertebral arteries, and internal jugular veins of all specimens were isolated and injected with red silicone for the arterial system

and blue silicone for the venous system. All specimens were stored in 50% alcohol solution for further dissection. Before dissecting, computed tomographic (CT) scan was used to collect image data for the Navigation System II (Stryker, Kalamazoo, Michigan, United States). Crowe–Davis mouth gag was used to open the mouth and maximize the surgical space for the transoral approach. All surgical dissections were performed using 0° and 30° endoscopes (Karl Storz GmbH and Co., Tuttlingen, Germany).

Endoscopic Transnasal Transpterygoid Approach

Exposure of the Lateral and Medial Boundaries of Upper PPS

The ethmoidal sinus was removed to expose the medial wall of orbit, and the sphenoid sinus was opened to fully expose the lateral recess (►Figs. 1 and 2A). The original ostium of maxillary sinus was identified after resecting the root of the uncinate process (►Fig. 1C), and the medial wall of maxillary sinus was removed to expose the anterior wall of the pterygopalatine fossa (►Fig. 1D). The infraorbital canal can be identified within the maxillary sinus along the base of the orbit (►Fig. 1D). The sphenopalatine artery was sacrificed, and the posterior wall of the maxillary sinus was removed with Kerrison Rongeurs to fully expose the pterygopalatine fossa and the infratemporal fossa (►Figs. 1D and 2B). The palatine bone was drilled to expose the descending artery, greater palatine nerve, and pterygoid process (►Fig. 2B). The soft tissues of the pterygopalatine fossa were displaced laterally to identify the vidian canal; the vidian canal was drilled medially to expose foramen lacerum (►Fig. 2C and D). The pterygoid base was drilled between the pterygoid plates and the lateral and medial pterygoid muscles were detached from the lateral and medial pterygoid plates, respectively. The pterygoid process was completely removed, and the muscles of the medial boundary of PPS were exposed and dissected from each other (►Fig. 3A).

Identifying the Contents of Upper PPS

The superior constrictor, tensor, and levator veli palatini muscles limit the upper PPS medially (►Fig. 3A). The prestyloid compartment of the upper PPS is mainly filled with fat tissue. The tensor veli palatine muscle divides the prestyloid compartment into lateral and medial spaces. The lateral space is located between the medial pterygoid muscle and tensor veli palatine muscle. The medial space is located between the tensor veli palatine muscle and superior pharyngeal constrictor muscle (►Fig. 3A). The surrounding fat tissue of the prestyloid compartment was removed completely. Further dissection of the surrounding soft tissue through the lateral space leads to the lateral portion of the PPS. At this stage, the posterior division of the mandibular nerve and part of the deep lobe of the parotid gland can be exposed (►Fig. 3B). By removing the soft tissue in the medial space, the branches of the ascending palatine artery will be encountered (►Fig. 3A). Careful removal of soft tissue through the medial space between the tensor veli palatine muscle and superior pharyngeal constrictor muscle can expose the poststyloid compartment. By opening the carotid sheath

Fig. 1 Endoscopic view of transnasal approach (right side). (A) Endoscopic view of the right nasal cavity. (B) The ethmoidal sinus was totally removed to expose lamina papyracea and the anterior and posterior ethmoidal arteries. The bone of superior turbinate was removed to expose the olfactory nerves under the mucosa. (C) The original ostium of maxillary sinus was exposed after resecting the root of uncinate process. (D) The medial wall of maxillary sinus was removed to expose the posterior wall of maxillary sinus. The bone of posterior of maxillary sinus has been removed. The infraorbital artery and nerve run through the infraorbital canal beneath the orbital floor. The sphenopalatine artery passes through the sphenopalatine foramen into the nasal cavity. A., artery; Ant., anterior; Eust., Eustachian; IT, inferior turbinate; LP, lamina papyracea; Med., medial; MO, maxillary ostium; MS, maxillary sinus; MT, middle turbinate; N., nerve; NS, nasal septum; Olf., olfactory; Pos., posterior; SPA, sphenopalatine artery; Sph., sphenoid; ST, superior turbinate.

and further dissecting into the depth, the internal carotid artery, ascending pharyngeal artery, cervical sympathetic chain, lower cranial nerves IX to XII, and internal jugular vein can be fully exposed (►Fig. 3E, 3F).

Endoscopic-Assisted Transoral Approach

Exposure of the Prestyloid Space

A vertical incision was made through the oral mucosa and superior pharyngeal constrictor muscle starting from the soft palate to the tongue base along the palatoglossal fold (►Fig. 4A). The pterygomandibular raphe separates the superior pharyngeal constrictor muscle from the buccinator muscle (►Fig. 4B). After the superior pharyngeal constrictor muscle is cut medial to the pterygomandibular raphe and retracted medially, the fat pad of the prestyloid space can be exposed (►Fig. 4C). After carefully removing the fat tissue in the prestyloid space, the ascending palatine artery was identified between the styloglossus and stylopharyngeus muscles (►Fig. 4D). The styloid diaphragm is a key anatomic landmark for the TO approach to the PPS. It is a fibrous sheet extending from the styloid process and contains the posterior belly of the digastric muscle, the styloid group of muscles (stylohyoid,

styloglossus, and stylopharyngeus), and the stylohyoid and stylomandibular ligaments and connects with the parotid fascia. The styloid diaphragm divides the PPS into the pre-styloid and retrostyloid compartments. The external carotid artery (ECA) ascends through the prestyloid space between the styloglossus and stylohyoid muscles (►Fig. 4E). Generally, the stylomandibular ligament that extends from the apex of the styloid process to the posterior border of the angle of mandible covers the stylohyoid muscle and part of the ECA (►Fig. 5A). Further removal of the stylomandibular ligament can help to expose the ECA, the stylohyoid muscle, and the posterior belly of the digastric muscle (►Fig. 5B).

Exposure of the Poststyloid Space

The styloglossus and stylopharyngeus muscles were retracted laterally to expose the carotid sheath (►Fig. 4F). After moving the carotid sheath laterally, the ascending pharyngeal artery and cervical sympathetic chain can be identified (►Fig. 6A and B). The ascending pharyngeal artery typically arises from the deep part of the ECA trunk and ascends to the skull base posteromedial to the ICA. In the PPS, the cervical sympathetic chain extends to the skull base between the carotid sheath anteriorly and the prevertebral

Fig. 2 Endoscopic view of transpterygoid approach (right side). (A) The anterior wall of sphenoid sinus has been removed to expose the lateral recess. The depth of lateral recess is affected by the degree of pneumatization of sphenoid sinus. The prominence of the optic nerve and internal carotid artery is located on the lateral wall of sphenoid sinus. The OCR lies on the lateral wall of sphenoid sinus between the ICA below and the optic nerve above. The Müller's muscle is a thin layer of smooth muscle fibers that covers the inferior orbital fissure in the orbit and can be an important anatomical landmark in endoscopic approaches to the skull base. (B) The neural, vascular, and muscular structures in the pterygopalatine and infratemporal fossae have been exposed after removing the bone and periosteum of the posterior wall of maxillary sinus. The descending palatine artery and greater palatine nerve are often sacrificed for the endonasal transpterygoid approach. (C) The vidian nerve goes posterolaterally toward the foramen lacerum and can be a good landmark for the anterior genu of the petrous ICA. The root of pterygoid process has been removed to expose the medial pterygoid muscle, foramen ovale, foramen vesalii, and scaphoid fossa. The scaphoid fossa is a small oval depression in the pterygoid process and serves as the origin of tensor veli palatini muscle. (D) The medial pterygoid plate has been removed to expose the medial pterygoid muscle and the tensor veli palatini muscle. The superior pharyngeal constrictor muscle is medial to the tensor veli palatini muscle, and its upper border has a crescentic interval that occupied by the levator veli palatini muscle and Eustachian tube. The salpingopharyngeus muscle originates from the superior border of the medial part of Eustachian tube, goes downward, and blends with the palatopharyngeus muscle. A., artery; ADTA, anterior deep temporal artery; DPA, descending palatine artery; Eust., Eustachian; GPN, greater palatine nerve; ICA, internal carotid artery; Lat., lateral; M., muscle; Med., medial; N., nerve; OCR, opticocarotid recess; Post., posterior; PPG, pterygopalatine ganglion; PSAA, posterior superior alveolar artery; Ptery., pterygoid; SPA, sphenopalatine artery; Temp., temporal.

fascia posteriorly (►Fig. 6C and D). Careful opening of the carotid sheath can expose the lower cranial nerves (IX–XII) (►Fig. 6D and E). Further careful dissection into the depth between the styloid muscles and ICA will expose the accessory nerve, the jugular vein, and the transverse process of C1 (►Fig. 6F). Dissection of the soft tissue in the PPS near the base of tongue should be done carefully to avoid damage to branches of the glossopharyngeal and vagus nerves and the pharyngeal plexus (►Fig. 5E, 5F).

Identifying the Structures Lateral to the Carotid Foramen

Further dissection along the styloid process with removal of soft tissue between the parotid gland and styloid process will expose the spine of the sphenoid bone (►Fig. 7A, B, and E). It serves as the origin of the pterygospinous and sphenomandib-

ular ligaments (►Fig. 7A). The pterygospinous ligament stretches between the upper part of the posterior border of the lateral pterygoid plate to the spine of sphenoid (►Fig. 5C and D). The sphenomandibular ligament stretches from the spine of the sphenoid bone to the lingula of the mandibular foramen. The inferior alveolar nerve is separated from the lingual nerve by the sphenomandibular ligament as it enters into the mandibular foramen (►Fig. 3D). The lateral wall of the carotid foramen and the vaginal process of the tympanic part of the temporal bone separate the parapharyngeal ICA from the deep lobe of the parotid gland at the entrance of ICA into the petrous bone (►Fig. 7A, B, and F–H). By retracting the styloid process medially and dissecting between the medial pterygoid muscle and the styloid muscles, the extratemporal segment of the facial nerve, the posterior auricular artery, and the stylo-mastoid artery can be carefully exposed (►Fig. 7C and D).

Fig. 3 Transnasal endoscopic view of the upper parapharyngeal space (right side). (A) The prestyloid compartment of upper pharyngeal space is divided into lateral and medial spaces. The main contents of lateral space are fat tissues and small veins. The medial space is filled with ascending palatine artery and fat tissues. In the medial space, the ascending palatine artery will give branches to supply the levator veli palatini muscle and the soft palate. (B) The lateral space is narrow and limited by the medial pterygoid muscle and lateral pterygoid plate laterally. The medial pterygoid muscle can be detached from the lateral pterygoid plate. After removing the lateral pterygoid plate, the medial pterygoid muscle was retracted laterally to expose the prestyloid space of upper pharyngeal space. (C) The inferior alveolar nerve and the lingual nerve pass between the lateral and medial pterygoid muscles. (D) The sphenomandibular ligament is a thin, flat band that originates from the sphenoidal spine and descends to the lingula of the mandibular foramen. The lingual nerve is separated from the inferior alveolar nerve by the sphenomandibular ligament when it gets attached to the lingula of the mandibular foramen. (E) Dissecting along the medial space will lead to the poststyloid compartment of upper parapharyngeal space in which the ICA, jugular vein, and posterior cranial nerves can be identified. (F) The ICA was retracted laterally to expose the cervical sympathetic trunk and ascending pharyngeal artery. The ascending pharyngeal artery goes upward to the skull base between the ICA and the side of the pharynx. A., artery; ADTA, anterior deep temporal artery; APA, ascending palatine artery; Br., branch; CST, cervical sympathetic trunk; DPA, descending palatine artery; Eust., Eustachian; GPN, greater palatine nerve; IAN, inferior alveolar nerve; ICA, internal carotid artery; Lat., lateral; LN, lingual nerve; LVPM, levator veli palatini muscle; M., muscle; Med., medial; N., nerve; PG, parotid gland; Post., posterior; Ptery., pterygoid; SML, sphenomandibular ligament; SPA, sphenopalatine artery; SPCM, superior pharyngeal constrictor muscle; Sup., superior; Temp., temporal. TVPM, tensor veli palatini muscle; IX, glossopharyngeal nerve; X, vagus nerve; XI, accessory nerve; XII, hypoglossal nerve.

Fig. 4 Transoral endoscopic view of the parapharyngeal space (right side). (A) A vertical incision on the oral mucosa extended from the soft palate to the tongue base. The retromolar pad can be an anatomical landmark, which is frequently pear shaped and located on the alveolar process of the mandible. (B) The oral mucosa was removed to expose the submucosal structures. The palatoglossus muscle was elevated to expose the superior pharyngeal constrictor muscle and the salpingopharyngeus muscle. The salpingopharyngeus muscle originates from the superior border of the medial cartilage of the Eustachian tube, go downward, and merge with the palatopharyngeus muscle. The pterygomandibular raphe extends from the pterygoid hamulus of the medial pterygoid plate to the posterior end of the mylohyoid line of the mandible and separate the superior pharyngeal constrictor muscle from the buccinator muscle. (C) After cutting and elevating the superior pharyngeal constrictor muscle, the fat tissues in the prestyloid space and the medial pterygoid muscle were identified. (D) The fat tissues in the prestyloid space have been removed to identify the ascending palatine artery that passes upward between the styloglossus and stylopharyngeus muscles. (E) The styloid diaphragm is a key landmark to identify the border between the prestyloid and retrostyloid compartments. The external carotid artery passes upward between the styloglossus and stylohyoid muscles. The glossopharyngeal nerve descends along the posterior edge of stylopharyngeus muscle. (F) The parapharyngeal ICA can be exposed after dissecting between the stylopharyngeus muscle and the superior pharyngeal constrictor muscle. It is a direct route to identify the parapharyngeal ICA through transoral approach. A., artery; ECA, external carotid artery; ICA, internal carotid artery; M., muscle; Med., medial; N., nerve; PMR, pterygomandibular raphe; Ptery., pterygoid; SPCM, superior pharyngeal constrictor muscle.

Fig. 5 Transoral endoscopic view of the parapharyngeal space and its related structures (Right side: A–D; left side: E and F). (A) Dissecting between the medial pterygoid muscle and the styloglossus muscle will lead to the stylomandibular ligament. The stylomandibular ligament extends from the apex of the styloid process to the posterior border of the angle of the mandible. This ligament separates the external carotid artery from the prestyloid space. (B) Further dissection between the medial pterygoid muscle and the styloid muscles group will expose the deep lobe of parotid gland and the retromandibular vein. (C and D) The pterygospinous ligament has been detached from the posterior border of the lateral pterygoid plate from where the ligament stretches to the spinous process of the sphenoid. (E) The pharyngeal branches of the vagus and glossopharyngeal nerves pass across the internal carotid artery and form the pharyngeal plexus that locates on the upper border of the middle pharyngeal constrictor muscle. (F) After retracting the ICA laterally, the branch of cervical sympathetic trunk to the pharyngeal plexus will be exposed. A., artery; APA, ascending palatine artery; Br., branch; CST, cervical sympathetic trunk; ECA, external carotid artery; ICA, internal carotid artery; L., ligament; M., muscle; Med., medial; P, parotid gland; PMR, pterygomandibular raphe; Post., posterior; PP, pharyngeal plexus; Ptery., pterygoid; SML, stylomandibular ligament; IX, glossopharyngeal nerve; X, vagus nerve; XII, hypoglossal nerve.

Results

Exposure of PPS

The detailed structures in the PPS including pre- and post-styloid compartments could be exposed by removing the surrounding soft tissues of the PPS through both approaches

in all specimens. During dissection through an endoscopic TP approach, the pterygoid process, medial pterygoid muscle, levator and tensor veli palatini muscles, and Eustachian tube could serve as safety orienting landmarks. The terminal branches of the ascending palatine artery may be encountered between the tensor veli palatini muscle and superior

Fig. 6 Transoral endoscopic view of ICA and posterior cranial nerves (right side). (A) After opening the carotid sheath, the ICA was retracted laterally to expose the ascending pharyngeal artery. (B) The ascending pharyngeal artery originates from the external artery and goes upward between the ICA and the side of the pharynx. After a short common trunk, the ascending pharyngeal artery divides into pharyngeal and neuromeningeal trunks and locates on the surface of the longus capitis muscle. (C) Further dissection between the ICA and the longus capitis muscle will lead to the cervical sympathetic trunk. In the parapharyngeal space, cervical sympathetic trunk ascends posteromedial to the ICA and lies on the longus capitis muscle. (D) Dissecting downward between the ICA and the side of the pharynx can meet the superior laryngeal nerve. This nerve arises from the vagus nerve and descends medial to the ICA. (E) The posterior cranial nerve can be exposed between the stylopharyngeus muscle and the ICA. (F) Further dissecting posteriorly leads to the transverse process of C1, jugular vein, and accessory nerve. A., artery; APA, ascending palatine artery; Br., branch; C1, the first cervical vertebra; ICA, internal carotid artery; M., muscle; Med., medial; N., nerve; PG, parotid gland; Ptery., pterygoid; Sup., superior; IX, glossopharyngeal nerve; X, vagus nerve; XI, accessory nerve; XII, hypoglossal nerve.

pharyngeal constrictor muscle (—Fig. 3A). When an endoscopic TO approach was used, the medial pterygoid muscle, the styloid muscle groups, and styloid process can serve as safety landmarks. Moreover, the styloglossus and stylopharyngeus muscles could provide muscular orienting landmarks to identify the ICA.

The Variation of the Parapharyngeal Segment of ICA

According to the criteria of Paulsen et al,¹⁶ the parapharyngeal segment of the ICA could be classified into four types: straight, tortuosity, kinking, and coiling. In this study, abnormal variations of the course of ICA were found in three (50%) out of six specimens through an endoscopic TO approach. Tortuosity

Fig. 7 Transoral endoscopic view of the structures lateral to the carotid foramen was showed (A–D; right side). Navigation system was used to identify the structures lateral to the carotid foramen (right side, E–H). (A) Under the 30° endoscope, dissecting anterosuperiorly between the styloid process and the deep lobe of parotid gland will lead to the tympanic part of the temporal bone and the spine of sphenoid bone. The spine of sphenoid bone serves as the origin of the pterygospinous ligament and the sphenomandibular ligament. (B) Endoscopic view of related bony structures lateral to the carotid foramen. The vaginal process of tympanic bone, the styloid process. This line can be a key landmark to identify the carotid foramen. (C) The posterior auricular artery arises from the external carotid artery and ascends posteriorly along the styloid process. (D) Further dissection along the posterior surface of the styloid process can expose the extratemporal segment of facial nerve. The stylomastoid artery arises from the posterior auricular artery and goes upward into the stylomastoid foramen. (E) The pointer was put on the spine of sphenoid bone. (F) The vaginal process of tympanic bone was identified. (G) This view showed the relationship between the styloid process and the vaginal process of tympanic bone. The vaginal process of tympanic bone is located on the anteromedial side of the styloid process. (H) The lateral wall of carotid foramen separates the mandibular fossa from the carotid canal. A., artery; APA, ascending palatine artery; ECA, external carotid artery; ICA, internal carotid artery; L., ligament; M., muscle; Med., medial; MMA, middle meningeal artery; N., nerve; PG, parotid gland; Post., posterior; Ptery., pterygoid; SP, spinous process; SML, sphenomandibular ligament; VP, vaginal process.

was detected bilaterally in one specimen. Kinking was found unilaterally in one specimen, and coiling was detected unilaterally in another specimen.

Limits of Each Approach

The advantages and disadvantages of each approach to the PPS are summarized in ►Table 1.

Endoscopic Transnasal Transpterygoid Approach

The length from the anterior nasal spine to the ICA is 8.32 ± 0.22 cm. The transnasal TP approach provides a direct, deep, narrow, superomedial access to the PPS that is bounded laterally by the medial and lateral pterygoid muscles, medially by the lateral wall of the pharynx, superiorly by the skull base, inferiorly by the hard palate, and posteriorly by the ICA and prevertebral muscles (►Fig. 3). However, wide exposure of the ICA near the skull base often requires a resection of the Eustachian tube. In addition to providing access to the PPS, the transnasal TP approach can be modified to give access to the infratemporal fossa through the space between the lateral and medial pterygoid muscles.

Endoscopic Transoral Approach

The distance between the palatoglossal fold and the ICA is 2.41 ± 0.21 cm. This approach provides wide, short access to the PPS. The TO surgical corridor passing between the mandible and the lateral wall of oropharynx is limited, laterally by the medial pterygoid muscle, the parotid gland, and the mandible; medially by the superior pharyngeal constrictor muscle and the tonsil; superiorly by the skull base; inferiorly by the base of tongue; and posteriorly by the ICA, the jugular vein, the posterior cranial nerves, and the prevertebral muscles (►Figs. 4–6). An endoscopic TO approach to the upper PPS requires visualization with an angled

(30°/45°) endoscope (►Figs. 6 and 7). The surgical corridor between the stylopharyngeus muscle and the superior pharyngeal constrictor muscle can give direct access to the carotid sheath (►Fig. 4F). With an angled endoscope, dissecting anterosuperiorly between the styloid process and the deep lobe of parotid gland will lead to the tympanic part of the temporal bone, the spine of the sphenoid bone, the facial nerve, the lateral wall of the carotid foramen, the vaginal process of the tympanic bone, and the posterior auricular artery (►Fig. 7). However, it is difficult for the endoscopic TO approach to expose the area around the Eustachian tube.

Combined Endoscopic Transoral and Transnasal Transpterygoid Approach

The hard palate limits transition between the upper and lower PPS. The combination of endoscopic TO and transnasal TP approach can eliminate this anatomical barrier by approaching the PPS behind the hard palate. This combined approach allows exposure of the entire contents of the PPS without disturbing important neurovascular structures.

Discussion

The PPS is one of the most complex and challenging anatomical areas of the head and neck and contains many important vascular and neural structures. It is located between the pterygoid musculature and lateral pharyngeal wall, which makes its surgical management very challenging even for skilled and experienced surgeons.^{3,5–7} Surgical approaches to this region require detailed and precise anatomic knowledge, especially when the endoscopic-assisted approach is used. Understanding the anatomical structures in the PPS from different viewpoints can facilitate precise localization of vital structures. Some preliminary anatomical descriptions

Table 1 Advantages and limitations of each approach to the parapharyngeal space

Approach	Advantages	Limitations
Endoscopic transnasal transpterygoid approach	Good exposure of upper portion of PPS. Surgical exposure could be extended to the infratemporal fossa and nasopharynx. No incision on the oral mucosa.	Exposure of the lower PPS below the hard palate is limited. Resection of the medial wall of maxillary sinus and turbinectomy are necessary. The surgical corridor is long and narrow. Eustachian tube resection is mandatory to have a big surgical field. It is necessary to detach the medial and lateral muscles from the pterygoid plate.
Endoscopic transoral approach	Good exposure of lower portion of PPS. The surgical corridor is short and wide. Providing a direct access to the ICA. No effect on the nasal function. Good exposure of posterior cranial nerves. Allowing three- or four-handed manipulation.	Exposure of the area around Eustachian tube is difficult. Incision on the oral mucosa is required. Exposure of the upper portion of PPS requires a maneuver under the side-viewing endoscope.
Combined endoscopic transnasal and transoral approach	Optimal exposure of the entire PPS. Eliminating the limitation of hard palate. The multiportal approach provides freer surgical maneuver. Good control of the major neurovascular structures.	Incision of the oral mucosa. Indications are limited to the tumor that crosses the upper and lower PPS or when the ICA needs to be identified and preserved.

Abbreviation: ICA, internal carotid artery; PPS, parapharyngeal space.

of the upper PPS via transnasal TP approach and endoscopic-assisted TO approaches have been reported, but detailed description of anatomy in the PPS is still incomplete.^{8–10,12,14}

The mainstay of treatment for PPS tumors is surgery. The choice of approach is dependent on the size, location, and pathology of the tumor. Traditional surgical approaches include transcervical, transoral, transmandibular, transparotid, and various combined approaches, and each of them has its own advantages and limits.^{3,6,7} Generally, open approaches require a skin incision with a visible scar. The TO approach for the management of PPS lesions was traditionally criticized owing to limited visualization, risk of infection, narrow space, and lack of vascular control.¹⁷ But with advances in robotic-assisted surgery and the wide application of endoscopic techniques, the TO approach has been used again by many authors.^{8,10,15,18} Meanwhile, with the evolution of endoscopic skull base surgery, the transnasal approach has also been adopted to manage lesions in the PPS.^{9,11}

The endoscopic transnasal TP approach can provide a direct route to the upper PPS, but it has also some drawbacks, such as a long and narrow surgical corridor, constricted lateral exposure, limited inferior access, and Eustachian tube resection when extended surgical exposure is needed.¹³ The trajectory of the endoscopic transnasal TP approach to the upper PPS is restricted laterally by the medial and lateral pterygoid muscles. Sometimes, the pterygoid plates and muscles need to be removed to get more lateral exposure, which may lead to impaired masticatory function. Resection of the Eustachian tube is necessary for exposure of the upper parapharyngeal ICA, but results in Eustachian tube dysfunction after surgery. The vidian nerve and Eustachian tube have been used as critical landmarks for foramen lacerum and petrous ICA, respectively.^{19–21} However, there is no reliable anatomic landmark for the parapharyngeal ICA as it can be very tortuous, and anatomical relationships are distorted. Consequently, the indication for endoscopic transnasal TP approach to the PPS is confined to benign lesions and limited malignant tumors that are located mainly in the upper portion of the PPS.

The TO approach can provide a direct route to the lower lateral portion of the PPS without dissection of the pterygoid muscles and can overcome the inferior access limit of the transnasal TP approach (→ **Figs. 4 and 5**). Compared with the transnasal approach, the TO approach provides a shorter and wider surgical corridor to the PPS and can facilitate exposure of the parapharyngeal ICA. As parts of the styloid diaphragm that separates the prestyloid and poststyloid spaces, the styloglossus and stylopharyngeus muscles can be considered the safe anterior boundary of the parapharyngeal ICA.¹⁴ After removing the fat tissues in the prestyloid space, careful dissection between the stylopharyngeus muscle and the superior pharyngeal constrictor muscle will lead to the parapharyngeal ICA with the opportunity for proximal control. However, if carotid injury occurs during the surgery, the TO approach might provide less control of the proximal ICA than a transcervical approach. However, the risk of both approaches seems to be same when the injury to the carotid occurs near the skull base. Although the TO approach provides adequate access to the upper PPS when viewed with an

angled endoscope (→ **Figs. 4–6**), it is difficult to expose the area around the Eustachian tube.

An endoscopic-assisted TO approach combined with a transnasal TP approach can overcome many deficiencies that are often encountered when the transnasal approach is used alone. A combined approach can provide optimal exposure of the entire PPS without the limitations imposed by the hard palate. A combined approach allows for a four-handed technique and permits ample mobility for surgical instruments. However, the main indications for this combined approach should be limited to tumors that span the upper and lower portion of the PPS or when the parapharyngeal segment of the ICA needs to be controlled during endoscopic transnasal TP surgery.

As most of the tumors in the PPS are benign and located in the prestyloid space, an understanding of the anatomical landmarks in the prestyloid space of PPS is essential to expose the tumor during surgery. The sequential anatomical landmarks during the endoscopic transnasal TP approach to the prestyloid space of PPS are as follows: the pterygoid process, medial and lateral plates, lateral and medial pterygoid muscles, tensor veli palatine muscle, and superior pharyngeal constrictor muscle. The prestyloid compartment of PPS is mainly filled with fat tissue and could be entered by retracting the medial pterygoid muscle and tensor veli palatine muscle laterally. When the endoscopic TO approach is selected to the lesions in the lower part of the prestyloid space of PPS, the superior pharyngeal constrictor muscle, palatoglossal fold, pterygomandibular raphe, and styloid diaphragm could be used as the sequential anatomical landmarks to identify the location of tumor. However, the lesions in the prestyloid space often push the peripheral anatomic structures; therefore, the styloid group of muscles could not be identified usually. Therefore, once the incision was made on the oral mucosa and superior pharyngeal constrictor muscle, the dissection would be performed on the surface of the tumor itself.

Many complications have been described in the literature after various surgeries of the PPS, which include cranial nerve injury, tumor spillage, infection, Horner's syndrome, first bite syndrome, trismus, hematoma, vascular injury, dysphagia, and Frey's syndrome. The most common complication in the cumulative series was injury to the vagus nerve that affected 13 to 14% cases.^{22,23} When the endoscopic transnasal TP approach is used to treat the lesions in the PPS, the extra complications of nasal cavity, including nasal bleeding, adhesion, nasal dryness, and crusting, may occur. The endoscopic TO approach to PPS tumor resection may also have many potential complications including tumor spillage, bleeding, infection, vascular and neural injury, and dysphagia. When compared with the traditional transcervical approach, the endoscopic TO approach has limited exposure and high risk of tumor spillage and neurovascular injury. Therefore, the patients should be selected cautiously for this approach and be informed the possibility of converting into the traditional open approach.

Conclusion

The PPS is one of the most complex areas of the head and neck and contains many important vascular and neural

structures. Endoscopic-assisted TO (with or without surgical robotic system) and transnasal TP approaches provide new strategies to manage lesions in the PPS. An endoscopic-assisted TO approach can also serve as an adjunct to other approaches for identification of the parapharyngeal ICA. Precise anatomic knowledge is essential to treat lesions of PPS without risking significant surgical complications.

Conflicts of Interest

All authors have no funding, financial relationships, or conflicts of interest to disclose.

Note

Dr. Xicai Sun and Dr. Bo Yan contributed equally to this work.

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