Endoscopic Endonasal Access to the Jugular Foramen: Defining the Surgical Approach

Dennis L.Y. Lee¹ Edward D. McCoul² Vijay K. Anand² Theodore H. Schwartz^{2,3,4}

¹Department of Ear, Nose and Throat, United Christian Hospital, Affiliated Unit of the Chinese University of Hong Kong, Kwun Tong, New Kowloon, Hong Kong

²Department of Otolaryngology-Head and Neck Surgery, New York Presbyterian Hospital, Weill Cornell Medical College, New York, New York, United States

³Department of Neurological Surgery, New York Presbyterian Hospital, Weill Cornell Medical College, New York, New York, United States

⁴Department of Neurology and Neuroscience, New York Presbyterian Hospital, Weill Cornell Medical College, New York, New York, United States

Address for correspondence and reprint requests Vijay K. Anand, M.D., F.A.C.S., Department of Otolaryngology-Head and Neck Surgery, New York Presbyterian Hospital, Weill Cornell Medical College, New York, New York, United States, 772 Park Avenue, New York, NY 10021 (e-mail: vijayanandmd@aol.com).

J Neurol Surg B 2012;73:342–351.

Abstract

Keywords

- endoscopy
- endonasal
- infratemporal fossa
- parapharyngeal space
- jugular foramen
- skull base
- cranial base
- surgery

Introduction The endoscopic endonasal approach to the parapharyngeal space (PPS) and jugular foramen is not well defined. We sought to systematically define the important landmarks and limitations of this new surgical technique using an endoscopic transmaxillary transpterygoid corridor.

Methods Endoscopic dissection was performed in both sides of two latex-injected cadaver heads. Left-sided dissections were facilitated by the addition of a sublabial maxillary antrostomy. The pterygopalatine fossa, infratemporal fossa, and PPS were sequentially dissected and the endoscopic perspective was examined. Measurements were obtained from the surgical orifices to the upper cervical internal carotid artery (ICA) and internal jugular vein (IJV).

Results Successful access to the PPS and jugular foramen was achieved in each dissection. The lateral pterygoid plate, mandibular branch of the trigeminal nerve, middle meningeal artery, levator veli palatini muscle, Eustachian tube, and stylopharyngeal fascia were identified as landmarks for the upper cervical ICA and the IJV. The mean distance from the nasal sill was markedly greater than from an ipsilateral sublabial antrostomy.

Conclusion The endoscopic endonasal approach can provide adequate access to the PPS, carotid sheath, and jugular foramen. Multiple landmarks are useful to guide the dissection within these deep spaces and may facilitate the clinical application of this approach.

Introduction

The limits of endoscopic endonasal surgery continue to expand as anatomical study offers new perspectives for the skull base surgeon. Advances in knowledge, along with

sophisticated endoscopic instrumentation and intraoperative navigation systems, now permit endoscopic surgeons to access targets at the anterior, middle, and posterior skull base. Our group has developed a system of four different

received

August 9, 2011

accepted after revision

February 12, 2012

published online

August 14, 2012

Copyright © 2012 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.
Tel: +1(212) 584-4662.

DOI <http://dx.doi.org/10.1055/s-0032-1322796>.
ISSN 2193-6331.

corridors, each specialized to access certain anatomical targets,¹ which complements the descriptions of endoscopic approaches in relation to the internal carotid artery (ICA).²⁻⁴ We have previously described the transmaxillary transpterygoid approach to the pterygopalatine fossa (PPF), infratemporal fossa (ITF), Meckel's cave, petrous apex, lateral sphenoid sinus, and lateral cavernous sinus.^{1,5-7} The endoscopic approach to the jugular foramen is an extended application of the transmaxillary corridor and may represent the posterolateral limit of endoscopic skull base surgery.⁸

Access to the jugular foramen presents a challenge to the endoscopic surgeon because of the deeply situated structures and the limited available anatomical descriptions of that region from the endoscopic perspective.^{9,10} In contrast, the complex anatomy of the PPF, ITF, and parapharyngeal space (PPS) is relatively well described with respect to the external view.¹¹⁻¹³ As the applications of endoscopic skull base surgery continue to evolve, a full appreciation of the endoscopic perspective of the PPS, carotid sheath, and jugular foramen will be essential for the skull base surgeon.^{9,10,14} Therefore, the primary aim of this study was to refine the anatomical model for the endoscopic endonasal approach to these deeply situated structures and identify surgical landmarks for clinical application. A secondary aim was to assess the application of a sublabial maxillary antrostomy to reduce the operating distance in selected cases.

Methods

This study was conducted in the dissection laboratory of the research institution of the senior authors. Endoscopic endonasal dissection was performed in both sides of two-colored-latex-injected cadaver heads. Dissections were performed using both a four-handed, two-surgeon technique and a single-surgeon technique. Endoscopes with 0-degree and 30-degree angled optics were used for visualization, and a high-definition camera and the AIDA system were used for photography and image storage (Karl Storz Endoscopy, Tuttlingen, Germany). Endoscopic sinus and skull base surgical instruments (Storz) and high-speed cutting and diamond burrs were used for dissection (Anspach, Palm Beach Gardens, Florida, USA). The PPF, ITF, and PPS were examined through the endoscopic transmaxillary transpterygoid corridor. Measurements from the left and right nasal sill and the sublabial antrostomy to the parapharyngeal ICA (PPICA) and internal jugular vein (IJV) were obtained using a surgical ruler at the conclusion of each dissection.

Anatomic Definitions

The PPF is an anatomical space that communicates medially with the nasal cavity and laterally with the ITF. The PPF communicates with the ITF through the pterygomaxillary fissure laterally.¹⁵ The anterior compartment of the PPF contains the third part of the internal maxillary artery (IMA) and its branches, whereas the posterior compartment contains the vidian nerve (VN), the maxillary division of the trigeminal nerve (V2), and the pterygopalatine ganglion (PPG) and its branches.^{5,16-18}

The ITF is an anatomical space that communicates medially with the PPF and posteromedially with the PPS. The ITF contains the lateral pterygoid muscle (LPtM) and the temporalis muscle, the first and second part of the IMA and its branches, the mandibular division of the trigeminal nerve (V3), and the otic ganglion.^{11,12}

The PPS is an inverted pyramidal space extending from the skull base to the level of the hyoid bone, lateral to the pharynx and posteromedial to the ITF. The styloid diaphragm is an important and consistent structure that divides the PPS into prestyloid and poststyloid regions.¹⁹ The styloid diaphragm is formed, from lateral to medial, by the posterior belly of the digastric muscle, the stylomandibular and stylohyoid ligaments, the styloid muscle group (stylohyoid, styloglossus, and stylopharyngeus) and the stylopharyngeal fascia (SPhF), and attaches to the anterior border of the of the PPICA.¹⁹ The prestyloid region contains fatty tissue together with the tensor veli palatini muscle (TVPM), levator veli palatini muscle (LVPM), and cartilaginous Eustachian tube (ET). The poststyloid region contains the ICA, the IJV, the lower cranial nerves (CN IX through XII), and the sympathetic trunk.

Initial Exposure

In each specimen the posterior bony septum was removed to improve the endoscopic visualization and to provide adequate room for a four-handed dissection. Thereafter, an endoscopic medial maxillectomy was performed from the nasolacrimal duct anteriorly to the posterior wall of the maxillary sinus posteriorly. The nasolacrimal duct was transected to improve exposure for the subsequent dissection. The medial maxillary wall was drilled down to the level of the nasal floor to facilitate visualization and instrumentation of the deeper structures. At this point, the sphenopalatine foramen with the sphenopalatine artery (SPA), the posterior wall of the maxillary sinus, and the infraorbital canal were exposed (►Fig. 1).

The dissection laboratory was set up to imitate a typical operating room arrangement, in which a right-handed surgeon stands on the patient's right side. This arrangement requires the surgeon to maintain a different angle with the dissection instruments relative to body position when performing a left-sided dissection versus a right-sided dissection. To address this issue related to patient positioning, a sublabial maxillary antrostomy was created on the left side of the specimen. This additional antrostomy was not utilized during right-sided dissections.

Exposure of the PPF

Removal of the posterior wall of the maxillary sinus exposed the PPF medially and part of the ITF laterally. The major branches of the IMA were identified in the anterior compartment with careful dissection: the posterior superior alveolar artery, the infraorbital artery, the descending palatine artery with its greater and lesser palatine branches, and the SPA and its nasoseptal branch (►Fig. 2A).^{5,16} The palatovaginal artery is a branch of the IMA that courses posteromedially toward the palatovaginal canal while remaining superficial to the PPG and the greater palatine nerve (►Fig. 2B).^{9,20}

Figure 1 Endoscopic endonasal 0-degree view of the right posterior wall of maxilla after medial maxillectomy. The sphenopalatine artery (SPA) branches and a nasoseptal branch (NSB) are seen near the sphenopalatine foramen (SPF). ET, Eustachian tube; IOC, infraorbital canal; MT, middle turbinate.

Following anterior PPF dissection, the IMA and its branches were resected to expose the neural structures in the posterior compartment of the PPF. These structures include the VN, the PPG, the greater and lesser palatine nerves, the zygomatic nerve, and the V2 with its branches including the infraorbital nerve (ION) (►Fig. 3). The VN was directed posteriorly into the vidian canal, while the V2 and the foramen rotundum were consistently identified superolaterally.²¹ After giving off communicating branches to the

PPG, the V2 became the ION coursing posteriorly toward the infraorbital foramen. The greater palatine nerve in the palatine canal was consistently identified once the anterior edge of the perpendicular plate of the palatine bone was removed. The zygomatic nerve could not be confidently identified because of its position lateral to the ION. Once the VN was transected just proximal to its junction with the PPG, the pterygoid process at its basal attachment to the basisphenoid was fully exposed.

Exposure of the ITF

Removing the posterior wall of the maxilla laterally exposed the vertically oriented temporalis muscle fibers (►Fig. 3). In contrast, the LPTM was readily identified by the horizontal orientation of the muscle fibers. The superior head of the LPTM originated from the greater wing of the sphenoid, and the inferior head of the LPTM originated from the lateral surface of the LPTP. The space between the temporalis muscle and the LPTM was filled with adipose tissue. Removal of this fat pad by gentle traction exposed the buccal nerve and the second part of the IMA. The middle meningeal artery (MMA) was consistently identified at the lower head of the LPTM as it coursed superiorly to the foramen spinosum.

Subsequent to this dissection the LPTM was resected to facilitate better exposure of the ITF. The foramen ovale and the main trunk of V3 were found posterior to the lateral pterygoid plate (LPTP) as a reliable relationship. The MMA was variably observed either posterolateral to the posterior division of V3 or crossing medial to the inferior alveolar nerve. The MMA consistently entered the foramen spinosum posterolateral to the foramen ovale (►Fig. 4A–C). The chorda tympani nerve was identified coursing in a posterior-to-anterior direction and joining the lingual nerve in the ITF (►Fig. 4A, B). The auriculotemporal nerve encircling the MMA (►Fig. 4A) and the accessory MMA arising from the MMA and entering the

Figure 2 Endoscopic endonasal 0-degree view of the right pterygopalatine fossa and part of the infratemporal fossa. (A) Posterior wall of the maxilla and the underlying periosteum and fat pad have been removed, exposing the internal maxillary artery (IMA) and its branches. (B) Magnified view of the pterygopalatine fossa shows the pharyngeal artery arising from the lesser palatine artery (LPA) and passing posterior to the greater palatine nerve (GPN). Deep Temp Art., deep temporal artery; GPA, greater palatine artery; GPN, greater palatine nerve; IOA, infraorbital artery; NSB, nasoseptal branch of sphenopalatine artery; PPG, pterygopalatine ganglion; PSAA, posterior superior alveolar artery; SPA, sphenopalatine artery.

Figure 3 Endoscopic endonasal 0-degree view of the right pterygopalatine fossa and the infratemporal fossa. The internal maxillary artery (IMA) and its branches have been resected to reveal the neural structures in the posterior compartment of the pterygopalatine fossa. The vidian nerve (VN) and the pterygopalatine ganglion (PPG) appear lateral to the sphenopalatine foramen (SPF). The VN is directed posteriorly into the vidian canal (Vidian c.). The maxillary branch of the trigeminal nerve (V2) and the foramen rotundum (RF) are superolateral to the VN. The fat pad in the infratemporal fossa has been removed to expose the lateral pterygoid muscle (LPtM) and the temporalis muscle (Temp. mus.). Buccal n., buccal nerve; ET, Eustachian tube; GPN, greater palatine nerve; ION, infraorbital nerve.

foramen ovale with the V3 (►Fig. 4D) were also identified. The medial pterygoid muscle (MPtM) formed the inferior limit of this boundary with the PPS, and the interpterygoid fascia formed the superior limit (►Fig. 5). The fat of the prestyloid compartment was visible through this fascia.

Exposure of the PPS

Drilling the pterygoid process and removing the LPtP allowed full exposure of the MPtM. Access to the PPS required drilling the pterygoid process superiorly to the foramen rotundum and vidian canal and inferiorly to the level of the nasal floor. The prestyloid compartment of the PPS was entered by resecting the MPtM, which was done as low as possible to expose the TVPM (►Fig. 6A). The interpterygoid fascia was then opened to expose the prestyloid fat pad (►Fig. 6B). The TVPM was identified originating from the upper border of the cartilaginous part of the ET. The TVPM was oriented medially, anteriorly, and inferiorly and was situated lateral to the medial pterygoid plate (MPtP). Removal of the TVPM allowed visualization of the MPtP, the prestyloid fat pad, the LVPM, and the styloid diaphragm.

The LVPM was identified as a thick, rounded muscle running inferiorly along the axis of the cartilaginous ET. As previously described, the styloid diaphragm is an important structure that divides the PPS into prestyloid and poststyloid compartments.¹⁹ In the endoscopic transpterygoid approach, only the styloid process, stylopharyngeus muscle and the

SPhF of the styloid diaphragm were well appreciated from the endoscopic view (►Fig. 7). Opening the SPhF exposed the poststyloid compartment and the PPICA (►Fig. 8). The styloid process and the stylopharyngeal muscles were consistently positioned lateral to the PPICA, whereas the glossopharyngeal nerve (CN IX) coursed between them (►Fig. 9). After resection of the stylopharyngeal muscle the IJV could be seen posterior and lateral to the PPICA. The glossopharyngeal nerve (CN IX), vagus nerve (CN X), and the pharyngeal branch of the vagus nerve were easily identified between the PPICA and the IJV (►Fig. 10A). The spinal accessory nerve (CN XI) was expected to be directed posteroinferiorly from the jugular foramen, lateral to the IJV, but was not easily identified in the endoscopic perspective because of its deep position. The hypoglossal nerve (CN XII) emerged from the hypoglossal canal and was directed inferiorly and posteriorly to the PPICA and medial to the vagus nerve at this level (►Fig. 10B, C).

To attain a complete view of the PPS, the PPICA was exposed up to the first genu in the carotid canal. Drilling along the medial and inferior aspect of the VN from the first to the second genu of the ICA facilitated this exposure. At the first genu the horizontal petrous ICA turned vertically into the paraclival ICA, fixed firmly with the fibrocartilaginous tissue inferiorly in the foramen lacerum, as the VN passed superior and lateral to the second genu of the ICA (►Fig. 11A). Further drilling laterally from the second genu allowed access to the petrous ICA and the first genu of the ICA. This narrow corridor was enlarged by removal of the cartilaginous ET, which allowed the best exposure of the PPICA (►Fig. 11B).

Results

PPF Dissection

The endoscopic anatomy of the PPF was noted while creating access to the deeper spaces. The IMA and its branches within the anterior compartment of the PPF demonstrated anatomical variability, whereas the anatomy of the neural structures in the posterior compartment of the PPF was consistent. Our dissection confirmed that the VN and PPG were always posterior to the SPA and lateral to the SPF. The foramen rotundum and V2 were consistently identified lateral and superior to the vidian canal.

ITF Dissection

Identification of the V3 was a key component of the ITF dissection. The LPtP was consistently found just anterior to the V3 as it exited the foramen ovale. The buccal nerve, found consistently between the superior and inferior head of the LPtM, could be most easily identified anteriorly. We found that tracing the buccal nerve posteriorly, medially, and superiorly between the LPtM and the TVPM was a useful landmark to identify the anterior division of the main trunk of the V3 and the foramen ovale. The V3 was consistently found anterior to the PPICA and serves as a landmark for that vessel.

The course of the second part of the IMA in the ITF was variable, running either lateral to the LPtM or medially between the LPtM and the LPtP. There were no constant anatomic relationships for most of the branches of the IMA in

Figure 4 Endoscopic endonasal 30-degree views showing the relationships between the middle meningeal artery (MMA) and the mandibular branch of the trigeminal nerve (V3) in the left (A, C, D) and right (B) infratemporal fossa. At the level of the division of the V3 into the lingual nerve (Lingual n.) and inferior alveolar nerve (Inf. alveolar n.), the MMA is variably observed either posterior (A), crossing medial (B), or lateral (C) to the inferior alveolar nerve, which is the posterior branch of the posterior division of the V3. The chorda tympani nerve (CT) runs from posterior to anterior and it joins the lingual nerve (Lingual n.) in the infratemporal fossa (A, B). The auriculotemporal nerve (Auriculotemporal n.) arises from the posterior division of V3 and it encircles the MMA (A). (D) The MMA passes through the foramen spinosum (FS) at the skull base posterolateral to the foramen ovale (FO). The accessory middle meningeal artery (Access. MMA) arises from the MMA and it passes through the FO together with V3. IMA, internal maxillary artery; LptM, lateral pterygoid muscle; MPtM, medial pterygoid muscle.

the ITF. However, the MMA was consistently identified inferior and medial to the lower head of the LptM and directed superiorly toward the foramen spinosum. The MMA had a variable relationship to the inferior alveolar nerve, but was consistently found posterior to the main trunk of the V3. The MMA was found anterior to the PPICA, which served as an additional landmark to that vessel. The chorda tympani, accessory MMA, and auriculotemporal nerve encircling the MMA were all identified within the ITF. The interpterygoid fascia between the MPtM and LptM formed the boundary between the ITF and PPS.

PPS Dissection

Opening the interpterygoid fascia provided entry to the PPS and exposure of the prestyloid fat pad. The origin of the TVPM was found in the prestyloid space, and removal of the TVPM revealed the LVPM. We found that the origin of the LVPM at the basisphenoid and the bony-cartilaginous junction of the ET were important landmarks, as they were found anterior to

the PPICA in each specimen. The SPhF was another important landmark for the PPICA because once it was opened the PPICA came into view. The IJV was always found posterior and lateral to the PPICA and posterior to the coronal plane of the styloid process.

Identification and preservation of the neural structures of the PPS was achieved in each dissection. The CN IX was consistently present between the styloid muscles and the PPICA. The CN X and its pharyngeal branch were consistently found on the lateral side between the PPICA and the IJV. The CN XI was difficult to identify because of the posterior course of the nerve. The CN XII was consistently found posterior to the PPICA and medial to the vagus nerve. Sacrifice of the cartilaginous ET was necessary to obtain the most complete view of the PPICA.

Measurement of Operating Distances

The measurements from the surgical orifices to the great vessels in each specimen are presented in ►Table 1. The mean

Figure 5 The mandibular branch of the trigeminal nerve (V3) and the middle meningeal artery (MMA) are retracted laterally to show an endoscopic endonasal 30-degree view of the left parapharyngeal space behind the infratemporal fossa. The medial pterygoid muscle (MPtM) and the interpterygoid fascia (InterPt. fascia) form the boundary between the two spaces. The prestyloid compartment fat pad behind the interpterygoid fascia can be seen. LPtM, lateral pterygoid muscle.

operating distance was 12.1 cm from the ipsilateral nasal sill to the IJV. Mean operating distances to the PPICA and IJV from the contralateral nasal sill were each 0.5 cm greater than from the ipsilateral nasal sill. Where a sublabial maxillary antrostomy was utilized, the reduction in mean operating distance was 48% less to the PPICA and 52% less to the IJV when compared with the distance from the contralateral nasal sill.

Discussion

The ITF and PPS have traditionally been approached by open techniques, such as the Fisch type C lateral skull base approach and the pre-auricular subtemporal infratemporal fossa approach.^{22,23} However, significant morbidity can occur as a result of facial nerve transposition, temporomandibular joint dislocation, mandibular resection, and middle ear and external ear obliteration. Up to a 30% incidence of cranial nerve deficits has been reported after lateral skull base surgery for glomus jugulare lesions.²⁴ Use of the endoscopic endonasal transpterygoid approach to the PPS may reduce surgical morbidity in well-selected patients. At present, the anatomical description of these regions in the endoscopic perspective is limited,^{9,10,14} and reports of endonasal resection of PPS lesions are sparse.²⁵ The goal of this study was to improve the understanding of the surgical anatomy of the PPS, carotid sheath, and jugular foramen from the endoscopic perspective.

Our group has categorized the endonasal endoscopic approaches to the skull base into corridors based on the sinonasal structures that must be traversed to access the surgical target.¹ In this study, we confirmed that the endoscopic endonasal transpterygoid approach provides adequate visualization and access to the PPF, ITF, and PPS. Endoscopic medial maxillectomy and posterior septectomy provide the initial exposure and the four-handed technique is preferred for optimal instrumentation. Dissection on the left side by a single right-handed surgeon was facilitated by the addition of an ipsilateral sublabial maxillary antrostomy, which has been previously described for removal of lesions in the ITF.¹⁴ In particular, this technique is beneficial when a right-handed surgeon standing on the right side of the table is performing a left-sided dissection. A similar benefit may be found for a right-sided antrostomy when a left-handed surgeon is performing a right-sided dissection. It should be emphasized that

Figure 6 Endoscopic endonasal 30-degree views showing the left prestyloid compartment of the parapharyngeal space has been entered. (A) The medial pterygoid muscle (MPtM) has been resected as low as possible to expose the tensor veli palatini muscle (TVPM). (B) The interpterygoid fascia has been opened to expose the prestyloid fat pad. Buccal n., buccal nerve; Inf. alveolar n., inferior alveolar nerve; InterPt fascia, interpterygoid fascia; Lingual n., lingual nerve; LPtM, lateral pterygoid muscle; MMA, middle meningeal artery.

Figure 7 Endoscopic endonasal 30-degree view of the left styloid diaphragm and the parapharyngeal space. The tensor veli palatini muscle has been resected and the prestyloid fat removed to expose the levator veli palatini muscle (LVPM) and the medial part of the styloid diaphragm, which is formed by the styloid process, the stylopharyngeal muscle (SPhM), and the stylopharyngeal fascia (SPhF). The Eustachian tube has been preserved. Inf. alveolar n., inferior alveolar nerve; Lingual n., lingual nerve; LPtM, lateral pterygoid muscle; MMA, middle meningeal artery; V3, mandibular branch of the trigeminal nerve.

Figure 8 Endoscopic endonasal 30-degree view of the left parapharyngeal space. The stylopharyngeal fascia (SPhF) has been opened to reveal the internal carotid artery (ICA). The middle meningeal artery (MMA) has been cut near the skull base. The mandibular branch of the trigeminal nerve (V3), the MMA near the skull base, the origin of the levator veli palatini muscle (LVPM), and the SPhF are important landmarks anterior to the parapharyngeal ICA. The Eustachian tube has been preserved.

Figure 9 Endoscopic endonasal 30-degree view of the left parapharyngeal internal carotid artery (ICA), the glossopharyngeal nerve (IX), and the styloid muscles. The styloid process, the stylopharyngeal muscle (SPhM), and the styloglossal muscle (SGM) are positioned lateral to the ICA. The cranial nerve IX lies between the ICA and the SPhM. The Eustachian tube has been preserved.

surgeon handedness is not believed to be a limiting factor in accessing the skull base, though issues related to patient positioning may be improved by the addition of a sublabial antrostomy. These potential benefits were not specifically assessed in this study, but may include a wider angle for visualization and improved access to lateral structures.

Because of the deeply situated position of the jugular foramen relative to the nasal cavity, every additional millimeter of surgical exposure serves to enhance the endoscopic perspective. Drilling the medial maxillary wall and the pterygoid process to the level of nasal floor improves the lower limit of exposure. To extend the upper level of exposure, the VN can be traced posteriorly until reaching the second genu above the foramen lacerum, followed by excision of the cartilaginous ET and drilling from medial to lateral from the second genu of the ICA to the first genu of the ICA to expose the petrous ICA and the upper end of the PPICA. Distances to the great vessels via an endoscopic approach have not been previously reported and may be useful in surgical planning and anticipation of the need for instruments that can traverse extended operating distances. The observation that operating distance is reduced by ~50% with use of a sublabial antrostomy suggests another potential benefit of this technique when accessing deeply situated structures at the skull base.

Systematic dissection of the ITF identified several landmarks in the approach to the PPS. Our experience agrees with that of other authors that the LPtP is an important landmark to identify the V3 in the ITF.^{5,9} Moreover, we observed that the buccal nerve always passes between the superior and

Figure 10 Endoscopic endonasal 30-degree views of the left parapharyngeal internal carotid artery (ICA), the internal jugular vein (IJV), and the lower cranial nerves (CN). The stylopharyngeal muscle has been removed, and the Eustachian tube has been preserved. (A) The IJV is posterior and lateral to the ICA and posterior to the styloid process. CN IX, CN X, and the pharyngeal branch of the CN X (Ph. br. of X) is found between the ICA and the IJV. The CN XI is not found because of its posterior course. (B) The ICA has been retracted anteromedially to reveal the CN XII, which is on the medial side between the ICA and the IJV. The sympathetic trunk (ST) appeared posterior to the CN XII. (C) The ICA has been retracted laterally and shows the CN XII running inferomedial to the CN X. Asc. Ph. Art., ascending pharyngeal artery; SGM, styloglossal muscle.

inferior heads of the LPtM, and that the V3 can be easily found by tracing the buccal nerve posteriorly, medially, and superiorly. The MMA is identified below the lower border of the LPtM and runs superomedial to the LPtM toward the foramen spinosum, which is just posterior to the foramen ovale. We confirmed that V3 is a useful landmark to identify the PPICA.^{9,14} The MMA should also be considered a landmark for this purpose, as it is consistently found posterior to the V3 and anterior to the PPICA.

We performed layer-by-layer dissection to expose the structures in the PPS, sequentially identifying and removing the pterygoid process, LPtP, MPtM, and TVPM. This was followed by removal of the prestyloid compartment fat pad,

division of the stylopharyngeal muscle, and opening of the SPhF to reveal structures in the poststyloid compartment. We found that the PPICA can be defined endoscopically by a series of structural landmarks. These landmarks, from anterior to posterior, include the LPtP, the V3, the MMA, the origin of the LVPM, the bony-cartilaginous junction of the ET, and the SPhF. Although preservation of the ET may be a desirable goal in undertaking this approach, the maximal exposure was achieved by resection of this structure.

Although the endoscopic endonasal transpterygoid approach to the jugular foramen has been defined, we foresee several limitations that should be considered before clinical application. First, the corridor from the nostrils to the PPICA

Figure 11 Endoscopic endonasal 0-degree views of the right internal carotid artery (ICA) from the parapharyngeal segment to the paraclival segment. The right medial pterygoid muscle, the tensor veli palatini muscle, the levator veli palatini muscle, the Eustachian tube, and the stylopharyngeal fascia are removed. The lateral pterygoid plate (LPtP), the lateral pterygoid muscle, and the interpterygoid fascia (InterPt fascia) are kept intact. (A) Relationship between the vidian nerve (VN) and the second genu of the ICA (2nd genu ICA). Drilling the clivus medial to the VN exposes the paraclival ICA segment, and drilling the petrous bone inferior to the VN exposes the petrous ICA segment. The second genu of the ICA is the angulated segment between the horizontal petrous ICA segment and the vertical paraclival ICA segment, and it lies on the fibrocartilaginous tissue in the foramen lacerum. (B) Tracing the petrous ICA segment laterally leads to the first genu of the ICA (1st genu ICA), which is the angulated segment between the vertical parapharyngeal ICA segment (PPICA) and the horizontal petrous ICA segment. The ICA from the PPICA to the paraclival ICA is well-appreciated and the superior limit for the exposure of the parapharyngeal space can be reached. MCF, middle cranial fossa.

Table 1 Measurement of Surgical Orifices to the Parapharyngeal Internal Carotid Artery and the Internal Jugular Vein in Each Dissection

		Ipsilateral Nasal Sill (cm)	Contralateral Nasal Sill (cm)	Left Maxillary Antrostomy (cm)
Specimen 1				
Left	ICA	11.3	12.0	6.0
	IJV	11.5	12.3	6.6
Right	ICA	12.0	12.3	—
	IJV	12.3	12.8	—
Specimen 2				
Left	ICA	11.2	11.8	5.5
	IJV	12.0	12.3	6.3
Right	ICA	11.6	12.0	—
	IJV	12.5	13.0	—
Mean				
	ICA	11.5	12.0	5.8
	IJV	12.1	12.6	6.5

ICA, internal carotid artery; IJV, internal jugular vein.

and IJV is lengthy, and specialized instruments may be necessary in lieu of standard endoscopic sinonasal instruments. Second, a bloody view may be anticipated because of the pterygoid venous plexus, and hemostasis may be time consuming while creating the corridor. Third, the morbidity of masticatory dysfunction may still occur due to resection of the LPTM and MPtM. Fourth, this approach only accesses the upper level of the PPS above the level of the nasal floor; lesions that extend below this level may not be amenable to removal by the endonasal route. Fifth, most of the lesions in the PPS are benign and will displace the ICA and IJV. When the great vessels are displaced posteriorly it is logical to consider the endonasal approach. However, if the lesions displace the great vessels anteriorly, the open approach may be preferred. Finally, there is no proximal vessel control in this technique without a second incision. Besides meticulous hemostasis and careful dissection, an additional external incision with vascular control may be necessary during the procedure. Moreover, although this dissection has been demonstrated in a cadaver model, the practical limitations of surgical dissection in an operative setting remain to be assessed. Despite these limitations, the endoscopic endonasal approach to the jugular foramen region may be beneficial for well-selected patients. Future experience will determine the precise indications for this technique.

Conclusion

This study revealed several consistent anatomic relationships that are relevant to the endoscopic endonasal transpterygoid approach to the jugular foramen region. The LPTP, V3, MMA, LVPM, ET, and SPhF were important landmarks to identify the PPICA and IJV in the PPS. Operating distance can be improved by the addition of a sublabial maxillary antrostomy in select-

ed cases. With judicious patient selection, this approach may have significant benefits compared with traditional open surgical techniques.

Note

The authors disclose no funding received from any organizations and no conflict of interest concerning the materials or methods used in this study or findings specified in this paper.

References

- Schwartz TH, Fraser JF, Brown S, Tabaei A, Kacker A, Anand VK. Endoscopic skull base surgery. Classification of operative approaches. *Neurosurgery* 2008;62:990–998
- Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. *Neurosurg Focus* 2005;19:E3
- Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum. *Neurosurg Focus* 2005;19:E4
- Kassam AB, Gardner P, Snyderman C, Mintz A, Carrau R. Expanded endonasal approach: fully endoscopic, completely transnasal approach to the middle third of the clivus, petrous bone, middle cranial fossa, and infratemporal fossa. *Neurosurg Focus* 2005;19:E6
- Hofstetter CP, Singh A, Anand VK, Kacker A, Schwartz TH. The endoscopic, endonasal, transmaxillary transpterygoid approach to the pterygopalatine fossa, infratemporal fossa, petrous apex, and the Meckel cave. *J Neurosurg* 2010;113:967–974
- Fraser JF, Mass AY, Brown S, Anand VK, Schwartz TH. Transnasal endoscopic resection of a cavernous sinus hemangioma: technical note and review of the literature. *Skull Base* 2008;18:309–315
- Raithatha R, McCoul ED, Woodworth GF, Schwartz TH, Anand VK. Endoscopic endonasal approaches to the cavernous sinus. *Int Forum Allergy Rhinol* 2012;2:9–15

- 8 Snyderman CH, Pant H, Carrau RL, Prevedello D, Gardner P, Kassam AB. What are the limits of endoscopic sinus surgery?: the expanded endonasal approach to the skull base. *Keio J Med* 2009;58:152–160
- 9 Falcon RT, Rivera-Serrano CM, Miranda JF, et al. Endoscopic endonasal dissection of the infratemporal fossa: Anatomic relationships and importance of eustachian tube in the endoscopic skull base surgery. *Laryngoscope* 2011;121:31–41
- 10 Dallan I, Bignami M, Battaglia P, Castelnovo P, Tschabitscher M. Fully endoscopic transnasal approach to the jugular foramen: anatomic study and clinical considerations. *Neurosurgery* 2010;67(3 Suppl Operative):ons1–ons7; discussion ons7–8
- 11 Vrionis FD, Cano WG, Heilman CB. Microsurgical anatomy of the infratemporal fossa as viewed laterally and superiorly. *Neurosurgery* 1996;39:777–785, discussion 785–786
- 12 Isolan GR, Rowe R, Al-Mefty O. Microanatomy and surgical approaches to the infratemporal fossa: an anaglyphic three-dimensional stereoscopic printing study. *Skull Base* 2007;17:285–302
- 13 Moore KL. *Clinically Oriented Anatomy*. Baltimore: Williams & Wilkins; 1999
- 14 Theodosopoulos PV, Guthikonda B, Brescia A, Keller JT, Zimmer LA. Endoscopic approach to the infratemporal fossa: anatomic study. *Neurosurgery* 2010;66:196–202, discussion 202–203
- 15 Daniels DL, Mark LP, Ulmer JL, et al. Osseous anatomy of the pterygopalatine fossa. *AJNR Am J Neuroradiol* 1998;19:1423–1432
- 16 Alfieri A, Jho HD, Schettino R, Tschabitscher M. Endoscopic endonasal approach to the pterygopalatine fossa: anatomic study. *Neurosurgery* 2003;52:374–378, discussion 378–380
- 17 Fortes FS, Sennes LU, Carrau RL, et al. Endoscopic anatomy of the pterygopalatine fossa and the transpterygoid approach: development of a surgical instruction model. *Laryngoscope* 2008;118:44–49
- 18 Solari D, Magro F, Cappabianca P, et al. Anatomical study of the pterygopalatine fossa using an endoscopic endonasal approach: spatial relations and distances between surgical landmarks. *J Neurosurg* 2007;106:157–163
- 19 Bejjani GK, Sullivan B, Salas-Lopez E, et al. Surgical anatomy of the infratemporal fossa: the styloid diaphragm revisited. *Neurosurgery* 1998;43:842–852, discussion 852–853
- 20 Morton AL, Khan A. Internal maxillary artery variability in the pterygopalatine fossa. *Otolaryngol Head Neck Surg* 1991;104:204–209
- 21 Osawa S, Rhoton AL Jr, Seker A, Shimizu S, Fujii K, Kassam AB. Microsurgical and endoscopic anatomy of the vidian canal. *Neurosurgery* 2009;64(5, Suppl 2):385–411, discussion 411–412
- 22 Fisch U. Infratemporal fossa approach to tumours of the temporal bone and base of the skull. *J Laryngol Otol* 1978;92:949–967
- 23 Sekhar LN, Schramm VL Jr, Jones NF. Subtemporal-preauricular infratemporal fossa approach to large lateral and posterior cranial base neoplasms. *J Neurosurg* 1987;67:488–499
- 24 Woods CI, Strasnick B, Jackson CG. Surgery for glomus tumors: the Otology Group experience. *Laryngoscope* 1993;103(11 Pt 2, Suppl 60):65–70
- 25 Zimmer LA, Hirsch BE, Kassam A, Horowitz M, Snyderman CH. Resection of a recurrent paraganglioma via an endoscopic transnasal approach to the jugular fossa. *Otol Neurotol* 2006;27:398–402