Potential Surgical Exposure of the Parapharyngeal Internal Carotid Artery by Endonasal, Transoral, and Transcervical Approaches

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Abstract

Objectives Endoscopic and endoscopic-assisted approaches to the parapharyngeal space have been reported; however, their potential for vascular exposure has not been previously assessed. This study aims to compare the potential exposure and control of the parapharyngeal internal carotid artery (ppICA) via various approaches.

Design and Main Outcome Measures Ten cadaveric specimens were dissected bilaterally, exposing the ppICA via endonasal, transoral, and transcervical approaches. Length of the exposed vessel and potential control were assessed (feasibility and time required to place an encircling suture).

Results Endoscopic transoral and transcervical–transmandibular approaches expose a significantly longer segment of the ppICA (6.89 and 7.09 cm) than the transoral and endonasal approaches. Vascular control was achieved via endoscopic–endonasal, endoscopic–transoral, and open techniques in 121.6, 64.8, and 5.2 seconds, respectively.

Conclusion Histopathology, goals of surgery, and familiarity of the surgeon with each technique may ultimately determine the choice of approach; however, this study suggests that exposure of the ppICA by endoscopic-assisted transoral approach is comparable to that of a transcervical–transmandibular approach. Vascular control was feasible under elective circumstances. However, the difficulty varied widely, potentially reflecting the challenges of controlling an injured ppICA. However, one must note that active bleeding obscures the surgical field in ways that may impair ppICA control. Furthermore, the results may not reflect clinical scenarios where tumor distorts the surgical field.

Nonetheless, the study suggests that, in properly selected patients, the endoscopic-assisted transoral approach avoids problems associated with unsightly scars, mandibular osteotomy, and facial nerve manipulation, whereas, the transcervical–transmandibular approach offers the swiftest vascular control.

Keywords

- ▶ parapharyngeal space
- ▶ internal carotid artery
- ▶ endoscopic endonasal approach
- ▶ endoscopic transoral approach
- ▶ transcervical approach

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Introduction

The parapharyngeal space (PPS) comprises an inverted pyramid-shaped area with its base at the temporal bone and its apex at the greater cornu of the hyoid bone. It contains a complex anatomy with multiple neurovascular structures within the carotid sheath, that is, internal carotid artery (ICA), internal jugular vein, and cranial nerves [CNs] IX–XII). Its deep position, critical contents, complexity of surrounding soft tissues, and bony boundaries compound its surgical access.

Primary parapharyngeal tumors are rare, accounting for only 0.5% of all the head and neck tumors. Benign neoplasms are most common; therefore, surgical resection is the mainstay of treatment.^{1,2} Multiple open surgical approaches have been advocated, each offering varying degrees of exposure and functional outcomes.^{3–5} In general, however, an increase in surgical exposure requires greater mobilization or resection of normal tissue, and therefore, is associated with greater morbidity.

Endoscopic endonasal skull base surgery has evolved as an acceptable technique for the treatment of various skull base lesions, seeking to decrease surgical morbidity while yielding adequate oncologic outcomes.^{6–8} Following a similar philosophy, striving to minimize side effects and sequelae, various anatomical and clinical studies have reported alternative approaches to the PPS, employing endoscopic and robotic assistance via transnasal and transoral windows.^{9–16}

Surgical planning should consider the histopathology and goals of treatment; therefore, selecting a surgical approach that provides adequate exposure for the intended goal of the surgery, whether it is biopsy, decompression, debulking, or complete removal of the tumor, while minimizing functional morbidities. When selecting a surgical approach, whether it is open, endoscopic assisted, or endoscopic, one should consider the potential extent of the tumor, need for exposure, and control the site of origin, as well as extensions of the tumor in the PPS, with their respective displacement of vascular structures.

In parallel with the surgical exposure to remove the tumor, the surgeon should consider the prevention and effective management of complications, particularly catastrophic bleeding arising from the ICA. Preservation of ICA patency is ideal, but its proximal and distal control may require special instruments and endovascular surgery.^{17–19} This study aims to compare the potential surgical exposure and vascular control obtained with open, endoscopic-assisted, and endonasal endoscopic approaches (EEAs) to the parapharyngeal ICA (ppICA) under the controlled environment of a cadaveric model.

Materials and Methods

This study was conducted at the Anatomy Laboratory Toward Visuospatial Surgical Innovations in Otolaryngology and Neurosurgery (ALT-VISION), at The Ohio State University Wexner Medical Center. Ten cadaveric specimens, injected with colored latex, were dissected bilaterally to expose the ppICA. Each specimen underwent bilateral sequential dissection of the PPS via endoscopic endonasal, traditional transoral, endoscopic-assisted transoral, transcervical–sub-

mandibular, transcervical–transparotid, and transcervical–transmandibular approaches.

Conceptually, the PPS is divided in the axial plane by the fascial condensation generating pre- and poststyloid compartments. To better illustrate potential areas of exposure afforded by the various approaches, the PPS was divided in the vertical plane into three levels defined by bony landmarks. The upper part of the PPS was defined as that area extending from the skull base to the hard palate, the middle PPS was defined as the area between the hard palate and the mandibular angle, and the lower PPS was defined as the area extending from the level of the mandibular angle to the greater cornu of the hyoid bone.

Once the ppICA was exposed via each approach, the length of the exposed segment was measured, and its dimensions were documented with still photographs. To assess the potential for surgical control of the ICA, an attempt was made to dissect the vessel 360 degrees and to place an encirclement suture around the vessel. The time taken to achieve vascular control was recorded using a stop watch, thus, measuring the time starting when a single surgeon held a suture in a Kelly clamp (for open technique) or Blakesley forceps (for endoscopic technique), ready to be placed around the vessel, and stopping when the surgeon had passed the suture to securely encircle the vessel.

Operative Technique

Endoscopic Endonasal Approach

Endoscopic dissections were completed with 0 degree rod lens endoscope coupled to a high-definition camera and monitor. An Advanced Image and Data Acquisition (AIDA) system was used for still photography (Karl Storz Endoscopy, Tuttlingen, Germany).

An endoscopic total ethmoid-sphenoidectomy was followed by a medial maxillectomy with a Denker's extension to widen the lateral approach to the infratemporal fossa. The posterior and part of the lateral maxillary walls were removed. Following the identification of the infraorbital nerve, the sphenopalatine, posterior nasal, and vidian neurovascular bundles were transected and the soft tissues of the pterygopalatine fossa were lateralized to expose the anterior aspect of the pterygoid process and pterygoid muscles. The pterygoid process was removed and pterygoid muscles were transected and dissected deeply to identify the mandibular nerve (V3) and its branches at the level of the foramen ovale. The medial aspect of the ppICA was identified posteromedially to V3 (► Fig. 1).

Traditional Transoral Approach

An incision was carried over the mucosa just lateral to the tonsillar bed, extending from the posterior edge of the hard palate along the medial aspect of the mandibular angle to the posterior floor of mouth. The tonsillar fossa and the superior constrictor muscle were dissected and retracted medially. Several branches of the external carotid artery supplying the oropharynx were encountered and transected as the dissection proceeded deeply to expose the PPS. After partial transection of the styloid muscles and ligaments, the medial

Fig. 1 Cadaveric dissection illustrating an endoscopic endonasal view of the left ppICA (0 degree lens). IX, X, XI, cranial nerves IX, X, XI; ET, eustachian tube; FO, foramen ovale; FR, foramen rotundum; IMA, internal maxillary artery; MMA, middle meningeal artery; ppICA, parapharyngeal internal carotid artery; VC, vidian canal; V2, maxillary branch of trigeminal nerve; V3, mandibular branch of trigeminal nerve.

aspect of the ppICA was visualized at the depth of the surgical field. However, it could not be dissected 360 degrees and a suture could not be placed due to its deep location and poor visualization under the naked eyes.

Endoscopic Transoral Approach

Using a 0-degree rod lens endoscope via the previously described incision for a traditional transoral approach, the insertion of medial pterygoid muscle on the medial aspect of the mandibular angle was identified on the lateral boundary of

the surgical field, and the superior constrictor muscle was identified on the medial boundary. The superior insertion of styloglossus and stylopharyngeus muscles were dissected and transected, so that the styloid process could be palpated with an instrument at the superolateral aspect of the surgical field. The medial aspect of the ppICA was found posteriorly on the lateral border of the superior constrictor muscle (► **Fig. 2**).

Transcervical–Submandibular Approach

A submandibular skin incision, 2 to 3 cm inferior to the lower border of mandible, was carried through the platysma muscle. A subplatysmal superior flap was elevated while identifying and preserving the marginal mandibular branch of the facial nerve. This exposed the submandibular gland and allowed its dissection from the anterior border of the sternocleidomastoid muscle (SCM) and the posterior belly of the digastric muscle. Following the anterior displacement of the submandibular gland, the PPS was accessed and dissected to expose the lateral aspect of the ppICA and lower CNs within the carotid sheath.

Transcervical–Transparotid Approach

The previously described submandibular skin incision was extended superiorly to the preauricular area and a skin flap was elevated following a plane just above the superficial musculoaponeurotic fascia. The parotid gland was dissected from the anterior border of the SCM and the posterior belly of digastric muscle. The facial nerve trunk and its branches were identified and dissected to mobilize the superficial lobe of the parotid gland anteriorly. Subsequently, the deep lobe of the parotid gland was dissected free from the facial nerve and then resected. The posterior belly of the digastric muscle and the stylomandibular ligament were divided to allow a posteromedial dissection exposing the lateral aspect of the ppICA in the poststyloid space.

Fig. 2 Endoscopic transoral view of the left ppICA (0 degree lens): (A) Using the previous incision of the traditional transoral approach exposing the left ppICA. (B) Exposure of left ppICA and neurovascular structures within the carotid sheath. XII, cranial nerve XII; IJV, internal jugular vein; MPtM, medial pterygoid muscle; ppICA, parapharyngeal internal carotid artery; SP, styloid process.

Transcervical–Transmandibular Approach

The previously described submandibular skin incision was extended anteriorly to midline to join a perpendicular midline incision that split the submental area, mentum, lower lip, and vestibular mucosa. Lateral elevation following a subperiosteal plane exposed the mandibular symphysis and parasymphyseal area exposing and preserving the mental nerves. A mandibular osteotomy was done between the two central incisors and the mucosa of the floor of mouth along the glossogingival sulcus was transected. Muscles attached to the medial mandible were divided to increase its lateral rotation to approach the anteromedial aspect of the ppICA.

360 Degrees Dissection and Control of the ICA via Endoscopic Endonasal and Endoscopic-Assisted Transoral Approaches

The carotid sheath was opened and the ICA was dissected free from all adjacent neurovascular structures using blunt dissecting instruments. A suture encircling the ICA was deployed using a one-handed technique with blunt and angled instruments.

360 Degrees Dissection and Control of the ICA via Open Transcervical Approach

The transcervical–submandibular approach was chosen to assess the time taken for passing the suture around the ppICA. A suture encircling the ppICA was deployed using a two-handed technique with the help of artery clamps.

Statistical Analysis

The mean length of the exposed ppICA was compared using Student's *t*-test. The time taken to place the suture around the ICA was also compared among endoscopic endonasal, endoscopic-assisted transoral, and open techniques using Student's *t*-test. A *p*-value less than 0.05 was considered statistically significant.

Results

Several observations were evident from the respective dissections. An endoscopic endonasal approach exposed the ppICA from the skull base to the floor of the nose (mean length 2.715 ± 0.184 cm), whereas the transcervical–submandibular and the transcervical–transparotid approaches exposed the ppICA for a mean length of 3.69 ± 0.140 and 4.595 ± 0.174 cm, respectively. The length of ppICA exposed by the transcervical–transmandibular approach was significantly higher compared with the other approaches ($p = 0.0000$) (►Table 1 and ►Fig. 3).

The traditional transoral approach exposed only the middle level and prestyloid part of the PPS. Due to its deep location and limited view, the exposed ICA could not be measured and a suture could not be placed via this approach. Endoscopic assistance greatly facilitated the visualization and allowed exposure of the ppICA for an average length of 6.89 ± 0.179 cm. The transcervical–transmandibular approach afforded the maximum visualization of the ppICA, exposing its entire length from the greater cornu of

Table 1 Measurement of exposed ppICA via different approaches

	Endoscopic endonasal		Endoscopic transoral		Transcervical–submandibular		Transcervical–transparotid		Transcervical–transmandibular	
	Right (cm)	Left (cm)	Right (cm)	Left (cm)	Right (cm)	Left (cm)	Right (cm)	Left (cm)	Right (cm)	Left (cm)
Specimen 1	2.5	2.7	6.5	6.8	3.0	3.5	4.0	4.5	6.8	7.0
Specimen 2	2.7	2.6	7.0	6.5	3.5	3.4	4.5	4.3	7.1	6.7
Specimen 3	2.5	2.5	6.6	6.7	3.3	3.6	4.6	4.8	6.8	7.2
Specimen 4	2.8	3.0	7.0	7.0	3.6	3.5	4.5	4.7	7.0	7.2
Specimen 5	3.0	3.0	7.2	7.0	3.7	3.5	4.8	4.5	7.4	7.0
Specimen 6	2.7	2.5	7.0	6.7	3.5	3.3	4.8	4.4	7.0	6.8
Specimen 7	2.5	2.6	6.8	7.0	3.6	3.8	4.7	5.0	7.1	7.2
Specimen 8	3.0	3.0	7.2	7.0	3.8	3.5	5.0	4.5	7.5	7.3
Specimen 9	2.8	2.5	6.8	6.8	3.4	3.5	4.5	4.5	7.1	7.0
Specimen 10	2.6	2.8	7.0	7.2	3.6	3.7	4.5	4.8	7.2	7.4
Mean length	2.71	2.72	6.91	6.87	3.50	3.88	4.59	4.60	7.1	7.08
Total mean length	2.715 ± 0.184^a		6.890 ± 0.179^b		3.690 ± 0.140^a		4.595 ± 0.174^a		7.090 ± 0.174	

Abbreviation: ppICA, parapharyngeal internal carotid artery.

^aThe average span of ppICA exposed by the transcervical–transmandibular approach was significantly longer to that of the endoscopic endonasal, transcervical–submandibular, and transcervical–transparotid approaches ($p = 0.0000$, standard deviation = 0.15, 0.10, and 0.15, respectively).

^bA significant difference in the average length of the exposed ppICA was found when comparing the endoscopic transoral and the transcervical–transmandibular approaches ($p = 0.0001$, standard deviation = 0.10).

Fig. 3 Exposed segment of the ppICA being measured with a ruler. (A) Endoscopic endonasal approach exposing the ppICA from the skull base to the hard palate (mean length 2.725 cm). (B and E) The entire segment of ppICA from the skull base to the upper neck can be exposed via endoscopic transoral and the transcervical–transmandibular approaches (mean length 6.89 and 7.09 cm, respectively). (C and D) Transcervical–submandibular and transcervical–transparotid approaches can reveal part of the ppICA with mean length 3.69 and 4.595 cm, respectively; their limitations are the facial nerve, mandible, and styloid process. BOT, base of tongue; FN, facial nerve; H, greater cornu of hyoid bone; ppICA, parapharyngeal internal carotid artery.

the hyoid bone to the skull base (mean length 7.09 ± 0.174 cm). As expected, there was a statistically significant difference between the length of ppICA exposed by these two approaches ($p = 0.0001$).

Visualization of the ICA via an open approach includes 270 degrees of the vessel (mostly anterolateral), while the endoscopic view perceives only the medial 180 degrees (► Fig. 4). However, circumferential dissection and the passing of an encircling suture around the ppICA was possible in all specimens via both endoscopic and open transcervical approaches, albeit with differences in the time needed to complete the task. Time required to encircle the ppICA during the endoscopic endonasal, endoscopic-assisted transoral, and open transcervical approaches was 121.6 ± 16.2 , 64.8 ± 12.7 , and 5.2 ± 0.9 seconds, respectively. Compared with the transcervical approach, the differences in the time required by both the endoscopic endonasal and endoscopic-assisted transoral approaches were significant ($p = 0.0000$) (► Table 2 and ► Fig. 5).

Discussion

Multiple open surgical approaches have been described for the surgical treatment of PPS lesions, each offering

varying degrees of exposure and working space. A transcervical approach for the PPS lesions was first described by Morfit²⁰ in 1955. Subsequently, others have reported the successful surgical treatment of PPS lesions via multiple transcervical approaches.^{1,2,4,5,21–23}

This study provides evidence supporting that the transcervical–submandibular and the transcervical–transparotid approaches provide adequate exposure for the lesions in the lower and middle parts of the PPS. Both of these approaches can access the pre- and poststyloid PPSs but neither enables reaching the cranial base under direct visualization. Consistent with Cohen et al,²⁴ this study suggests that the pre- or poststyloid (axial plane) location of the tumor has less effect when using a transcervical approach. Conversely, invasive or vascular lesions in the superior part of the PPS, abutting or involving the skull base, require extended surgical techniques (i.e., mandibulotomy) to increase the exposure in the vertical plane; thus, avoiding a blind dissection.^{2,4} Ariel et al introduced the mandibular osteotomy in 1954 aiming to improve and increase access to the PPS.²⁵ Different types of mandibulotomy and mandibulotomy techniques have since been extensively reported for adequate exposure and vascular control of the PPS lesions.^{20,26–28} In this study, we performed an anterior mandibulotomy and the study supports that this

Fig. 4 (A) ppICA via endoscopic approach visualizing 180 degrees (0 degree endoscopic lens) and (B) open transcervical approach exposing up to 270 degrees of the anterior and lateral walls of the vessel. ppICA, parapharyngeal internal carotid artery.

Table 2 Time of task completion passing an encircling suture around the ICA

	Endoscopic endonasal		Endoscopic transoral		Open transcervical	
	Right (s)	Left (s)	Right (s)	Left (s)	Right (s)	Left (s)
Specimen 1	148	155	88	94	6	5
Specimen 2	158	134	82	77	6	7
Specimen 3	118	123	57	56	4	5
Specimen 4	134	128	68	78	6	4
Specimen 5	115	101	63	55	6	6
Specimen 6	109	112	48	68	4	6
Specimen 7	123	110	55	58	5	3
Specimen 8	108	115	59	74	6	7
Specimen 9	112	122	66	48	4	5
Specimen 10	96	111	49	53	3	6
Mean time	122.1	121.1	63.5	66.1	5.0	5.4
Total mean time	121.6 ± 16.2 ^a		64.8 ± 12.7 ^a		5.2 ± 0.9	

Abbreviation: ICA, internal carotid artery.

^aCompared with the open transcervical approach the time required to encircle the ppICA via endoscopic endonasal and endoscopic transoral approaches was significantly longer ($p = 0.0000$, standard deviation = 16.0 and 12.2, respectively).

Fig. 5 Demonstration of circumferential dissection and passing a suture around the ICA, which can be performed via both endoscopic (A and B) and open transcervical (C) approaches. ICA, internal carotid artery.

approach can expose the superior aspect of the PPS. It can provide extensive exposure of the ICA, which can be particularly helpful in case of management of a vascular injury. One must consider, however, that while open approaches provide extensive exposure and effective management of a vascular injury, they are commonly associated with unfavorable outcomes including facial and neck scars, facial nerve injury, malocclusion or nonunion of the mandible, need for a tracheostomy, and nasogastric tube placement that consequently may extend the hospital stay.²⁹ Lateral mandibulotomy (parasymphectomy or ramus osteotomy) is an alternative osteotomy technique, which rather requires manipulation of the lateral structures, that is, facial nerve and parotid gland to access the entire PPS. A double mandibular osteotomy without lip splitting technique was described in 2007 by Kolokythas et al³⁰ and in 2014 by Satpathy et al.³¹ Both studies reported minimal complications and adequate exposure of the PPS including the skull base and pterygomaxillary fossa, as well as visualization of the great vessels.

Some prefer the traditional transoral approach to manage select lesions in the prestyloid space.^{4,32,33} However, this approach offers limited visualization of deep structures in the poststyloid space and it may also be associated with accidental injuries of vessels and nerves. Using an intraoral incision identical to that of the traditional transoral approach, this study showed that endoscopic assistance can indeed enhance visualization; therefore, assisting with extension of the dissection in the superior, inferior, and posterior directions. This can expand the application of the intraoral approach to manage extensive tumors of the PPS. The endoscopic-assisted transoral approach seems to offer a balance between adequate exposure and avoiding significant surgical morbidity; thus, better preserving the patient's quality of life.

"Endoscopic assistance" during traditional approaches has been applied to the other complex and deep anatomical sites, including the PPS, aiming to enhance visualization; thus, minimizing surgical morbidities.^{9–14} Although not included in this study, endoscopic assistance extends and magnifies the visualization of the surgical field to areas not visible with line of sight tools such as loupes or microscope (or naked eye). Another potential strategy would be to combine two or more different approaches to enhance exposure while minimizing morbidity. Using a combined endoscopic nasal and endoscopic-assisted transoral approaches can be used for managing some paranasal sinus lesions that extend downward to the PPS obviating the need for an open technique.

This study suggests that the extent of ppICA exposure provided by the endoscopic-assisted transoral technique is equal to that of the transcervical–transmandibular technique in terms of surgical view. These two approaches avoid the anatomical limitations of lateral approaches (i.e., disruption of the mandible, styloid process, and facial nerve). Both approaches expose the pre- and poststyloid PPSs including the entire length of the ppICA (from the skull base to the greater cornu of the hyoid bone), although the transcervical–transmandibular approach affords superior ease of instru-

mentation. Counterintuitively, the endoscopic-assisted technique provided superior visualization particularly for the middle and superior aspects of the PPS. This advantage, however, should be tempered by its associated difficulty of instrumentation. Furthermore, these and other findings of the study should not be misconstrued as an endorsement for any particular approach. Histopathology, distortion of the anatomy by tumor, goals of the surgery, instrumentation availability, institutional resources, surgeon's experience and training, and the relationship of the lesion to the ICA are critical considerations during the selection of a surgical approach that cannot be adequately emulated in a cadaveric model. In addition, there are other alternatives not studied in this model. Chan et al reported successful transvestibular endoscopic approach on four patients with the tumor involving PPS and infratemporal fossa.¹² The surgical technique of transvestibular endoscopic approach is similar to endoscopic transoral approach in this study. Its limitation is also the same, which is the difficult management of major vessels in the poststyloid space.

In addition, O'Malley and Weinstein first reported the application of robotic surgery for PPS tumor excision in 2007.¹⁶ Multiple authors have since reported their experience in excising PPS tumor via robotic surgery discussing feasibility and safety.^{34–37} The advantages of this techniques include superior illumination using three-dimensional high-definition camera with tremor reduction and using instruments that can be worked in a narrow corridor. However, Boyce et al mentioned its limitation in exposure of far lateral tumors and those with superior extension tumors which can be overcome by combining the technique with a transcervical approach.³⁸

All techniques used in this study have intrinsic anatomical limitations that prevent the exposure (and instrumentation) of some part of the ppICA. The hard palate represents a barrier for the endoscopic endonasal approach, whereas the mandible, the styloid process, and the facial nerve restrict the transcervical approaches. The direct exposure offered by the transcervical–submandibular approach only includes the caudal part of the ppICA, as it is restricted superiorly by the angle of mandible. However, many of the lesions managed though these approaches are benign and their cephalic aspect can be dissected with blunt digital manipulation. The transcervical–transparotid approach can attain direct exposure of the ppICA up to the styloid process; however, it is limited superolaterally by the mandibular ramus and the facial nerve. The characteristics of each surgical approach to the PPS are offered in **Table 3**.

Although the incidence of ICA injury during the skull base surgery is low; however, its consequences are potentially catastrophic, as it can lead to death, neurological deficits, pseudoaneurysm, arteriovenous fistula, and vascular occlusion. Therefore, difficulty to achieve ICA control during an EEA is a major concern. A higher risk of ICA injury during endoscopic skull base surgery has been correlated with higher levels of surgical complexity; thus, these cases require an experienced multidisciplinary team and adequate instruments to optimize the capacity to overcome this critical complication.^{19,39}

Table 3 Characteristics of surgical approaches to the PPS

Approaches	Direct visualization of PPS (vertical levels)	PPS Prestyloid	PPS Poststyloid	Vascular control
Endoscopic endonasal approach	Upper	No	Yes	Possible
Transoral	Middle	Yes	No	Very difficult
Endoscopic-assisted transoral	All levels (instrumentation is limited for upper and lower)	Yes	Very difficult	Possible
Transcervical–submandibular	Middle and lower	Yes	Yes (middle PPS requires “blind” blunt dissection)	Adequate
Transcervical–transparotid	Middle (limited by styloid and ascending mandibular ramus) and lower	Yes	Yes (needs retraction of facial nerve)	Adequate
Transcervical–transmandibular	All levels	Yes	Yes	Best

Abbreviation: PPS, parapharyngeal space.

Moreover, advanced lesions that encase the ICA and highly vascular tumors mandate proximal and distal control of the vessel. In addition, preservation of adjacent CNs during the ligation or clipping the ICA, often requires a 360-degree dissection of the vessel; thus, separating the adjacent lower CNs. Therefore, the ability of a surgical approach to afford identification and dissection for vascular control should be considered. In general, open transcervical approaches provide a wider access for the management of vascular injury. However, this study suggests that the ICA can be electively controlled using endoscopic or endoscopic-assisted techniques. Circumferential dissection and passing of an encircling suture around the ICA can be achieved through both the endonasal and transoral corridors. However, this study only shows the potential to control the ICA under controlled conditions. These laboratory findings may not necessarily reflect a live scenario where the anatomy may be altered and when significant hemorrhage obscures the field and complicates the hemodynamic management. Furthermore, placing a direct suture does not exactly mimic clinical scenarios with greater challenges in the form of bleeding and anatomical distortion place, which will compound the placement of an encircling suture to achieve control of an injured pplICA near the skull base. Other methods, such as a muscle patch followed by endovascular treatment for endonasal ICA injuries and the use of hemostatic, atraumatic vascular clamps for ICA injuries during an open procedure followed by direct repair, are far more preferable techniques than encircling the ICA with sutures. However, the time to complete the encirclement provides an idea of the difficulty to dissect and control the ICA during each particular approach.

As previously alluded, a major limitation of the study is that multiple other factors affecting the choice for a surgical approach cannot be addressed in a cadaveric model. To achieve the maximum benefit of each approach, adequate tumor removal, effective vascular control, and favorable functional outcomes; the nature of pathology, location, and extension of tumors; as well as the surgeon's experience should be considered.

Conclusion

Endoscopic and endoscopic-assisted techniques are advantageous in the avoidance of external scar, mandibular osteotomy, and facial nerve manipulation. Control of the pplICA via endonasal endoscopic and transoral endoscopic-assisted approaches, albeit possible, is associated with a higher degree of difficulty, even in a cadaveric model where the anatomy is not distorted by tumor and when bleeding is not hampering visualization. Therefore, one must aware that the findings of this study represent guidelines of potential exposure of the pplICA but that are not directly transferable to a clinical scenario. Tumor histopathology, goals of the surgery, instrumentation availability and institutional resources, surgeon's experience and training, and the relationship of the lesion to the ICA are foremost elements that dictate the selection of the approach.

Disclosure

The authors declare that there are no financial disclosures and there is no conflict of interest.

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