Evolution of transmaxillary approach to tumors in pterygopalatine fossa and infratemporal fossa: anatomic simulation and clinical practice

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Abstract

Background: The endoscopic transnasal approach has been proven to have advantages on the removal of the tumors in pterygopalatine fossa (PPF) and infratemporal fossa (ITF). Herein, this study aimed to describe a modified approach for resection of the tumors in these areas, both in cadaveric specimen and clinical patients.

Methods: The 20 adult cadaveric specimens and five patients with tumors in PPF and ITF were enrolled in this study. For the cadaveric specimens, ten were simulated anterior transmaxillary approach and ten were performed modified endoscopic transnasal transmaxillary approach. The exposure areas were compared between two groups and main anatomic structure were measured. Surgery was operated in the five patients with tumors of PPF and ITF to verify the experience from the anatomy. Perioperative management, intraoperative findings and postoperative complications were recorded and analyzed.

Results: The modified endoscopic transnasal transmaxillary approach provided as enough surgical exposure and high operability to the PPF and ITF as the anterior transmaxillary approach did. The diameter of maxillary artery in the PPF was 3.77 ± 0.78 mm (range: 2.06–4.82 mm), the diameter of middle meningeal artery in the ITF was 2.79 ± 0.61 mm (range: 1.54–3.78 mm). Four patients who suffered schwannoma got total removal and one of adenocystic carcinoma got subtotal removal. The main complications were facial numbness and pericoronitis of the wisdom tooth. No permanent complication was found.

Conclusions: With the widespread use of neuroendoscopy, the modified endoscopic transnasal transmaxillary approach is feasible and effective for the resection of tumors located in PPF and ITF, which has significant advantages on less trauma and complications to the patients.

Keywords: Neuroendoscopy; Pterygopalatine fossa; Infratemporal fossa; Maxillary sinus; Surgical approach

Introduction

Tumors in the pterygopalatine fossa (PPF) and infratemporal fossa (ITF) are still challenging to neurosurgeons. Lesions in this area, such as meningioma, schwannoma or nasopharyngeal angiofibroma, although benign tumors, because of their deep location and proximity to various arteries and cranial nerves are still difficult to be safely and completely removed. Compared with lateral approaches, the anterior approaches have been proven to have obvious advantages as: (1) Avoiding of craniotomy; (2) shorter distance to reach the tumors; and (3) extradural approach that reduce the opportunity of infection and cerebrospinal fluid (CSF) leakage.[1] With the wide application of neuroendoscopy, surgery can be accomplished without open method or only miniature incision.[2]

PPF is a narrow and inverted pyramid-shaped space that is located posteriorly of the dorsal wall of maxillary sinus (MS) which contains pterygopalatine ganglion, vidian nerve, maxillary nerve (V2) and its branches, and pterygopalatine segment branches of maxillary artery. ITF is localized below the floor of middle cranial fossa which contains the lateral and medial pterygoid muscles, branches of mandibular nerve (V3), and pterygial segment of the maxillary artery, with the lateral pterygoid plate as its medial border. There are two major directions of approaches to reach the PPF and ITF: the anterior approach which opens the anterior wall of MS by either Weber-Fergusson or sublabial incision, and the transnasal approach which open the medial wall of MS.[3,4] This study compared the anterior transmaxillary approach and modified endoscopic transnasal transmaxillary approach, on their exposure area and operability to the PPF and ITF,

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then utilized the experiences from the anatomic observation to the surgery of tumors located in these areas.

Methods

Ethical approval

The study was conducted in accordance with the *Declaration of Helsinki* and was approved by the Ethics Committee of Beijing Tiantan Hospital (No. KY2014–021–02). Written informed consent was obtained from each patient before enrollment in the study.

Specimens

From 2010 to 2015, 20 adult cadaveric heads were studied to simulate the surgical approaches. Before the dissection, all the specimens were injected with red and blue silicone through the internal carotid artery (ICA) and internal jugular vein respectively, as standardized method described. All the heads were fixed in the head holders. For 10 specimens (microscope group), the anterior transmaxillary approach was simulated with the microscope (Carl Zeiss, Oberkochen, Germany) in order to accomplish the work of measurement of the main arteries and nerves; and for other 10 specimens (endoscope group), the modified endoscopic transnasal transmaxillary approach was performed to compare the feasibility and operability with the microscope group, using rigid endoscope (0 and 30-degree lens, Karl Storz, CA, USA). High-speed drills were used in both microscope and endoscope maneuver. For both groups, left sides were dissected first.

Anterior transmaxillary approach

For the microscope group, the Weber-Fergusson incision was used to expose the anterior wall of the MS. The fossa canina was recognized and is the initial point of drilling to the MS cavity. The bone windows were approximate to 2 cm × 2 cm and the infraorbital foramen should be completely preserved. After removal of the mucosa of MS, the infraorbital foramina were opened to dissociate the infraorbital artery (IOA) and infraorbital nerve (ION). Both the length of IOA and ION were measured. The posterior wall of MS was drilled from the point beneath the bundle of IOA and ION, and then enlarged to 1 cm × 1 cm. After removal of the fat in the PPF, Morton classification was observed, and the diameters of maxillary artery, sphenopalatine artery, descending palatine artery, and Vidian artery were measured. The lateral posterior wall of MS was removed carefully to expose branches of V3, pterygoid muscle, and venous plexus. After cutting off the upper heads of lateral pterygoid muscle and deeper and superficial heads of medial pterygoid muscle, the pterygoid muscles were dragged laterally, in order to measure the diameters of middle meningeal artery, anterior deep temporal artery, and posterior deep temporal artery. All the data of measurement were recorded, and the range and mean of each object were calculated.

Modified endoscopic transnasal transmaxillary approach

For the endoscope group, an endonasal prelacrimal recess-maxillary sinus corridor was adopted. The mucous membranes near the adhering portion of the inferior nasal concha on the lateral wall of the nasal cavity were cut open and peeled under the subpericon osteum. The adhering edge of the inferior nasal concha and the bony nasolacrimal duct were exposed. After severing the adhering edge of the inferior nasal concha and the bony lateral wall of the nasal cavity, a mucosal nasolacrimal duct-inferior nasal concha flap was formed, and the MS was exposed through the medial wall. Neuroendoscopy revealed a bulge of posterolateral wall of the MS. The local mucous membrane and the bony posterolateral wall of the MS were peeled, and then the pterygopalatine fossa was exposed.

Area of exposure

The area of exposure for both anterior transmaxillary approach and endoscopic transnasal transmaxillary approach was evaluated by the visuality and operability of the main boundary of PPF and ITF: the V2 in the PPF as the superior line, the vertical margin of the temporal muscle as the lateral line, the line between vidian nerve and pterygopalatine ganglion as the medial line, and the intersection point of medical wall, dorsal wall and base of the MS as the inferior point.

Patients selection and clinical protocol

From 2016 to 2018, five patients were enrolled in this study from Department of Neurosurgery, Beijing Tiantan Hospital. All the clinical information of the patients was recorded, including main complaint, neurological examination, computed tomography (CT), and magnetic resonance imaging (MRI). Diagnoses were concluded as tumors of PPF and ITF by the radiological images, which were evaluated to be fit for the modified endoscopic transnasal transmaxillary approach by the same chief operator and clinical team. No biopsy was performed before the operation.

After general anesthesia, nasal cavity was checked by the endoscope (0 and 30-degree lens, Karl Storz, CA, USA) and nasal mucosa was compressed by surgical cotton with adrenaline to reduce the bleeding. The mucosa anterior to the inferior nasal concha was cut perpendicularly to expose the eminence of the nasolacrimal duct. After drilling the bony nasolacrimal duct, the mucosal nasolacrimal duct was turned with nasal mucous together to the midline. The posterior wall of MS was carefully removed while the periosteum to be preserved. After identifying the sphenopalatine artery and pterygopalatine ganglion, the periosteum was removed to open the PPF anteriorly. The tumors in the PPF were resected piecemeal and the terminal branches of maxillary artery were identified and cauterized. After removal of the tumor and hemostasis of the surgical field, the iodoform gauze was compressed for further hemostasis and education from the inferior meatus. Finally, the mucosal nasolacrimal duct and nasal mucous were restored by suture (Supplementary material Video 1, http://links.lww.com/CM9/A19, showed a brief surgical procedure of the modified endoscopic transnasal transmaxillary approach).

A CT scan was performed 4 to 6 h after the operation to identify the hemorrhage of the surgical field. Neurological complications were recorded before discharge and at

3-months' follow-up. Postoperative MRI scan was performed no later than 1 week and the iodoform gauze was removed 1 to 2 weeks after the operation.

Results

Anatomic findings

In the MS, the IOA and ION could be guided to identify the direction to the PPF [Figures 1A and 2A]. The mean length of IOA and ION and diameters of IOA are shown in Table 1. In this study, we found 40% of the IOA had common trunk with posterior superior alveolar artery which also had anterior superior alveolar artery as its branch artery. The diameters of maxillary artery, sphenopalatine artery, descending palatine artery, and Vidian artery in the PPF are also shown in Table 1. The descending palatine artery was branched into greater palatine artery and lesser palatine artery that run through greater palatine foramen and lesser palatine foramen, separately. The sphenopalatine artery is the terminal branch of maxillary artery that runs through the sphenopalatine foramen to access the nasal cavity, and has anastomotic branches with descending palatine artery. Also, the Vidian artery has anastomotic branches with the sphenopalatine artery [Figure 1A]. In the PPF, the V2 set branch to the pterygopalatine ganglion before extended to ION, and the ganglion is divided into several branches such as posterior superior alveolar nerve, greater palatine nerve and lesser palatine nerve, accompanied with the eponymous arteries. The Vidian nerve joins the pterygopalatine ganglion after running outside the Vidian canal.

After stripping the lateral posterior wall of MS carefully, mucosa was found between bone layer of MS and posterior superior alveolar artery with its branches [Figures 1B and 2B]. After cutting the heads of pterygoid muscles and removing the pterygoid venous plexus, the pterygoid segment of maxillary artery with its branches could be seen and measured [Figure 1B]. The diameters of middle meningeal artery, anterior deep temporal artery, posterior deep temporal artery, buccal artery and inferior alveolar artery are shown in Table 2. The branches of V3 are the main nerve system in the ITF, which may influence the complication postoperatively. In the ITF, the V3 is separated into two nerve trunks after running outside

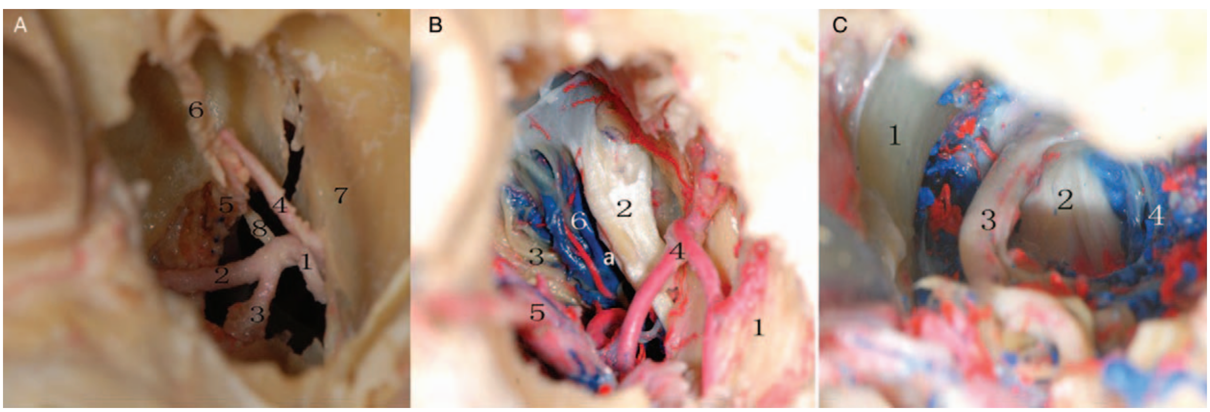

Figure 1: Anatomic view of microscope group. (A) Main neurovascular structure in the PPF: 1: maxillary artery; 2: sphenopalatine artery; 3: descending palatine artery; 4: posterior superior alveolar artery (detached); 5: maxillary nerve; 6: ION; 7: lateral wall of MS; and 8: Vidian artery. (B) Vascular and muscles in the ITF: 1: buccal muscle; 2: lateral pterygoid muscle; 3: medial pterygoid muscle; 4: buccal artery; 5: IOA; 6: pterygoid venous plexus. (C) Nerves in the ITF: 1: lateral pterygoid plate; 2: posterior trunk of V3; 3: buccal nerve; 4: pterygoid venous plexus. IOA: Infraorbital artery; ITF: Infratemporal fossa; ION: Infraorbital nerve; MS: Maxillary sinus; PPF: Pterygopalatine fossa; V3: Mandibular nerve.

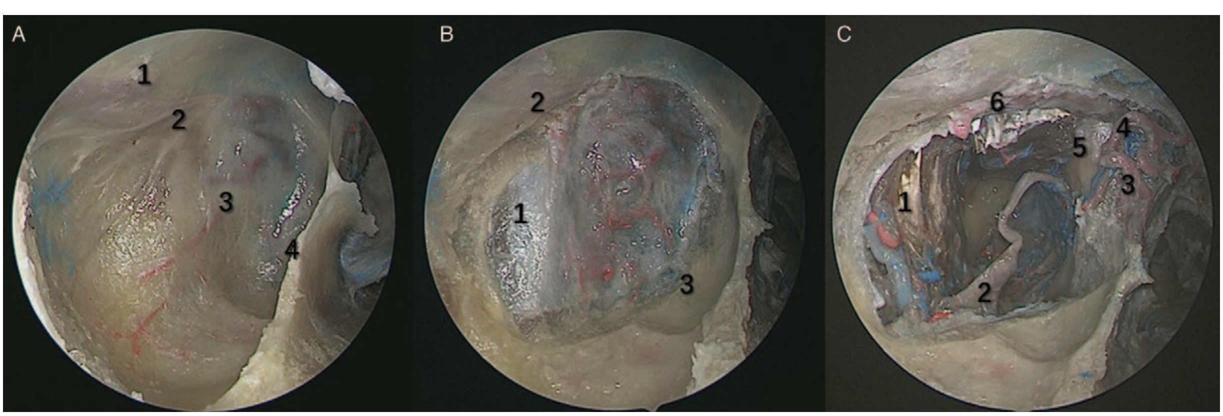

Figure 2: Anatomic view of endoscope group. (A) Dorsal wall of MS: 1: ION; 2: posterior superior alveolar nerve and branches; 3: posterior superior alveolar artery and branches; and 4: medial wall of MS. (B) Mucosa of lateral posterior wall of MS: 1: mucosa; 2: ION; and 3: intersection point of medical wall, dorsal wall and base of the MS. (C) Main structure in the PPF and ITF: 1: temporal muscle; 2: buccal nerve; 3: descending palatine artery; 4: sphenopalatine artery; 5: lateral pterygoid plate; and 6: IOA and ION. IOA: Infraorbital artery; ION: Infraorbital nerve; ITF: Infratemporal fossa; MS: Maxillary sinus; PPF: Pterygopalatine fossa.

Table 1: Measurement of main arteries and nerves in the PPF in adult cadaveric specimens.

Items	Values (mm), mean ± SD	Range (mm)
Length of IOA	4.41 ± 1.10	3.31–6.28
Diameter of IOA	0.17 ± 0.33	0.11–0.22
Diameter of MA	3.77 ± 0.78	2.06–4.82
Diameter of SPA	2.84 ± 0.62	1.68–3.84
Diameter of DPA	2.47 ± 0.58	1.50–3.34
Diameter of VA	1.84 ± 0.52	0.78–2.80
Length of V2	4.75 ± 0.89	3.34–6.10

DPA: Descending palatine artery; IOA: Infraorbital artery; MA: Maxillary artery; PPF: Pterygopalatine fossa; SD: Standard deviation; SPA: Sphenopalatine artery; VA: Vidian artery; V2: Maxillary nerve.

Table 2: Measurement of main arteries in the ITF in adult cadaveric specimens.

Items	Diameter (mm), mean ± SD	Range (mm)
MMA	2.79 ± 0.61	1.54–3.78
ADTA	1.71 ± 0.47	1.02–2.82
PDTA	2.06 ± 0.44	1.30–2.70
BA	1.37 ± 0.55	0.64–2.50
IAA	1.76 ± 0.60	0.80–3.20

ADTA: Anterior deep temporal artery; BA: Buccal artery; IAA: Inferior alveolar artery; ITF: Infratemporal fossa; MMA: Middle meningeal artery; PDTA: Posterior deep temporal artery; SD: Standard deviation.

the FO. The anterior trunk is relatively thinner which has branches of deeper temporal nerve, masseteric nerve, lateral pterygoid muscle nerve and buccal nerve [Figures 1C and 2C]. The posterior trunk is thicker that had inferior alveolar nerve, lingual nerve and auriculotemporal nerve as its branches.

For both the anterior transmaxillary approach and the endoscopic transnasal transmaxillary approach, the boundary we delineated in the PPF and ITF could be observed satisfactorily. Compared with the anterior approach, the medial approach showed equally high operability and no obstruction.

Clinical, radiological, perioperative and histopathological characteristics of five patients

Among the five patients including three females and two males, the age ranged from 26 to 52 years. The main complaints were as follows: facial numbness in three patients, ophthalmodynia in one patient and neuralgia of pterygopalatine nerve in one patient. All lesions were enhanced on the pre-operative MRI, with clear boundary in four patients and unclear in one patient [Figure 3A–3C]. Skull base bone defect was found in the CT scan [Figure 3D–3F]. All the patients received modified endoscopic transnasal transmaxillary approach to remove the tumors. During the operation, we found apophysis for the anterior wall of PPF in four patients and bone destruction in one patient. The tumors were resected piecemeal [Figure 4]. No hematoma in the surgical area was found in the CT scan postoperatively, and pathology showed schwannoma in four patients and adenocystic carcinoma in one patient. The postoperative MRI showed total removal of the lesion for the schwannomas and subtotal removal for the adenocystic carcinoma [Figure 5]. One patient suffered facial numbness after the surgery who did not present this symptom before, and another patient presented pericoronitis of the wisdom tooth 1 week postoperatively. Both the patients recovered within 3-month follow-up after the treatment with mecobalamin and metronidazole, respectively.

Discussion

For the treatment of the tumors of PPF and ITF, there are two major directions of operative approaches: lateral approaches and anterior approaches. Because the tumors of these areas are deep located, the lateral approaches may face the obstruction of temporal muscles, the vertical segment of the mandible, or even the parapharyngeal tissue. Since last decades, anterior approaches have aroused more attention from surgeons.[5-7] In 1997, Couldwell *et al*[1] presented the transmaxillary approach to the PPF and the anterior cavernous sinus using a sublabial incision to expose the maxilla, which could avoid facial incision and osteonecrosis. Three years later, another published article described this approach to reach the ITF and expose part of the lateral skull base area.[8] Klossek *et al*[9] reported a case of schwannoma in the PPF dissected by endoscopic approach in 1994, which might be the first attempt using the neuroendoscopy.

The PPF is the most important structure when utilizing the transmaxillary approach, which is regarded as the major neurovascular crossroad between the oral cavity, nasal cavity, nasopharynx, orbit, and the middle cranial fossa.[10] There are several pathways to reach the PPF from nasal cavity. In 2003, Alfieri *et al*[11] used the endonasal middle meatal transpalatine approach, the endonasal middle meatal transantral approach, and the endonasal inferior turbinectomy transantral approach to expose the PPF and ITF in eight cadaveric specimens, and found that the inferior turbinectomy transantral approach allowed the widest view and room for surgical maneuvering. During the anatomy procedure, in order to obtain better exposure of PPF and ITF from nasal corridor, a more extensive resection of the medial wall of MS is needed, which can be achieved by ethmoidectomy and sphenoidotomy or inferior turbinectomy.

The aim of management of PPF and ITF is to transpose them in order to expose larger area of lateral skull base. Therefore, understanding of major anatomic relationship of neurovascular structure is crucial. In this study, we described the relationship of the main anatomic structure and measured some arteries and nerves in the PPF and ITF, which may subserve the identification and management during the anatomy and surgery. The V2 in the PPF is the guide nerve which should be identified and utilized to follow to the FR, especially when compressed or bent by tumors. The Vidian nerve is a landmark for identification of the petrous ICA during endonasal endoscopic approaches to the skull base which should be protected.[12] Morton *et al*[13] separated the segment of maxillary artery

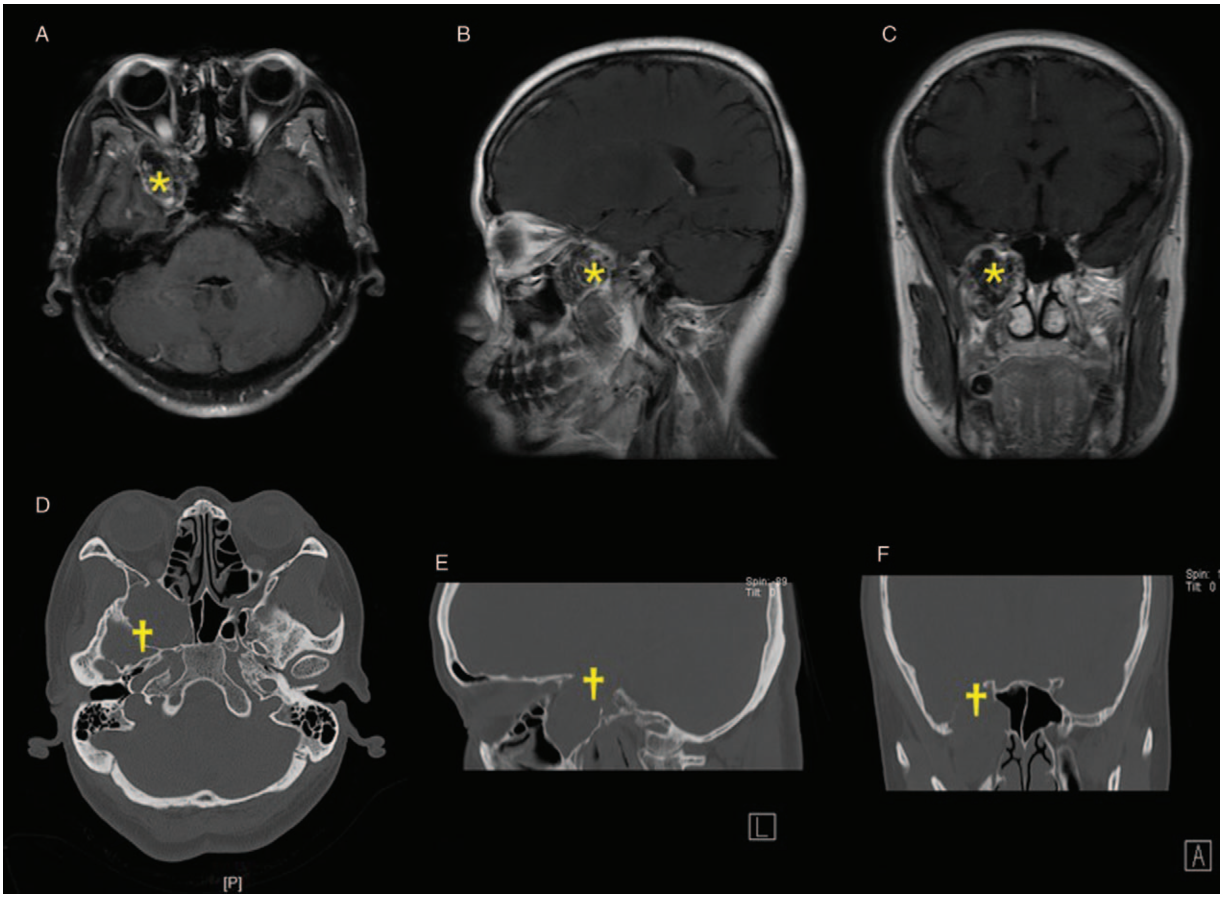

Figure 3: Preoperative sagittal (A), coronal (B), and axial (C) enhanced MRI demonstrated a tumor in the right PPF and ITF (asterisk), with relatively clear boundary and no surrounding edema. Preoperative sagittal (D), coronal (E), and axial (F) CT (bone window) showed skull base bone defect eroded by the tumor (Cross symbol). CT: Computed tomography; ITF: Infratemporal fossa; MRI: Magnetic resonance imaging; PPF: Pterygopalatine fossa.

into three areas, and the arteries for each area constituted three kinds of type: Y-type, M-type and intermediate type, which had the percentage of 33%, 16%, and 50% in the study. In the present study, the results were 27%, 13%, and 60%. The divergence might be caused by different human race.

The exposure area of specific approach is the essential factor to confirm the advantage. Elhadi *et al*[14] compared endoscopic ipsilateral endonasal transmaxillary, contralateral endonasal transseptal transmaxillary, and Caldwell-Luc approaches in four cadaveric heads, and showed no significant differences in area of exposure. In our experience, with the application of neuroendoscopy, the endoscopic transnasal transmaxillary approach showed as sufficient exposure of the PPF and ITF as the anterior transmaxillary approach did, which meant several clinical significances.

The anatomy simulation has essential differences from the real operation techniques. For example, an inferior turbinectomy may cause several clinical complications such as cool sensation of normal breathing, delayed bleeding, local crusting, and chronic pharyngitis.[15] Besides, the surgeons must consider bleeding, skull base reconstruction and infection postoperatively which the cadaveric anatomy cannot simulate. The significance of the anatomic study was to confirm the operability and feasibility of the surgical maneuver, to understand the spatial relationship of the important structures, and to accomplish the measurement work for better identification. The clinical practicability can only be realized by operation. In this perspective, we tried to explore a medial maxillary corridor to the PPF and ITF from the nasal cavity, which could avoid sacrificing the inferior turbinate and nasolacrimal duct in order to preserve their physiological function. The otolaryngology and maxillofacial surgeons utilized this method to deal with lesions in the MS, such as inverted papilloma, nasal polyps, and sinonasal juvenile ossifying fibroma.[16-19] In this study, we attempted endonasal prelacrimal recess-maxillary sinus corridor to realize the exposure of the PPF and ITF, which had advantages of simpler procedure and better reservation of turbinates. Tumors' total removal has proven well visuality and operability of certain approach. In our study, we got total removal for all the benign lesions, along with no serious or permanent complications, which showed no disadvantage than open surgery.

The application of neuroendoscopy gives neurosurgeons great opportunities to accomplish wider exposure by smaller incisions and osteotomy. The endoscopic approache need not subject to the limitation of tunnel vision by the microscope, because the angle lens by the

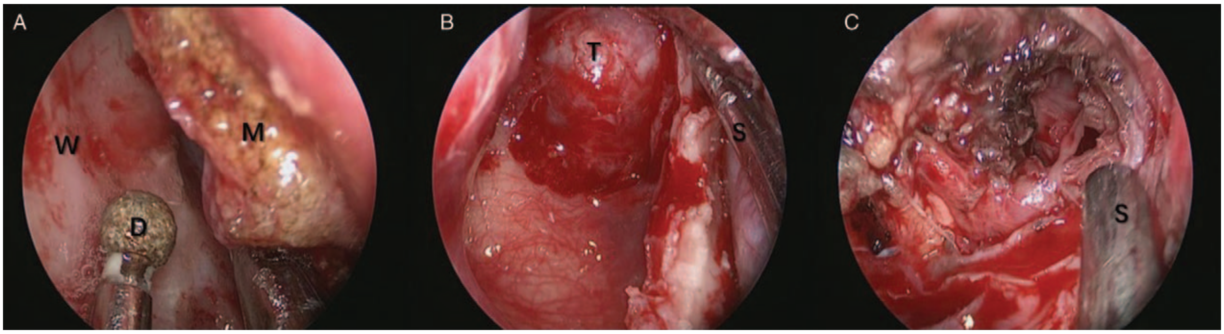

Figure 4: Intraoperative endoscopic view: (A) mucosa of inferior nasal concha and middle nasal meatus (M) was turned to the midline and medial wall of MS (W) was prepared to be drilled (D); (B) the tumor (T) in the PPF and ITF; and (C) tumor was removed by suction (S).

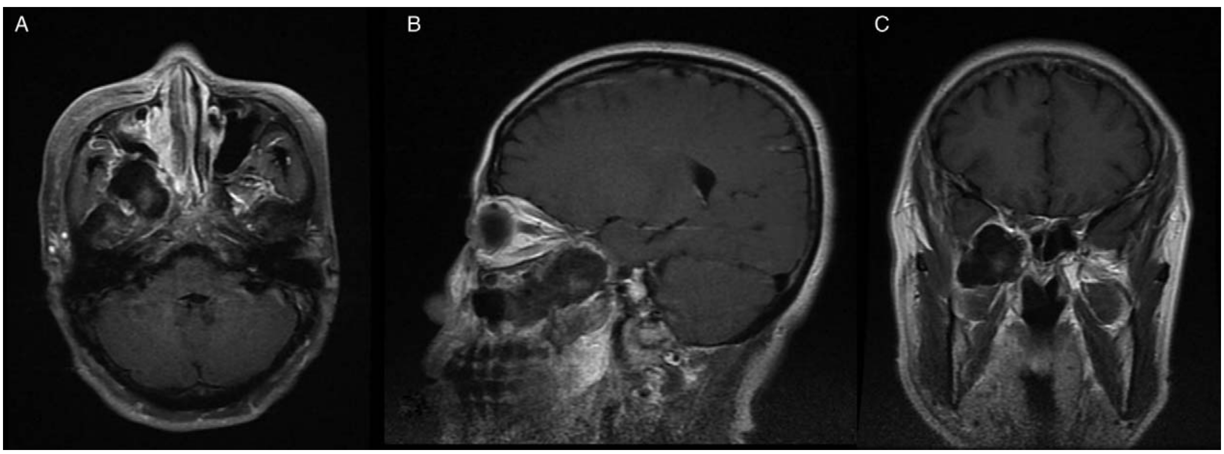

Figure 5: Postoperative sagittal (A), coronal (B), and axial (C) enhanced MRI demonstrated at seven days after surgery showed totally removal of the tumor. MRI: Magnetic resonance imaging.

endoscopy can provide a panoramic view to the target region. The other advantages of the endoscopic approach to the skull base tumors include: avoidance of external incisions, decreased trauma to soft tissue and bone, fewer complications, reduced risk of neurologic damage, improved postoperative quality of life, and faster recovery time.[20] Specific to our study, since the anterior transmaxillary approach and modified endoscopic transnasal transmaxillary approach has almost equal exposure to the PPF and ITF, the medial endoscopic approach has undoubted advantages as follows: completeness of lateral nasal mucosa, preservation of physiological function of nasal cavity, avoidance of anterior superior teeth nerve injury and gingiva numbness, and significances of cosmetology.

In conclusion, with the wide-spread use of neuroendoscopy, the modified endoscopic transnasal transmaxillary approach is feasible for resection of tumors located in PPF and ITF, which is low traumatic and effective. With enough training and understanding of the anatomic relationship, neurosurgeons should grasp this technique as well as surgeons from otolaryngology and maxillofacial surgery.

Conflicts of interest

None.

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