Endoscopic anterior transmaxillary “transalisphenoid” approach to Meckel’s cave and the middle cranial fossa: an anatomical study and clinical application

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**OBJECTIVE** Multiple approaches have been designed to reach the medial middle fossa (for lesions in Meckel’s cave, in particular), but an anterior approach through the greater wing of the sphenoid (transalisphenoid) has not been explored. In this study, the authors sought to assess the feasibility of and define the anatomical landmarks for an endoscopic anterior transmaxillary transalisphenoid (EATT) approach to Meckel’s cave and the middle cranial fossa.

**METHODS** Endoscopic dissection was performed on 5 cadaver heads injected intravascularly with colored silicone bilaterally to develop the approach and define surgical landmarks. The authors then used this approach in 2 patients with tumors that involved Meckel’s cave and provide their illustrative clinical case reports.

**RESULTS** The EATT approach is divided into the following 4 stages: 1) entry into the maxillary sinus, 2) exposure of the greater wing of the sphenoid, 3) exposure of the medial middle fossa, and 4) exposure of Meckel’s cave and lateral wall of the cavernous sinus. The approach provided excellent surgical access to the anterior and lateral portions of Meckel’s cave and offered the possibility of expanding into the infratemporal fossa and lateral middle fossa and, in combination with an endonasal transpterygoid approach, accessing the anteromedial aspect of Meckel’s cave.

**CONCLUSIONS** The EATT approach to Meckel’s cave and the middle cranial fossa is technically feasible and confers certain advantages in specific clinical situations. The approach might complement current surgical approaches for lesions of Meckel’s cave and could be ideal for lesions that are lateral to the trigeminal ganglion in Meckel’s cave or extend from the maxillary sinus, infratemporal fossa, or pterygopalatine fossa into the middle cranial fossa, Meckel’s cave, and cavernous sinus, such as schwannomas, meningoceles, and sinonasal tumors and perineural spread of cutaneous malignancy.

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**KEY WORDS** anterior transmaxillary; transalisphenoid; Meckel’s cave; middle cranial fossa; skull base; surgical technique

Meckel’s cave is a pouch of dural fold in the middle cranial fossa. Inside the diverticulum dwells the trigeminal nerve as it emerges from the posterior fossa, the Gasserran ganglion, and part of the 3 branches before they enter their respective foramina.22,22 Given the simple contents of the structure, few types of pathology affect the area. The most frequent tumor type that originates from Meckel’s cave is trigeminal schwannoma;2,17 other types include meningioma,17,23 epidermoid cyst,3,8,17,18 dermoid cyst,17 melanoma,7 and hemangiopericytoma.17

With advances in surgical anatomy and endoscopic technology, many skull base pathologies can be treated effectively while potentially decreasing cosmetic and neurological morbidity. The endoscopic endonasal transpterygoid approach to Meckel’s cave has been well described and has gained wide acceptance among skull base surgeons, and its clinical value has been proven.10,12,13,21,24 The approach provides excellent access to the medial, anterior, and inferior aspects of Meckel’s cave, but it is limited and unsuitable for treating lateral or extended lesions.13

Noting that Meckel’s cave lies on the anterior slope of the petrous apex, protected anteroinferiorly by the greater...
wing of the sphenoid, we investigated an anterior approach to Meckel’s cave via an anterior transmaxillary corridor through the pterygopalatine fossa, infratemporal fossa, and the greater wing of the sphenoid. We suggest the new term “transalisphenoid” for the procedure going through the greater wing of the sphenoid. In this article, we describe the details of this approach and discuss its potential advantages.

Methods

We performed cadaveric studies in the Surgical Neuroanatomy Laboratory at the University of Pittsburgh. Five cadaver heads were used. Each of them was injected intravascularly with colored silicone (red for the arterial system and blue for the venous system). Surgical dissection was performed bilaterally using skull base neurosurgical endoscopic instruments, including 4-mm rod-lens endoscopes (0° and 30°) that were coupled to a high-definition camera and an AIDA HD system (Karl Storz GmbH and Co.). Videos and still photos were taken during the dissections. Each specimen was scanned using thin-slice CT, and the Navigation System II (Stryker) was used for navigation. Two-hand and 3-hand techniques were used. After establishing this technique in the laboratory, we then applied it in 2 patients with tumors that involved Meckel’s cave, and we provide their illustrative clinical case reports later in the article.

Results

The endoscopic anterior transmaxillary transalisphenoid (EATT) approach was divided into the following 4 stages: 1) entry into the maxillary sinus, 2) exposure of the greater wing of the sphenoid, 3) exposure of the medial temporal fossa, and 4) exposure of Meckel’s cave and the lateral wall of the cavernous sinus. Potential extension of the approach to the infratemporal fossa and a combined transmaxillary transpterygoid approach were also demonstrated.

EATT Approach

Stage 1: Entry Into the Maxillary Sinus

The sublabial antrostomy (Caldwell-Luc procedure) was used. The ipsilateral upper lip was retracted, and an incision was made on the mucosa above the teeth (Fig. 1A and B). Soft tissue anterior to the maxillary bone was elevated, and the infraorbital nerve (ION) was exposed and protected. Entry into the sinus was allowed by using a chisel, Kerrison rongeurs, and a high-speed drill (Fig. 1C). The maxillary sinus mucosa was removed, and the posterior wall was exposed (Fig. 1D).

Stage 2: Exposure of the Greater Wing of the Sphenoid

The posterior wall of the maxillary sinus was removed, and the pterygopalatine fossa was exposed. The peristomal fascia and fat tissue were dissected carefully and removed. The ION was used as a landmark and guide to lead to the maxillary branch (V2) of the trigeminal nerve and foramen rotundum. Contents of the infratemporal fossa, including pterygoid muscles, the maxillary artery, and the deep temporalis muscle, were then exposed (Fig. 2A).

The ION was then mobilized from its groove on the roof of the maxillary sinus. The infraorbital branch of the
FIG. 2. Dissection steps in the transalisphenoid procedure. A: After removal of the posterior antral wall, contents of the pterygopalatine fossa (including the maxillary nerve [V2], the internal maxillary artery and its branches, the posterior superior alveolar artery [PSAA] running along the posterior superior alveolar nerve, the infraorbital artery [IOA], the descending palatine artery [DPA], the greater palatine nerve [GPN], and the sphenopalatine artery [SPA]) are exposed. The ION is dissected out of its bony canal (asterisk). B: The IOA and its 1–2 branches that connect to the intraorbital vasculature must be sacrificed to mobilize the ION superiorly and medially. The deep temporalis muscle (DTM) can be seen clearly. C: The internal maxillary artery (IMA) must be sacrificed to gain access to the infratemporal fossa, and the DTM and the upper head of the lateral pterygoid muscle (uLPM) are exposed. D: The DTM and uLPM are elevated subperiosteally to expose the greater wing of the sphenoid (GWS). The area of bone to be drilled is outlined by the yellow dashed line; the foramen rotundum (FR), pterygoid process (PP), foramen ovale, infraorbital fissure (IOF), and infratemporal crest (ITC) are used as landmarks. E: The GWS is drilled to paper-thin cortical bone; the IOF, V2, and mandibular nerve (V3) are used as its limitations. F: The temporal dura (asterisk) is exposed. The surgical corridor goes through the anterolateral triangle between V2 and V3. Figure is available in color online only.
maxillary artery must be sacrificed to mobilize the nerve. After being released, the nerve can be pushed above the infraorbital fissure to provide a corridor to the upper part of the infratemporal fossa (Fig. 2B and C).

The deep temporalis muscle was elevated subperiosteally and displaced laterally. The upper head of the lateral pterygoid muscle was elevated in the same manner and dissected along the lateral pterygoid plate and greater wing to expose the foramen ovale (Fig. 2D).

Stage 3: Exposure of the Medial Middle Fossa

Drilling of the greater wing of the sphenoid was then defined by using as landmarks the inferior orbital fissure anteriorly, the foramen rotundum medially, the foramen ovale posteriorly, and the infratemporal crest laterally (Fig. 2D). The surgical trajectory was confirmed with image guidance before advancing (Fig. 3). The lateral wall of the foramen rotundum should be drilled off to expose the posterior trunk of V2 for more mobility. The lateral border of the bony opening can be adjusted depending on extension of the lesion, although we found the infratemporal crest to be a reliable landmark. Lateral to the crest, the skull base slopes superiorly, which provides minimal additional access for the approach. The middle meningeal artery might be encountered and sacrificed if needed.

After drilling the greater wing, the anterior dural wall of the middle fossa was exposed, and the corridor was then continued by performing an interdural elevation in between the medial wall and floor of the middle fossa, namely, at the anterolateral triangle of the middle cranial fossa, as defined between V2 and the mandibular branch (V3) of the trigeminal nerve (Fig. 2F).

A 3D reconstruction of a postprocedural CT image (Fig. 4) showed the bony opening in relation to its surrounding bony structures and the perspective of the surgical corridor. The length and width of the bony opening were 2.17 and 1.48 cm, respectively. The slope of the trigeminal impression directly faced the surgical route of the transalisphenoid approach.

Stage 4: Exposure of Meckel’s Cave and Lateral Wall of the Cavernous Sinus

The dorsolateral wall of Meckel’s cave can be dissected interdurally between the dura propria of the posterior fossa origin (inner layer) and the dura propria of the middle fossa (outer layer). Because the dura of Meckel’s cave continues as the epineurium of the trigeminal branches, we found it easier to dissect along the cleavage at which V2 exits the medial temporal fossa at the foramen rotundum to develop a safe interdural separation (Fig. 5A). The dural cover of Meckel’s cave was then opened, and the Gasserian ganglion was exposed (Fig. 5B and C). Access to the lateral wall of the cavernous sinus was gained by continuing the dissection upward. The ophthalmic branch (V1) was found first. Then, the fourth cranial nerve and carotid artery were identified at the upper border of V1, followed by the third cranial nerve located at the roof of the sinus (Fig. 5D).

In 2 specimens, the trochlear nerve was found crossing the operative field laterally (temporal dura near the tentorium) to medially (inner wall of the cavernous sinus) on both sides (Fig. 5D). This possibility should be kept in mind while performing this surgery to avoid transecting the nerve at the end of tumor removal.

Surgical access and maneuverability were excellent in Meckel’s cave and laterally. However, we found limited maneuverability in the upper and anterior cavernous sinus. Access was blocked by the maxillary strut, a bony bridge between V2 and the superior orbital fissure. Although we could identify the trigeminal porus, or the mouth of Meckel’s cave, access to the posterior fossa was limited by the tentorium and petrous bone with the petrous carotid artery underneath it.

With the foramen ovale opened and the trigeminal ganglion exposed, we found that the motor root of the trigeminal nerve, which is medial and anterior to the ganglion, can be dissected out of the sensory branch, protected, and preserved (Figs. 5C and 6C).

Infratemporal Fossa Extension

Dissection of the infratemporal fossa was carried further with removal of the lateral pterygoid muscle. The
branches of the mandibular nerve were identified and ex-
posed (Fig. 6D). The buccal nerve was first identified be-
tween the 2 heads of the lateral pterygoid muscle; it then
ran along the medial border of the deep temporalis muscle
downward and forward. The deep temporalis muscle and
masseteric branches were followed along the inferior sur-
face of the greater wing toward the temporomandibular
joint. The lingual and mandibular nerves were found pos-
terior and medial to the lateral pterygoid muscle, against
the lateral plate of the pterygoid.

Combination With the Transmaxillary Transpterygoid
Approach
We also explored the possibility of combining the trans-
alisphenoid and transmaxillary transpterygoid approach-
es. The pterygoid base and lateral recess were drilled to
expose the Vidian nerve and gain access to the anterome-
dial part of Meckel’s cave, together with the anterior wall
of the cavernous sinus and paraclival carotid artery, and
the Vidian nerve. In those with a well-pneumatized lateral
recess, the area is exposed spontaneously after drilling the
pterygoid process (Fig. 6A). The medial wall of Meckel’s
cave can be opened to provide access to its anteromedial
part (Fig. 6B and C). The cavernous sinus can be accessed
also, but this access is limited to the inferolateral portion.
We found that the lingual process of the sphenoid bone,
between the carotid artery and Meckel’s cave, is a good
landmark for the exposure.

Illustrative Cases
Case 1: Squamous Cell Carcinoma of the Infratemporal
Fossa With Perineural Spread
A 73-year-old male patient presented with a 1-year his-
tory of progressive right-sided midface pain and numbness.
Physical examination revealed decreased sensation over
the right V2 distribution. CT imaging revealed a 3.6-cm
lesion centered in the posterior wall of the maxillary sinus
and infratemporal fossa, invading the pterygopalatine fos-
sa and foramen rotundum. MRI confirmed perineural ex-
tension of sinonasal malignancy along the maxillary nerve
to the level of Meckel’s cave and the Gasserian ganglion
(Fig. 7). An endoscopic transmaxillary transalisphenoid
and transmaxillary transpterygoid approach was recom-
mended in an attempt to achieve gross-total resection and symptomatic improvement before adjuvant therapy.

Surgery via a sublabial transmaxillary approach was performed. Soft, well-circumscribed, and vascularized tumor was found protruding into the maxillary sinus. Pathological sampling and debulking were done to provide access to the pterygoid bone and greater wing of the sphenoid. Given the small size of the tumor in the middle cranial fossa, which created less space for maneuverability, a combined transalisphenoid and transpterygoid approach was chosen. The tumor was resected from the ION and followed posteriorly to expose the Vidian nerve, infraorbital fissure, infratemporal crest, and foramen rotundum, which were widened by the tumor (Fig. 8A and B). The base of the pterygoid and greater wing of the sphenoid bones around the foramen rotundum were drilled off to expose the dura of the middle cranial fossa. With good exposure and a wide working space, interdural dissection was performed between the temporal lobe dura and the tumor-filled maxillary nerve toward the trigeminal ganglion (Fig. 8C and D). The nerve was transected just before entering Meckel’s cave to avoid a CSF leakage. Normal-looking nerve fibers were identified at the transection level, but microscopic tumor infiltration was still present. Nasal mucosa was harvested and used as a free graft to cover the exposed portion of the middle fossa dura (Video 1).

The patient recovered well after surgery, had no additional neurological deficit, and experienced relief of his severe preoperative pain. Postoperative MRI revealed complete macroscopic removal of the tumor. Pathological examination revealed the lesion to be a squamous cell carcinoma, and the patient underwent adjuvant radiation therapy.

Case 2: Middle Fossa Invasion of a Juvenile Nasopharyngeal Angiofibroma

An 11-year-old boy presented with bilateral nasal ob-
H. Q. Truong et al.

 Approximately 6 months. He also was experiencing right-sided hearing loss and constant tingling on his right cheek (V2 distribution). Physical examination confirmed right-sided hearing loss with middle ear effusion but intact sensation to light touch throughout the trigeminal branches. MRI revealed a markedly enhancing bulky mass centered in the area of the right pterygopalatine fossa with extension into the right posterior nasal cavity, nasopharynx, right cavernous sinus, right infratemporal fossa, and right middle fossa with compression of the right temporal lobe (Fig. 9). Endoscopic surgery in which endonasal and bilateral transmaxillary approaches were combined for total removal of the tumor with the possibility of staged surgery was offered. Endovascular embolization of the right internal maxillary artery and ascending pharyngeal artery was performed to reduce blood loss.

A bilateral sublabial transmaxillary procedure was performed. The first stage of surgery was carried out through endonasal and transmaxillary endoscopic approaches on both sides to remove the large portion of tumor in the nasal cavity, pharynx, and sphenoid sinus and debulk the tumor in the cavernous sinus and infratemporal fossa. The surgery was staged because of significant blood loss. The second stage was performed 1 week later for total removal of the tumor. Residual tumor around the right internal carotid artery (ICA) at the foramen lacerum and at the petrous bone and anterior wall of the cavernous sinus was dissected and removed in piecemeal fashion. Meckel’s cave was opened medially, and V3, V2, and the ION were identified and carefully dissected. A transalisphenoid procedure was performed to remove tumor at the superior orbital fissure near the apex and middle fossa lateral to Meckel’s cave to the lateral sphenoid wing. Minor CSF weeping was observed when the residual tumor was peeled en bloc from the temporal dura. Angled (45° and 70°) scopes, together

FIG. 6. Extension of the approach to the infratemporal fossa and medial aspect of Meckel’s cave. A: The combined transsphenoid and transpterygoid approach was performed through the transantral corridor. In this case, a well-pneumatized lateral recess (yellow dashed line) provides an excellent view of the anterior cavernous and paraclival ICA (pICA). B: After bone removal and interdural dissection, Meckel’s cave can be accessed from both sides of the trigeminal ganglion. The lingula of the sphenoid (LoS) can be used as a landmark for the transpterygoid approach in this combination. C: Exposure of the anteromedial aspect of the trigeminal ganglion with its relevant structures, the abducens nerve (AN) with its accompanying sympathetic branches of the internal carotid plexus (asterisk), and the cavernous ICA (cICA). The motor root can be exposed and dissected, which leads to the trigeminal porus (arrow). The lingula of the sphenoid was removed to show the petrolingual fissure. D: Overview of possible extension of the approach. Branches of V3 can be seen, as can the lingual nerve (LN), inferior alveolar nerve (IAN), buccal nerve (BN), masseteric nerve (MN), and branches to the deep temporalis muscle (DTB). The tip of the dissector is pointing to the arcuate eminence of the temporal bone. Figure is available in color online only.
with angled dissectors, were deployed to completely remove residual tumor in the middle cranial fossa. A fat graft was used to prevent CSF leakage (Video 2).

VIDEO 2. Video summary of case 2. Copyright Department of Neurosurgery, University of Pittsburgh. Published with permission. Click here to view.

The patient recovered well after the surgery, although he experienced right V2 hypoesthesia and transient sixth-nerve palsy. Postoperative imaging revealed total removal of the tumor (Fig. 10). Pathological results confirmed the tumor to be a nasopharyngeal angiofibroma.

Discussion

Standard transcranial and endoscopic endonasal approaches share territory at Meckel’s cave. The anterolateral corridor approaches, with the pterion as an entry point, provide good access to the lateral and upper cavernous sinus; however, to gain access to the anterior components of Meckel’s cave, the trajectory must dissect through the anteromedial and anterolateral triangles. For lesions located posteriorly inside the cave, the ganglion must be traversed. These approaches also confer a risk of morbidity that results from brain retraction and temporalis muscle elevation. Komatsu et al., in their anatomical study reports, suggested the endoscopic extradural supraorbital approach, which shares a similar corridor but might avoid the risk of complications and suboptimal cosmesis. No clinical application of this approach has been reported.

The corridor lateral to Meckel’s cave provides excellent access to the entire middle cranial fossa and upper part of the posterior cranial fossa by transecting the tentorium, but the important advantage of the corridor is the possibility it provides for combining it with transpetrosal approaches for complete removal of tumors that span the middle and posterior cranial fossae. However, the tradeoff is the risk of morbidity that might result from temporal lobe retraction and injury to the vein of Labbe, middle ear structures, facial nerves, and the petrous ICA. Several approaches for reaching Meckel’s cave endoscopically have been developed. The classification by Komatsu et al., includes 3 transcranial routes (the extradural supraorbital, extradural subtemporal, and retrosigmoid approaches) and the endonasal transpterygoid and transmaxillary transpterygoid approaches. Among those approaches, the endonasal transpterygoid approach has been applied clinically and resulted in reasonably good outcomes. However, because the route is slightly medial to Meckel’s cave, the approach provides limited access to lesions that are located or extend laterally in the middle cranial fossa.

The EATT approach creates a corridor anterior to Meckel’s cave and the medial middle cranial fossa. By going through the greater wing of the sphenoid, this approach provides surgical access directly anterior to Meckel’s cave, and the lesion is in line with the surgical corridor. This approach provides a better opportunity for microsurgical dissection of the tumor and neural tissue and, hence, preservation of function. The approach involves an interdural dissection technique, as shown in Video 1, so it is com-
pletely extradural in regard to the temporal lobe. It also requires minimal brain retraction, given that working space is created by the tumor.

In contrast to the endoscopic endonasal transpterygoid approach, this approach offers excellent surgical access to the anterior, lateral, and posterior portions of Meckel’s cave. The lateral limit is the line of the temporomandibular joint, as can be seen in Video 2. By going through the pterygopalatine and infratemporal fossa, this approach avoids the cavernous sinus and the associated risk of injury to the carotid artery and abducens nerve. Although the carotid artery can be encountered posteriorly when going through Meckel’s cave, the petrolingual ligament can serve as a landmark for recognizing and avoiding the artery. The majority of schwannomas, the most common pathology in Meckel’s cave, have been shown in previous study reports to be well defined from neighboring structures and to displace rather than engulf those structures. This approach can preserve the dura propria of the lateral wall and, thus, avoid injury to the cranial nerves and ICA.

Other than trigeminal schwannomas limited to Meckel’s cave, the stand-alone EATT approach can be a competitor for the endoscopic endonasal transpterygoid approach to epidermoid/dermoid cysts or melanomas in Meckel’s cave. The decision should be more affirmative when imaging can delineate the tumor to be medial or lateral to the ganglion.

Important to note is that the EATT approach offers multicompartmental access to the middle fossa and the infratemporal and pterygopalatine fossae. Therefore, it provides wide surgical intervention for tumors that span those 3 compartments. This approach, however, provides limited access to the posterior fossa because of the depth of the approach and depth of the trigeminal porus. In the case of dumbbell-shaped tumors, we do not know whether the trigeminal porus can be expanded enough to allow safe surgical intervention.

The EATT approach can conveniently be combined with the transantral transpterygoid approach to provide better access to the anteromedial aspect of Meckel’s cave and more surgical freedom when needed. The transantral transpterygoid and endonasal transpterygoid approaches were described and compared by Van Rompaey et al. In that study, they concluded that the 2 approaches provide similar workable access to Meckel’s cave. The authors also advocated the minimally invasive aspect of the transantral approach for avoiding the removal of sphenoid sinus, the posterior third of the nasal septum, the middle and lower turbinates, and the medial wall of the maxillary sinus. The authors also suggested that the transantral approach could be expanded to cover the whole lateral skull base, but they did not provide any further description, especially for how to approach the lateral aspect of Meckel’s cave. In contrast to Van Rompaey et al., we do not see the need to expose and dissect the paraclival carotid artery for Meckel’s cave lesions. We suggest using the lingula of the sphenoid bone to limit the bony exposure medially, because the lingula will continue laterally with the petro lingual ligament, which provides a natural separation between Meckel’s cave and the petrous carotid artery.

The transalisphenoid approach, in our opinion, offers the least invasive route for treating perineural spread of malignancy that involves trigeminal nerves, especially the V2 and V3 branches, such as squamous cell carcinomas, basal cell carcinomas, melanomas, and adenoid cystic carcinomas. The approach can follow the maxillary
nerve from its cutaneous portion through the maxillary sinus and pterygopalatine fossa to the Gasserian ganglion. The mandibular nerve can also be followed from the Gasserian ganglion to the mandible with infratemporal fossa dissection. Other possible routes of perineural spread, such as the greater and lesser palatine nerves, Vidian nerve, and pterygopalatine ganglion, can be addressed also. Interestingly to note is that the microsurgical counterpart of the approach for malignant maxillary nerve perineural spread was described in 2007 by DeMonte and Hanna, who also predicted the endoscopic application of the surgical route and advocated its advantages.

Angiofibromas are benign tumors that originate at the medial aspect of the pterygopalatine space but can extend through the inferior orbital fissure and gain access to the middle cranial fossa through the superior orbital fissure. The floor of the middle cranial fossa can be eroded, and large intracranial tumors can involve the lateral cavernous sinus. As shown in Video 2, the transalisphenoid approach, by following the course of the tumor, provides optimal access to the tumor both medial and lateral to the orbital apex.

Dural reconstruction should be a concern with the transantral approach, because a vascularized nasal septal flap, which has been found to be very effective for CSF leak prevention, is not available with this approach. We suggest multilayered free-graft reconstruction and possibly a lumbar drain for CSF diversion, because the arachnoid space around the Gasserian ganglion is connected to the posterior fossa.

The transalisphenoid approach requires subperiosteal elevation of only a part of the lateral pterygoid and deep temporalis muscles. Significant reduction in mastication power and postoperative pain while chewing are not expected. The ION is kept intact macroscopically during the dissection, but hypesthesia can result. Clinical validation is needed, however, to confirm and put forth the general indications for this approach.

Conclusions

The EATT approach is technically feasible and offers excellent surgical access to the anterior and lateral portion of Meckel’s cave, and the possibility of expansion toward the infratemporal fossa and lateral middle fossa. It can complement the current repertoire of surgical treatment for Meckel’s cave lesions and could be ideal for lesions that are located lateral to the trigeminal ganglion in Meckel’s cave or extend from the maxillary sinus, infratemporal fossa, or pterygopalatine fossa into the middle cranial fossa, Meckel’s cave, and cavernous sinus, such as schwannomas, meningiomas, and sinonasal tumors.

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The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions
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Supplemental Information
Videos

Previous Presentations
Portions of this work were presented in abstract poster form at the 27th Annual Meeting of the North American Skull Base Society, held in New Orleans, LA, March 3–5, 2017.

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