Anterior inferior petrosectomy: defining the role of endonasal endoscopic techniques for petrous apex approaches

Laboratory investigation

JAMIE J. VAN GOMPEL, M.D.,1 PUYA ALIKHANI, M.D.,1 MARK H. TABOR, M.D.,2 HARRY R. VAN LOVEREN, M.D.,1 SIVERO AGAZZI, M.D., M.B.A.,1 SEBASTIEN FROELICH, M.D.,4 AND A. SAMY YOUSSEF, M.D., PH.D.1

1Department of Neurosurgery and Brain Repair and 2Department of Otolaryngology-Head & Neck Surgery, College of Medicine, University of South Florida, Tampa, Florida; 3Department of Neurosurgery, Mayo Clinic Rochester, Minnesota; and 4Department of Neurosurgery, Lariboisière Hospital, University Paris Diderot, Paris, France

Object. Historically, surgery to the petrous apex has been addressed via craniotomy and open microscopic anterior petrosectomy (OAP). However, with the popularization of endoscopic approaches, the petrous apex can further be approached endonasally by way of an endoscopic endonasal anterior petrosectomy (EAP). Endonasal anterior petrosectomy is a relatively new procedure and has not been compared anatomically with OAP. The authors hypothesized that the EAP and OAP techniques approach different portions of the petrous apex and therefore may have different applications.

Methods. Four cadaveric heads were used. An OAP was performed on one side and an EAP was performed on the contralateral side; the limits of bony resection were defined. The extent of bony resection was then evaluated using presdissection and postdissection thin-slice CT scans. The comparative resection was then reconstructed using 3D modeling on Brainlab workstations.

Results. The average resection volumes for EAP and OAP were 0.297 cm$^3$ and 0.649 cm$^3$, respectively, representing a comparative percentage of 46% (EAP/OAP). An EAP and OAP achieved resection of 29% and 64% of the total petrous apex volume, respectively. Indeed, EAP addressed the inferior portion of the petrous apex located adjacent to the petroclival suture more completely than OAP, where 45% of the bone overlying the petroclival suture (petroclival angle to the jugular foramen) was resected with the EAP, while 0% was resected with the OAP.

Conclusions. In anatomically normal cadavers, OAP achieved nearly a 50% larger volumetric resection than EAP. Furthermore, while OAP appears to completely address the superior portion of the petrous apex, EAP appears to have a niche in approaches to lesions in the inferior petrous apex. Given these results, the authors propose that OAP be redefined as the “superior anterior petrosectomy,” while EAP be referred to as the “inferior anterior petrosectomy,” which more clearly defines the role of each approach in anterior petrosectomy.

(key Words • endoscopic • anterior petrosectomy • microsurgery • skull base)

PETROUS” is a Latin term meaning stone and has been used to describe the densely ossified portion of the temporal bone housing the internal auditory canal (IAC), cochlea, and labyrinth. The petrous temporal bone is a pyramid-shaped bone occurring at the confluence of the greater wing of the sphenoid and the basilar portion of the occiput, and laterally articulating with both the squamous and mastoid portions of the temporal bone (Fig. 1). Beginning with expanded middle fossa approaches in the 1950s, bone work was extended to include a region medial to the IAC involving the petrous apex. Kawase further popularized the approach for additional pathologies in the mid-1980s by resection of bone in Kawase’s triangle, now popularly known as anterior petrosectomy. The open microscopic anterior petrosectomy (OAP) is currently a well-defined procedure with application in lesions such as petroclival meningiomas, posterior circulation aneurysms, and petrous apex extradural lesions.
A linear incision anterior to the tragus extending from just below the root of the zygoma to above the superior temporal line was performed. The temporalis muscle was then split, dissected subperiosteally, and retracted laterally. A temporal craniectomy was then performed flush to the floor of the middle fossa centered over the root of the zygoma. If the zygomatic root was above the floor of the middle fossa, a separate osteotomy was performed to translate it inferiorly to allow full visualization of the floor of the middle fossa. The dura was then elevated posterior to anterior; the middle meningeal artery was identified at the foramen spinosum and was divided. The greater superficial petrosal nerve (GSPN) was preserved, with the periosteum of the floor of the middle fossa as a landmark to provide guidance for middle fossa drilling. The trigeminal impression was then identified, and the dura surrounding Meckel’s cave was elevated to allow for a retractor to be placed at the medial petrous apex and facilitate the bone work.

The extent of bone resection is limited by the trigeminal dura mater posteromedially and the GSPN anterolaterally. The superior petrosal sinus was elevated and mobilized from the petrous ridge. Utilizing the arcuate eminence, the IAC was estimated as the line bisecting the GSPN and arcuate eminence, and drilling was started at the petrous ridge to first identify the IAC. The IAC was skeletonized to the distal portion, and the cochlea was drilled until the membrane could be seen. The posterior and medial surfaces of the internal carotid artery (ICA) were then skeletonized. All bone was removed in Kawase’s quadrangular space down to the inferior petrosal sinus.

### Endonasal Anterior Petrosectomy

An EAP can be tailored depending on the pathology to be addressed and can consist of a medial approach with or without ICA mobilization or a transpterygoid infratemporal approach. However, the goal of this study was to determine maximal petrous apex resection; therefore, all approaches were combined in these cadaveric heads without pathology. Ipsilateral to the side of the EAP, the middle turbinate was resected. A wide sphenoidotomy was performed; the sphenoid floor was then drilled flush to the clival recess. A posterior maxillary antrostomy was then performed ipsilateral to the side of the approach, and the medial pterygoid plate was identified. The soft-tissue components of the pterygopalatine fossa were mobilized. The base of the pterygoid as well as the superior portions of the medial and lateral pterygoid plates were drilled. Following the vidian canal posteriorly, the C3 segment of the ICA was identified. The fibrocartilaginous tissue below the C3 segment of the ICA was removed to provide access to the inferior aspect of the petrous apex below the C3 segment of the ICA and to allow further mobilization of the ICA superiorly. The paraclival segment (posterior ascending portion of the C3 segment) of the ICA was further exposed. The lateral wall of the sphenoid sinus was removed, thus exposing the anterior aspect of the cavernous sinus and allowing further mobilization of the paraclival segment of the carotid artery laterally.

To allow further exposure below the C3 segment of the ICA, resection of the posterior aspect of the inferior or turbinate and the eustachian tube is necessary. After carotid mobilization, 0° and 45° endoscopes were used along with an angled drill to maximize petrous apex bone removal. Three-dimensional reconstructed imaging was performed for both OAP and EAP.
Calculation of Anterior Petrosectomy Resection Volumes

Preapproach and postresection skull base CT scans were loaded into Brainlab Curve (Brainlab Inc.), and cranial planning software was used to fuse the CT scans. Subsequently, resection volumes were identified by constructing a computer-generated tumor volume of both the bony resection and the total volume of the petrous apex. The total petrous apex volume was calculated by bisecting the IAC as the base of the petrous apex conical volume (Fig. 1). Volume measurement was performed 3 times; these volumes were then averaged to obtain a final volumetric average. Additional linear measurements were made from the petroclival angle (Fig. 1, asterisk) on 3D models to define the inferior extent of bony resection.

Results
Anterior Petrosectomy Resection Volumes

The average resection volumes for EAP and OAP were 0.297 cm³ and 0.649 cm³, respectively, representing a comparative percentage of 46% (EAP/OAP). The EAP and OAP achieved resection of 29% and 64% of the total petrous apex volume, respectively. The OAP left 2.2 ± 0.4 mm (mean ± SD) of residual bone above the petroclival angle, whereas all EAP approaches left no bone over the petroclival angle. The distance from the jugular foramen to the petroclival angle was 16.5 ± 2.5 mm (mean ± SD); the mean resection volume of the medial portion from the petroclival angle to the jugular foramen was 7.4 ± 2.2 mm (mean ± SD) for the EAP, whereas the OAP did not achieve resection in this region. Therefore, 45% of the bone overlying the petroclival suture from the petroclival angle to the jugular foramen was resected with the EAP, while 0% was resected with the OAP. The average resection volumes of both OAP and EAP (Fig. 2) confirm the different target for each approach; note that there is a difference in location of bone removal, with the OAP addressing the superior portion and the EAP addressing the inferior portion of the petrous apex.

Discussion

In this study, we demonstrate the relative differences between two techniques that are used to approach the petrous apex, namely the OAP and the EAP. Volumetric assessment demonstrated that OAP achieves a larger resection of the petrous apex (54% more) than EAP in anatomically normal cadaver specimens. Interestingly, the OAP appears to achieve more resection of the superior portion of the petrous apex, while the EAP addresses the inferior portion overlying the petroclival suture. This observation has led us to distinguish between the two approaches by reclassifying the OAP as the “superior anterior petrosectomy” and the EAP as the “inferior anterior petrosectomy.”

Selection and Optimization of Surgical Corridors

Anatomically, resection and bone drilling are governed by the operative corridors used. In patients undergoing OAP, access to the inferior portion of the petrous apex is limited by the temporal lobe; line of sight issues during bone resection over the IAC, and further by the variable height of the superior vestibular canal. Utilizing a 30° or 45° endoscope in the open approach with angled drills may overcome such limitations; however, we did not use endoscope-assisted techniques in this study. Alternatively, lesions situated in the inferior portion of the petrous apex may be well addressed by EAP, as demonstrated here. Predefined surgical corridors are often enhanced by the existence of pathology that may alter normal anatomy as noted by previous authors. In the absence of pathology that displaces the ICA laterally or opens an aperture over the maxillary division of the fifth cranial nerve, the paraclival and petrous portions of the ICA limit access to the superior portion of the petrous apex as demonstrated in this study. However, this limitation may potentially be overcome by using a more contralateral endonasal exposure such as the transmaxillary approach, which would provide a more lateral angle and better visualization of the contralateral petrous apex. Although these possibilities exist, they await further anatomical feasibility studies.

OAP Versus EAP: Risks and Benefits

Complications pertaining to each procedure should be weighed against potential benefits. In an OAP, bone removal over the IAC, cochlea, and potentially in a prominent superior vestibular canal may ultimately result in hearing loss; this potential complication is less pronounced with EAP. Facial nerve paralysis is possible in cases of OAP, as there is a risk of traction injury to the geniculate ganglion if the superior petrosal nerve is not properly identified and gently dissected. Concern regarding the possibility of an increased risk of seizures exists in an OAP, as typically this is performed with retraction of the temporal lobe; however, there are no existing clinical data to support this presumption. In both the OAP and EAP, there is a risk of carotid artery injury as both involve bone work around the ICA. However, in EAP the ICA appears to be in jeopardy more often, as the ICA is encountered first coming from an anterior direction through an endonasal route. The petrous apex is located behind the C3 segment and lateral to the posterior ascending portion of the C4 segment. Furthermore, the ICA may have to be completely unroofed to allow its slight mobilization to add a few degrees of the line of sight to the petrous apex. This possible complication has yet to be reported. Expanded endonasal approaches including EAP have significant approach-related risks of sinonasal discomfort and crusting. Furthermore, EAP has the additional risk of mechanical hearing loss in cases of proximal eustachian tube ligation and resection. This risk is not yet delineated in the literature; however, clinical experience shows that a certain percentage of these patients will need a tympanostomy to decrease eustachian tube dysfunction.

Defining the Role of EAP

Guided by our results (Fig. 2), EAP, or inferior anterior petrosectomy, appears to be appropriate for lesions in
the medial petrous apex, specifically in the inferior portion of the petrous apex overlying the petroclival fissure. Further extension into the clivus aids in exposure and may be feasible in this approach. Combined with these anatomical constraints, pathology significantly contributes to the extent of resection. Lesions that are suckable should be considered favorable, as fibrous tumors requiring bimanual and sharp dissection may create a challenge working with angled endoscopes and instruments. Therefore, lesions that are intrinsic to the petrous apex, clivus with extension to the petrous apex, or centered in the petroclival suture overlying the inferior petrosal sinus may be well approached with an EAP. These lesions are described in the literature and include petrous apex granulomas, which have an added advantage of providing a drainage pathway, as well as chordomas, pituitary adenomas, and chondrosarcomas. Lesions centered in the petrous apex near the superior petrosal sinus or in the superior portion of the petrous apex are seemingly more favorably addressed by an OAP (superior anterior petrosectomy). These lesions include chondrosarcomas, fibrous lesions such as petroclival meningiomas, and vascular intradural pathology such as aneurysms and anterior brainstem cavernomas presenting to pial surface. Although either approach may be considered for any of these pathologies, this anatomical study highlights the indications of each approach and may facilitate the selection of the optimal surgical approach.

**Limitations of the Study**

There are several limitations to this study. First, all cadavers were anatomically without pathology; however, current endoscopic literature demonstrates a plethora of cases in which more of the petrous apex is resected and is approached via corridors created by the pathology being addressed. Second, as in all purely anatomical studies, we are unable to predict the potential clinical complications, and one must be sincerely cautious in translating anatomical studies to real-life patients. Additionally, we tried to stay true to current practice when performing these anatomical studies. As mentioned earlier, augmentation of current technique, such as utilization of an angled endoscope, may potentially achieve improved resection rates of the petrous apex.

**Conclusions**

In anatomically normal cadavers, an OAP achieved nearly a 50% larger volumetric resection than EAP. Furthermore, while OAP appears to completely address the superior portion of the petrous apex, EAP appears to have a niche in approaches to lesions in the inferior petrous apex. Given these results, we propose that OAP be redefined as the “superior anterior petrosectomy” and EAP be referred to as the “inferior anterior petrosectomy,” which more clearly defines the role of each approach in anterior petrosectomy.
Disclosure

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 to the study and manuscript preparation include the following. Conception and design: Youssef, Van Gompel, Tabor, van Loveren, Agazzi, Froelich. Acquisition of data: Youssef, Van Gompel, Alikhani, Tabor, van Loveren. Analysis and interpretation of data: Youssef, Van Gompel, Alikhani, Tabor, van Loveren. Drafting the article: Youssef, Van Gompel, Alikhani, van Loveren, Agazzi. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Statistical analysis: Van Gompel. Administrative/technical/material support: Youssef, van Loveren. Study supervision: Youssef, Tabor, Froelich.

References


Accepted February 11, 2014.
Please include this information when citing this paper: published online March 21, 2014; DOI: 10.3171/2014.2.JNS131773.
Address correspondence to: A. Samy Youssef, M.D., Ph.D., Department of Neurosurgery, University of South Florida, 2 Tampa General Circle, Tampa, FL 33606. email: syoussefmd@gmail.com.