Landmarks to Identify Petrous Apex Through Endonasal Approach Without Transgression of Sinus

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Abstract

Objectives The use of nasopharyngeal landmarks to localize the petrous apex has not been previously described. We describe a purely endoscopic endonasal corridor to localize the petrous apex without transgressing any of the paranasal sinuses.

Methods Anatomical dissections of four formalin preserved cadaveric heads (eight petrous apices) were performed to evaluate the feasibility of a nonsinus-based approach and illustrate the surgical landmarks and measurements that are useful for surgery in this area.

Results The Eustachian tubes, fossa of Rosenmüller (FR), and posterior end of the middle and inferior turbinates are constant landmarks, which can be identified without opening any nasal sinuses. The petrous apex is located on an extended straight line connecting the upper end of the torus tubarius (TT) and the roof of the FR. The distance from upper end of TT to the roof of FR measured $9.875 (\pm 0.99)$ mm, and the distance from roof of the FR to the petrous apex measured $9.75 (\pm 1)$ mm.

Conclusion With well-defined landmarks, the inferior, medial petrous apex can be reached using the endoscopic endonasal approach without crossing the sinus cavities.

Keywords

- ▶ endoscopic endonasal approach
- ▶ petrous apex
- ▶ torus tubarius
- ▶ fossa of Rosenmüller

Introduction

The petrous apex represents a challenging region to access through a lateral-to-medial transcranial trajectory. In recent years, three endoscopic endonasal approaches (EEAs) target-

ing the petrous apex have been described,^{1,2} each of which traverses a paranasal sinus to reach the petrous apex.³

Using the EEA, we have gained progressive access to this region from a medial-to-lateral direction via a completely

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endoscopic and purely endonasal route, without the need to open any paranasal sinuses. We have found it useful to employ consistent landmarks and simple measurements to identify the petrous apex intraoperatively.

Methods

Specimen Preparation

For the anatomical dissection, four preserved cadaver heads were dissected using an extended EEA. Three heads were injected with colored latex, whereas the remaining head was not injected. The bony relationships were examined in two dried specimens of human skull bases (►Fig. 1).

Equipment Used

Endoscopic dissections were performed using rigid endoscopes (Karl Storz and Co., Tuttlingen, Germany) that were 4 mm in diameter, 18 cm and 30 cm long with 0, 30, and 45 degrees viewing angles.

The endoscopes were connected to a light source through a fiber optic cable and to a high definition endoscopic camera. The video camera was connected to a 26-in monitor. Images and videos were recorded using a high-definition recorder.

Endoscopic Endonasal Exposure of Petrous Apex

The fixed cadaveric tissues were stiff and difficult to retract; therefore, when necessary, middle and inferior turbinec-tomies were performed on the side of access. A posterior 2-cm septectomy was also performed in each cadaver as previously described in the literature.⁴ The nasopharynx was examined for consistent landmarks. We ultimately relied upon the torus tubarius (TT) and fossa of Rosenmüller (FR) as the most reliable landmarks. Mucosal dissection from

medial to lateral was initiated to reach the petrous apex. Endoscopes angled at 30 and 45 degrees were used to visualize the petrous apex.

A vertical incision lying approximately 1 cm medial to the TT, extending from the roof of FR to the caudal end of the TT, was found enough for clival exposure. This length was found best to match the height of the torus tubarius, where it enabled mobilization of the Eustachian tube laterally to expose the petroclival fissure (PCF, ►Fig. 2A) to follow.

A thick fibrous tissue was attached to the PCF, which was in continuation with a similar tissue at the foramen lacerum. Further dissection and removal of fibrocartilaginous tissue exposed the inferior medial aspect of petrous apex lateral to the PCF (►Fig. 3B, C, and E). The TT and FR mucosa was preserved for reference. The inferomedial aspect of the apex was drilled. Progressive drilling of petrous face between the PCF medially and lacerum laterally led us into the intracranial compartment medial to the ICA (►Fig. 3E–H). The ICA was seen intact lateral to the drilled apex (►Fig. 3E–H). The petrous apex could be identified medial to the carotid artery from an endonasal (anteroinferomedial, ►Fig. 3H) as well as intracranial (anterosuperolateral) perspective (►Fig. 3F and G).

Statistical Analysis

The mean distances and standard deviations (SDs) were calculated for each measurement and presented as the mean $\pm$ SD.

Results

Dry Bone

Examination of the dry skull revealed that the petrous apex had ventral presentation lateral to the clivus and medial to the ICA in foramen lacerum (►Fig. 1A) and could be

Fig. 1 Dry skull specimen examination. (A) Gross examination shows the relation of the petrous apex to clivus (the endoscopic light is shining over the PA). (B) Endoscopic view of the same specimen clearly identifies the PA lateral to the PCF. Cliv, clivus; FL, foramen lacerum; PA, petrous apex; PCF, petroclival fissure.

Fig. 2 Landmarks and measurements to localize the PA. (A) The location of the PA is constantly transected by line passing through the upper end of TT and FR. (B) The distance from the TT to FR is nearly 10 mm and from the FR to PA is nearly 10 mm. Cliv, clivus; FR, fossa of Rosenmüller; ICA, internal carotid artery; PA, petrous apex; TT, torus tubarius.

endoscopically visualized without the need to remove any of the pterygopalatine bones (►Fig. 1B).

Cadaveric Head Landmarks

During visualization of the nasopharyngeal space, the following landmarks were easily and constantly identified in all specimens: the posterior tail of middle and inferior turbinate, TT, FR, and choana (►Fig. 3A).

Relations and Measures

We based our anatomic relationships and measurements on the landmarks initially identified, prior to dissection, without the need of transgressing paranasal sinuses. The petrous apex was constantly located at the extension of an imaginary line passing through the upper end of the TT and FR (►Fig. 2A). The measurements from the top of the TT to the roof of the FR and the distance from the roof of the FR to the inferior medial petrous apex (►Fig. 2B and 3D) are presented in ►Table 1.

Discussion

We have identified a set of simple, reliable landmarks that can be used to identify the location of the petrous apex using an endonasal approach without transgressing a nasal sinus. Drilling the petrous bone between the PCF and foramen lacerum safely gave entrance to the cranial cavity medial to the ICA. Endonasal endoscopic approaches to the petrous apex have been described in previous publications^{1-3,5} and have been used to remove many lesions located in the petrous bone that present medially, such as cholesterol granulomas, cholesteatomas, petrous apicitis, metastatic tumors, and schwannomas.^{1,6,7} The advantage of the endonasal inferomedial approach to the petrous apex is the ability to avoid the potential complications of the transcranial route, such as brain retraction, fourth nerve injury, abducens nerve injury, facial nerve injury, vestibulocochlear nerve injury, and cerebrospinal fluid leak.⁸⁻¹⁰

The cranial course of the abducens nerve is divided into three main segments: cisternal, petrosal, and cavernous. The

proximal cisternal segment starts from the pontomedullary sulcus to the entrance into the meningeal dural layer. The petrosal segment extends from the dural entry point, passes below the sphenopetrous ligament and above the medial petrous apex to reach the cavernous sinus. This segment (Dorello's canal segment) is subdivided into a short intradural subsegment that runs into the wall of the inferior petrosal sinus and a longer gulfar subsegment that runs in the floor of the sphenopetroclival venous gulf above the petrous apex. Transcranial approaches to the petrous apex can lead to iatrogenic nerve injury at this proximal course.

Finally, the cavernous segment of the abducens nerve extends from its entrance to the posterior wall of the cavernous sinus up to its exit toward the superior orbital fissure (SOF). In this distal course of the abducens, it runs lateral to the cavernous carotid artery and is diverged from the petrous apex. In our approach to the inferomedial aspect of the apex, the distal course of the nerve diverged from the inferomedial apex. So, it was not amenable to direct injury in our approach. In addition, the inferomedial approach has a better access for resection of the petrous bone between the petroclival angle and jugular foramen along the PCF than the superolateral transcranial approach to the petrous apex.⁹ By avoiding the sinuses, the approach we describe also reduces the potential sinonasal complications.

Currently, the described approaches to the petrous apex use wide corridors with transgression of paranasal sinuses through the nasal corridor. The transsphenoidal approach gives wide medial exposure, either with or without carotid mobilization.¹¹ The transmaxillary transpterygoid approach gives antero-inferior access to the petrous apex,^{2,9,11} which can be further extended laterally to access Meckel's cave through the quadrangular space.¹² The difference between our approach and prior publications is that we emphasize the feasibility of reaching the petrous apex, without opening a sinus, through an inferomedial window avoiding the sphenoid sinus medially and maxillary sinus inferiorly. In fact, the petrous bone is located completely lateral to the clivus and behind the pterygoid bone. This detailed anatomy obviates the need for further sinus exposure, which should lower the rates of injury to the

Fig. 3 Stepwise endonasal endoscopic dissection of the left petrous apex. (A) Endoscopic exploration of the nasopharynx constantly identifies choana, posterior tail of the middle and IF, TT, and FR. The inferior nasal branch of sphenopalatine artery is visualized (black arrow). (B) Left paramedian exposure of the clivus and medial to lateral dissection of mucosa. The thick fibrocartilaginous tissue is attached to the PCF and FL. (C) Dissection of mucosa of the FR with preservation of the TT. The PA is hidden under the fibrocartilaginous tissue (white oval hollow). (D) Measurement of distance from TT to PA is 20 mm. (E) The fibrous tissue is removed and the apex is drilled. Sinus seeker is introduced through the drilled apex (red oval hollow). (F) Transcranial view shows the probe (white arrow) at the drilled apex medial to the ICA. The tip of the measuring tape is also visualized (black arrow). (G) Dissector is retracting the ICA from the transcranial side. (H) Dissector is visualized from the endonasal side through the defect of drilled PA medial to the ICA (white arrow). Ch, choana; Cliv, clivus; Fib, fibrocartilaginous tissue; FR, fossa of Rosenmüller; FL, foramen lacerum; ICA, internal carotid artery; IT, inferior turbinate; MT, middle turbinate; PA, petrous apex; PB, petrous bone; PCF, petroclival fissure; SS, sphenoid sinus; TT, torus tubarius.

sphenopalatine artery and vidian nerve, decrease the operative time, and decrease the incidence of chronic rhinosinusitis. Although CT- or MRI-guided navigation can also be used, it is not always accurate, and hence, anatomic landmarks are also helpful to confirm the location of the petrous apex.

The most feared complication in our approach is the injury to carotid artery; meticulous drilling of petrous bone and respecting the thick fibrous tissue at foramen lacerum can avoid this. In the rare case of an ICA injury,

we recommend packing the carotid to gain control, inflating a Foley catheter balloon in the sphenoid to maintain pressure, and immediately moving the patient down to the interventional radiology suite for carotid sacrifice as we have described in a prior publication.¹³

We identified endonasal landmarks that could be used to reach the petrous apex. The point of entry was easily located in relation to easily identified constant landmarks, which were visualized from the beginning of the approach without

Table 1 Endonasal endoscopic measurements of the nasopharyngeal landmarks to petrous apex localization

	TT–FR distance (mm) 9.875 (± 0.99)	FR–PA distance (mm) 9.75 (± 1.0)
Specimen 1 rt	10	10
Specimen 1 lt	10	9
Specimen 2 rt	11	10
Specimen 2 lt	10	10
Specimen 3 rt	11	11
Specimen 3 lt	10	11
Specimen 4 rt	9	8
Specimen 4 lt	8	9

Abbreviations: FR, fossa of Rosenmüller; lt, left side of the cadaveric head; PA, petrous apex; rt, right side of the cadaveric head; TT, torus tubarius.

the specific need of exposing deep landmarks. The location of the petrous apex was on a line passing through the upper part of the TT and FR (→Fig. 2A). The distance to the petrous apex from TT was nearly constant at approximately 20 mm in all cadaveric specimens.

A purely nasal corridor through a small inferomedial window to the petrous apex is enough to access the petrous bone medial to the carotid artery. The use of 45-degrees angled endoscopes is important in guiding vision and manipulation in the direction of the petrous apex. It also enables dissection behind the TT without the need of mobilizing the Eustachian tube. For small and cystic lesions, which mainly need drainage, this exposure fulfills the need. Larger lesions widen the corridor and displace the carotid laterally,¹ which should also aid in the dissection of lesions using this corridor. There is no doubt that for large complex lesions, a wider opening is useful, which will entail opening adjacent sinuses and even possible mobilization of the Eustachian tube. We have previously classified endonasal petrous apex approaches into transsphenoidal or transmaxillary transpterygoid;³ here we add a purely nasal corridor for directly targeting the petrous apex.

Conclusion

Purely nasal endoscopic approach can safely and effectively expose the inferior medial petrous apex with the use of a 45-degree angled endoscope.

Conflict of Interest
None.

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