Modified Endoscopic Endonasal Approach With a Minimally Invasive Transoral Approach—An Adjunct to Infrapetrous Approaches

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Objectives/Hypothesis: To evaluate the potential of a minimally invasive transoral–transpalatal approach (MITA) to the retrocarotid petrous apex, as an adjunct to endoscopic endonasal approaches (EEAs).

Study Design: Cadaver study.

Methods: Five cadaveric specimens were dissected raising an inverted U-shaped palatal mucoperiosteal flap, and drilling a rectangular palatotomy (between the greater palatine foramen, and just anterior to the palatine aponeurosis). This allowed a transpterygoid EEA with cross-court access (contralateral line of sight), followed by an extradural clivectomy that exposed the petroclival junction bilaterally. Surgical targets were marked on the posterior and medial surface of the petrous internal carotid artery (ICA), at its anterior genu, midhorizontal portion, and posterior genu. For each target and approach, the surgical freedom and angles of approach (in the horizontal and vertical planes) were calculated and statistically compared.

Results: Compared to EEA, the MITA resulted in greater surgical freedom for all targets, with the highest values at the anterior genu (1,661.37 mm² vs. 312.76 mm², P < .001), and maintaining superiority in this regard all the way to the posterior genu (847.84 mm³ vs. 138.91 mm³, P < .005). MITA also offered greater angles of approach for all targets.

Conclusions: This study suggests that the MITA may be indicated to supplement the exposure provided by a transpterygoid EEA. This technique, associated with low potential morbidity, offers an alternative to internal carotid lateralization while managing extradural lesions that are adjacent to the petrous ICA.

Key Words: Endoscopic skull base surgery, minimally invasive approaches, petrous carotid artery, petrous apex, transpalatal surgery.

Level of Evidence: NA

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INTRODUCTION

Expanded endonasal approaches (EEA) offer a minimal access corridor to the ventral skull base in the sagittal and coronal planes. Currently, there are no general contraindications to an EEA based on tumor size, nature, or consistency, although lateral extension does represent a limitation. An EEA to the petrous apex in patients with poorly pneumatized sphenoid sinuses presents a surgical challenge. Some lesions can be managed circumventing the petrous segment of the carotid artery with angled instrumentation; however, this is done at the expense of maneuverability, which paradoxically is more critical in the proximity of the great vessels. Other alternatives, such as lateralization of the carotid artery, carry a potential risk of internal carotid artery (ICA) injury; thus, it should be undertaken by experienced surgeons.

A transoral pathway offers an advantageous caudal to cephalad and medial to lateral view, which allows direct visualization and instrumentation of the petrous apex. Despite its well-established benefits, the morbidity associated with a soft palate split has detracted its use. This cadaveric study attempts to establish the feasibility, advantages, and limitations of a transoral approach through the hard palate, as an adjunct to an endoscopic transpterygoid infrapetrous approach to the petrous apex. This technique could offer a less morbid alternative to other transpalatal approaches, while reducing the need of manipulating the ICA.

MATERIALS AND METHODS

We studied five silicone-injected cadaveric human head specimens (10 sides). All dissections were performed in accordance with the institutional protocols at the Anatomical Laboratory Toward Viscuospatial Innovations in Otolaryngology and Neurosurgery at the Wexner Medical Center of The Ohio State University. All specimens underwent high-resolution computed tomography that was uploaded to an image guidance system (Stryker Navigation, Kalamazoo, MI). The surgical dissection was undertaken with standard angled suction, burr, and dissector blades, and conducted with 0°, 45°, and 70° rod-lens endoscopes (Karl Storz Endoscopy, Tuttlingen, Germany).
Dissection

To recreate an EEA, the nasal corridor was widened. The inferior turbinates were out-fractured laterally, and the ipsilateral middle turbinate was resected. Bilateral anterior and posterior ethmoidectomies and a posterior septectomy were performed. Wide sphenoidotomies, removing the sphenoid sinus floor until it was flush with the clival recess, were followed by an endoscopic endonasal transmaxillary, transpterygoid infrapetrous approach (infragpetrous EEA) (Fig. 1A) from the contralateral side (cross-court), as previously described. The cartilaginous portion of the eustachian tube was sectioned and separated from the levator veli palatine muscle. Next, a partial clivectomy was performed (without exposing the dura) and extended through the petroclival junction into the petrous apex, establishing a single cavity with the one obtained through infrapetrous dissection. The petrous segment of the carotid artery was exposed along its inferior and posterior–medial surface, from the foramen lacerum to the carotid foramen (Fig. 1B). The perios- teum surrounding the petrous apex was kept intact to maintain an extradural dissection. The cartilage at the foramen lacerum was partially removed. A palatal window (palatotomy) was created as follows (Fig. 2):

1. A Davis-Boyle mouth gag was opened to an oral aperture of at least 3 cm.
2. An inverted U-shaped incision was carried along the maxil- lary alveolar processes, leaving an adequate gingival cuff (facilitate suturing after completion).
3. A mucoperiosteal flap was raised, preserving its pedicles, the paired greater palatine neurovascular bundles.
4. A rectangular window was drilled between the greater pala- tine canals, leaving a bone strut between the fenestra and the greater palatine foramen. The posterior margin was set at least 1 cm anterior to the palatine aponeurosis insertion, whereas the anterior margin must be advanced at least 2 cm.
5. Endonasally, the mucosa of the nasal floor was dissected in a medial to lateral direction, over the area of the window.
6. The remaining portions of the base of the vomer and the maxillary crest were drilled flush with the nasal floor.

Landmarks were marked with ink at the bisected angles of the posterior–medial surface of the anterior genu, the posterior genu, at their intersection with the midhorizontal petrous carotid. With the assistance of the navigation system, the surgical freedom and angle of attack were measured and compared in all targets between the minimally invasive transoral-
transpalatal approach (MITA) and a cross-court infrapetrous EEA. All measurements were taken with a 20-cm curved ball-tip probe positioned over the targets behind the ICA, under direct endoscopic confirmation with a 70° rod-lens endoscope (its angled view unfailingly offered a complete visual exposure of the posterior–lateral petrous apex), while a second investigator verified the absence of vascular compression by the instrument (Fig. 3).

**Surgical Freedom**
Surgical freedom suggests the maximum working area in which the surgeon is able to maneuver the proximal ends of the instrument while the distal tip is fixed on the targets (anterior genu, mid-horizontal petrous carotid and posterior genu). Three-dimensional coordinates were determined by holding a stereotactic probe in each of the four extreme positions allowed by anatomic constraints: superior, inferior, medial, and lateral. This model has been previously tested for other minimal access approaches.3,4

**ANGLE OF ATTACK**
Using the same methodology, the maximum angle of attack was measured by fixing the distal end of the probe on the targets while moving the proximal end as far as possible in the axial (horizontal angle of attack) and sagittal planes (vertical angle of attack).4

**Statistical Methods**
Surgical freedom and angles of attack were compared between approaches through two-tailed paired t tests. Statistical significance was considered at $P < .05$. Comparative percentages were calculated for each technique.

**RESULTS**
Dissections were completed in 10 sides of the five specimens, and all measurements were successfully obtained in nine, except for one target in the midhorizontal portion of one of the sides, through an endonasal approach. Due to a pronounced inferior curvature of the horizontal petrous ICA, the probe was not able to reach that target without exerting vascular compression.

**Surgical Freedom**
The mean surgical freedom obtained with the MITA was significantly higher than the infrapetrous EEA for all targets. The highest surgical freedom obtained with MITA was found at the anterior genu (16.61 cm$^2$). Although, in comparison to the EEA, the highest gain in surgical freedom attained by MITA was observed at the midhorizontal portion of the petrous ICA (91.24% higher) (Table I).

**Angles of Attack**
As compared to the infrapetrous EEA, the angles of attack were significantly increased for all targets with the MITA. The largest gain in degrees obtained by the MITA was observed in the horizontal plane, in the midhorizontal portion of the petrous ICA (82.39% greater than EEA) (Table II).

**DISCUSSION**
The inclusion of angled rod-lens endoscopes to the surgical armamentarium allows the visualization of anatomic corners that might be impossible to observe through straightforward trajectories. However, enhanced visualization capabilities are not necessarily accompanied by a parallel rise in surgical maneuverability, and nowhere is this more apparent than in areas surrounded by delicate anatomic structures such as the petrous apex, situated posterior to the ICA.

Endoscopic endonasal techniques offer a comprehensive surgical exposure of the petrous apex up to the anterior margin of the internal auditory canal,2,5 especially to its inferior portion.6 Although tumors with a superior and lateral extension may offer a greater challenge, as the

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**TABLE I.** Surgical Freedom: MITA Versus Contralateral EEA.

<table>
<thead>
<tr>
<th>Target</th>
<th>MITA</th>
<th>Inftrapetrous EEA</th>
<th>MITA Comparative %</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG pICA</td>
<td>16.6</td>
<td>(5.72)</td>
<td>3.12 (4.21)</td>
<td>81.18%</td>
</tr>
<tr>
<td>MH pICA</td>
<td>13.48</td>
<td>(6.02)</td>
<td>1.18 (1.59)</td>
<td>91.24%</td>
</tr>
<tr>
<td>PG pICA</td>
<td>8.47</td>
<td>(6.23)</td>
<td>1.38 (1.66)</td>
<td>83.70%</td>
</tr>
</tbody>
</table>

Data are presented as mean cm$^2$ (standard deviation).
AG = anterior genu; EEA = endoscopic endonasal approach; MH = midhorizontal; PG = posterior genu; pICA = petrous internal carotid artery; MITA = minimally invasive transoral approach;
ICA limits an oblique surgical dissection, despite recurring to curved instruments and having a complete view of the surgical field. This shortcoming is even more evident in patients with poor sphenoid sinus pneumatization and/or a narrowed distance between the brainstem and ICA. Lateral mobilization of the petrous and paraclival portion of the ICA enables surgery on this anatomical area, but it is associated with risk of injury and requires a higher level of surgical expertise, especially if the ICA has been irradiated or in the presence of canal or vascular invasion.

Transoral and transpalatal approaches to the skull base have been reported and tested for over a century. Its use for lesions extending in the coronal plane have been less explored. However, increased morbidity risks associated to the detachment and split of the soft palate, along with resection of portions of the hard palate, have mostly limited its use to select lesions of the hard palate, and the periosteal flap is replaced. The risk for an oronasal fistula is low, as the palatal window is separate from the borders of the flap. Conversely, this approach inevitably increases operative time and risks additional morbidity to an EEA, such as postoperative buccal sensory deficit, postoperative bleeding arising from inferior turbinate trauma, and potentially higher risks of postoperative infection conveyed by contact with the oral flora. This study suggests an MITA only for the management of extradural tumors, especially those enveloping the ICA, requiring a more accurate dissection.

Although angled endoscopic techniques facilitate the visualization of the entire posterior–lateral petrous apex, the freedom of movement is restricted during EEA, and it could be improved by adding a MITA. The gain in surgical maneuverability could prove to be especially valuable in lateral areas, which are sometimes not possible to reach even after removing the medial third of the eustachian tube (as observed in one of the specimens). A MITA could be attempted before considering traditional open approaches or adjuvant medical treatment if EEA proves to be insufficient, and it is preferred to avoid ICA manipulation.

The proposed technique should carry a lesser risk of velopharyngeal insufficiency than traditional transoral approaches, as the soft palate is never transected, the palatine aponeurosis is never detached from the hard palate, and the perosteal flap is replaced. The risk for an oronasal fistula is low, as the palatal window is separate from the borders of the flap. Conversely, this approach inevitably increases operative time and risks additional morbidity to an EEA, such as postoperative buccal sensory deficit, postoperative bleeding arising from inferior turbinate trauma, and potentially higher risks of postoperative infection conveyed by contact with the oral flora. This study suggests an MITA only for the management of extradural tumors, especially those enveloping the ICA, requiring a more accurate dissection.

The morphology of the petrous ICA is variable between individuals, and can be asymmetric, which in addition to an inconsistent degree of elasticity in the nares of preserved heads could potentially explain a higher variability of surgical freedom observed with the endonasal techniques (standard deviation greater than the mean). This variability could play to the advantage of the endonasal corridor and be sufficient in most cases, reinforcing the role of a transpalatal corridor as secondary to an already completed transpterygoid infrapetrous EEA. Nevertheless, consistently superior results endorse MITA as a dependable option.

A limitation of this study is that it has been tested in laboratory conditions only. Another drawback is that all the specimens were edentulous, and the presence of teeth could partially hinder the instrumental range.
movement. It is also important to note that our experience with MITA does not account for the use of angled instrumentation and scopes.

ACKNOWLEDGMENTS

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BIBLIOGRAPHY