Clinical Correlates of the Anatomical Relationships of the Foramen Ovale: A Radioanatomical Study

Ahmed Youssef^{1,2} Ricardo L. Carrau¹ Ahmed Tantawy² Ahmed Ali Ibrahim² Daniel M. Prevedello³
Bradley A. Otto¹ Arturo C. Solares⁴ Leo F. S. Ditzel Filho³ Jason Rompaey⁴

¹ Department of Otolaryngology-Head and Neck Surgery, Ohio State University, Columbus, Ohio, United States

² Department of Otolaryngology-Head and Neck Surgery, Alexandria University, El Azareeta, Alexandria, Egypt

³ Department of Neurosurgery, The University of Ohio, Columbus, Ohio, United States

⁴ Department of Otolaryngology-Head and Neck Surgery, Georgia Regents Medical Center, Augusta, Georgia, United States

Address for correspondence Ahmed Youssef, MD, MRCS, Department of Otolaryngology-Head and Neck Surgery, Alexandria University, 8 Elgesh Street, El Azareeta, Alexandria 21131, Egypt (e-mail: ahmedyouseef2002@yahoo.com).

J Neurol Surg B 2014;75:427–434.

Abstract

Introduction Endonasal endoscopic transpterygoid approaches are commonly used techniques to access the infratemporal fossa and parapharyngeal space. Important endoscopic endonasal landmarks for the poststyloid parapharyngeal space, hence the internal carotid artery, include the mandibular nerve at the level of foramen ovale and the lateral pterygoid plate. This study aims to define the anatomical relationships of the foramen ovale, establishing its distance to other important anatomical landmarks such as the pterygoid process and columella.

Methods Distances between the foramen ovale, foramen rotundum, and fixed anatomical landmarks like the columella and pterygoid process were measured using computed tomography (CT) scans and cadaveric dissections of the pterygopalatine and infratemporal fossae.

Results The mean distances from the foramen ovale to columella and from the foramen rotundum to columella were found to be 9.15 cm and 7.09 cm, respectively. Analysis of radiologic measurements detected no statistically significant differences between sides or gender.

Conclusions The pterygoid plates and V3 are prominent landmarks of the endonasal endoscopic approach to the infratemporal fossa and poststyloid parapharyngeal space. A better understanding of the endoscopic anatomy of the infratemporal fossa and awareness of the approximate distances and geometry among anatomical landmarks facilitates a safe and complete resection of lesions arising or extending to these regions.

Keywords

- infratemporal fossa
- transpterygoid approach
- foramen ovale
- foramen rotundum
- V2
- V3

Introduction

The infratemporal fossa (ITF) is situated beneath the floor of the middle cranial fossa, posterior to the maxillary sinus, medial to the ramus of the mandible, and lateral to the nasopharynx and pterygopalatine fossa. The greater wing

of the sphenoid bone and the undersurface of the temporal bone form its roof. The lateral pterygoid plate along with the eustachian tube forms its medial wall. The deep aspect of the temporalis muscle inserting to the coronoid process, the mandibular ramus, and the temporomandibular joint (TMJ) bounds the ITF in its lateral aspect.^{1–3}

received

November 29, 2013

accepted after revision

May 27, 2014

published online

August 11, 2014

© 2014 Georg Thieme Verlag KG
Stuttgart · New York

DOI <http://dx.doi.org/10.1055/s-0034-1386654>.
ISSN 2193-6331.

The ITF houses the lateral and medial pterygoid muscles as well as important neurovascular structures such as the third branch of the trigeminal nerve (V3), the internal maxillary artery (IMA) (i.e., masticator space), and the carotid sheath with its contents (i.e., parapharyngeal space). The lateral pterygoid muscle occupies most of the superior ITF. Inferiorly, the ITF is mainly occupied by the medial pterygoid muscle that inserts into the angle of mandible. Posteromedially, the ITF contains the carotid sheath and its contents (internal carotid artery (ICA), internal jugular vein, and cranial nerves IX to XII), and the styloid complex.¹

In addition, the IMA, pterygoid venous plexus, maxillary vein, and the mandibular nerve and chorda tympani traverse the ITF.^{2,3} Medially, the ITF communicates with the pterygopalatine fossa via the pterygomaxillary fissure.

Multiple surgical approaches to the ITF have been suggested including the lateral preauricular and postauricular approaches, anterior transmaxillary or transnasal approaches, and inferior transmandibular approaches.³ Among others, traditional anterior approaches to the ITF include the maxillary swing and facial translocation approach, Le Fort I and/or II osteotomies, and the extended maxillary antrostomy approach.⁴ Endoscopic endonasal transpterygoid approaches have provided new corridors to access a variety of pathologies in the paramedian and lateral skull base.

Pathologic processes arising primarily in the ITF are commonly benign; therefore, surgical approaches should limit iatrogenic morbidity as much as possible. Accordingly, identification and protection of important neurovascular structures is paramount to achieve a successful surgery.^{5,6}

The ICA is the pivotal structure in the ITF; thus every surgical approach takes into consideration its identification and protection. Important landmarks for the endonasal endoscopic location of the poststyloid parapharyngeal space, hence the ICA, include the mandibular nerve at the level of foramen ovale and the lateral pterygoid plate. However, tumors frequently displace the anatomical landmarks compounding the surgical difficulty of identifying the vessel.

The aim of this work is to better define the anatomical relationships of the foramen ovale and the mandibular nerve, establishing their distance to other important anatomical landmarks like the pterygoid process and columella using cadaveric dissections and computed tomography (CT) scans.

Materials and Methods

Cadaveric Dissection

In accordance with institutional protocols, our cadaveric study received an institutional review board (IRB) exemption because the dissections were performed on deidentified cadaveric specimens. However, the Anatomy Laboratory Toward Visuospatial Surgical Innovations in Otolaryngology and Neurosurgery (ALT-VISION) at the Wexner Medical Center at OSU and researchers are certified by regulatory agencies dealing with the use of human tissues and cadaveric studies. Using a standardized method, five specimens were injected with red and blue silicone, through the ICA and internal jugular vein, respectively.

Visualization video and photo documentation were facilitated by the use of 0-, 30-, and 45-degree rod-lens endoscopes coupled to a high-definition camera and monitor (Storz Endoscopy, Tuttlingen, Germany). The surgical dissection was performed using paranasal sinus and skull base/neurosurgical endoscopic instruments (Storz Endoscopy, Tuttlingen, Germany) and a high-speed drill with angled handpiece, and diamond and cutting 4-mm burrs (Saber drill; Total Performance System, Stryker Corporation; Kalamazoo, Michigan, United States).

Ten infratemporal and pterygopalatine fossae (five cadaveric specimens) were dissected endoscopically using a transpterygoid approach. An endoscopic medial maxillectomy allowed the removal of the posterior wall of the maxillary sinus using Kerrison rongeurs, starting at the anterior aspect of the sphenopalatine foramen and proceeding from a medial to lateral direction.

Inserting the instruments from the contralateral side of the nose, which requires a posterior septectomy, enhances the angle of approach. However, to dissect the most lateral aspect of the ITF, it is preferable to extend the medial maxillectomy anteriorly. This requires removal of the remaining inferior turbinate and anterior aspect of the inferior meatus with backbiting rongeurs, osteotomes, or a high-speed drill. For full exposure, we remove the pyriform aperture and ascending process of the maxilla, dissecting and sharply transecting the lacrimal duct (endoscopic Denker or Sturman-Canfield approach). An endoscopic Denker approach requires a vertical incision just anterior to the head of the inferior turbinate and carried down to the bone, just over the edge of the pyriform aperture. Extension of the dissection laterally, following a subperiosteal plane, exposes the entire anterior maxilla including the infraorbital foramen, its corresponding nerve, and the inferior orbital rim.

After incising the investing periosteum and removing the fat of the pterygopalatine fossa, the main terminal branches of the IMA including the infraorbital, descending palatine, sphenopalatine, and posterior nasal arteries were identified. All branches were transected to expose the underlying nerves like the infraorbital, greater and lesser palatine, vidian, and pharyngeal nerves (→ Figs. 1 and 2).

We identified the short segment of the infraorbital nerve that traverses the infraorbital fissure on its way to the maxillary nerve. This delineates the border between infratemporal and pterygopalatine fossae. Its medial and posterior dissection leads to the foramen rotundum.

Wide exposure of the ITF requires a complete removal of the posterior wall of the maxillary sinus and some of the most posterior aspect of its lateral wall. The lateral limit is the vertically oriented temporalis muscle, just lateral to the lateral wall of the antrum. The lateral pterygoid muscle is readily differentiated by the horizontal orientation of the muscle fibers.

The second part of the IMA (muscular segment) has a variable course that may run superficial or deep to the lateral pterygoid muscle. This segment of the IMA gives off several branches near the anterior border of the lateral pterygoid muscle including the lingual and buccal arteries that course

Fig. 1 Endoscopic view of the infratemporal fossa. (A) Before and (B) after removal of posterior wall of maxillary sinus. MA, maxillary artery; MS, maxillary sinus; ION, infraorbital nerve; TM, temporalis muscle.

Fig. 2 Dissection of maxillary nerve (V2) and mandibular nerve (V3) after partial drilling of pterygoid plate and resection of lateral pterygoid muscle. FO, foramen ovale; FR, foramen rotundum; LPM, lateral pterygoid muscle; TM, temporalis muscle.

anteriorly. The middle meningeal artery may be seen medial to the lateral pterygoid muscle, coursing superiorly toward the foramen spinosum.

Resection of the lateral pterygoid muscle and drilling of the lateral pterygoid plate improves the exposure of the ITF including the visualization of V3, which lies posterior to the lateral pterygoid plate (► **Fig. 3**). Removal of bone from the floor and lateral walls of the sphenoid sinus exposes the bony floor of the middle cranial fossa, which is the superior

boundary of the ITF. Distances from the columella to foramen rotundum, columella to foramen ovale, and between foramen ovale and the pterygoid process were measured bilaterally using a ruler under endoscopic guidance (► **Figs. 3 and 4**).

Computed Tomography Analysis

CT angiographies obtained from 14 male and 14 female deidentified patients were chosen at random from a database comprising the scans of 173 adults (> 18 years of age). This

Fig. 3 Measurement of foramen ovale and rotundum to columella. FO, foramen ovale; FR, foramen rotundum; IMA, internal maxillary artery; V2, maxillary nerve; V3, mandibular nerve.

Fig. 4 Foramen ovale and its measurements to pterygoid process. FO, foramen ovale; FR, foramen rotundum; IMA, internal maxillary artery; PP, pterygoid process; V2, maxillary nerve; V3, mandibular nerve.

IRB-approved database was generated from a list of CT angiograms at Georgia Regents Medical Center from October 2011 through December 2012.

The scans were viewed and analyzed using the Osirix Software (Pixmeo, Switzerland). This open source DICOM viewer has the capacity to generate measurements between two separate points on a CT scan and is compatible with the Apple OSX operating system.

The distance from the columella to the foramen ovale was measured on the computed tomography angiograms (CTAs). The most anterior and inferior point of the columella and the most anterior and inferior point of the foramen ovale were

selected, and distances were calculated using the Osirix software (►Fig. 5).

The most anterior and inferior part of the columella was again used as reference point to measure the distance to the foramen rotundum. The most anterior part of the foramen rotundum on its extracranial surface was used as the second point. The distance was then calculated using the previously described technique (►Fig. 5).

The distance from the pterygoid prominence to the foramen ovale was measured as follows. We identified a point on the pterygoid prominence by finding the most anterior portion of the pterygoid process in an axial scan and then

Fig. 5 Measurements of foramen ovale and rotundum to columella.

Fig. 6 Measurements of foramen ovale to pterygoid plate.

aligning it with the most lateral aspect of the lateral pterygoid viewed on a coronal scan (►Figs. 6 and 7). The second point was placed on the most anterior and inferior aspect of the foramen ovale.

Results

Ten infratemporal and pterygopalatine fossae (five cadaveric specimens) were dissected endoscopically using a transpter-

yoid approach. Distances from the columella to the foramen rotundum, columella to foramen ovale, and the distance between foramen ovale and the pterygoid process are demonstrated in ►Table 1.

Analysis of the endoscopic measurements yielded that the mean distances from foramen ovale and foramen rotundum to the columella were 9.15 cm and 7.09 cm, respectively.

Radiologic measurements done in 28 CTAs showing average, standard deviation, and confidence intervals are shown

Fig. 7 Measurements of foramen ovale and rotundum to columella using three-dimensional computed tomography reconstruction. ICA, internal carotid artery; MMA, middle meningeal artery.

Table 1 Measurements done under endoscopic guidance

Head no.	Foramen ovale to columella		Foramen ovale to pterygoid plate		Foramen rotundum to columella	
	Right	Left	Right	Left	Right	Left
1. Male	8.5 cm	8.5 cm	2.2 cm	1.8 cm	6.6 cm	6.5 cm
2. Female	9.7 cm	9.5 cm	2.2 cm	2.0 cm	7.5 cm	7.5 cm
3. Male	9.5 cm	9.5 cm	2.5 cm	1.8 cm	7.0 cm	7.5 cm
4. Female	8.8 cm	8.5 cm	2.3 cm	2.0 cm	6.5 cm	6.5 cm
5. Male	9.5 cm	9.5 cm	2.2 cm	2.2 cm	7.5 cm	7.8 cm

in ►Table 2. Left and right measurements were then combined into the same data set, and the same calculations were implemented (►Table 3).

Our null hypothesis for the *t* test was that there is no difference in the measurements of left and right. The *p* value was > 0.05 indicating that the null hypothesis would be accepted. This supports the notion that there was not a statistically significant difference between the right and left measurements. Measurements for male and female patients were analyzed in a similar manner obtaining a *p* value > 0.05 , thus indicating no statistical significance between the measurements in male and female patients.

The average distance from foramen rotundum to columella was found to range from 6.599 cm to 6.957 cm in CTA measurements, whereas the endoscopic measurements mean distance was 7.09 cm. Regarding the foramen ovale measurements to columella, there is a statistically significant difference between the endoscopic measurement mean distance (9.15 cm) and the average of the radiologic measurements (7.25–7.52 cm).

Discussion

Multiple lateral and anterior approaches have been proposed to access the ITF.^{7,8} Lateral approaches include a combination of preauricular or postauricular incisions, parotidectomy with facial nerve rerouting and preservation, displacement or resection of the mandibular condyle, orbitozygomatic osteotomies, displacement of the temporalis muscle, identification and/or transposition of the petrous ICA, and a temporal or pterional craniotomy. Possible sequelae or risks include postoperative TMJ pain, dysfunction and trismus, facial paresis or paralysis, and possible hearing loss.⁹

Compared with lateral approaches to the ITF, the endonasal endoscopic transpterygoid approach provides better exposure of midline structures such as the nasopharynx, eustachian tube, sella, and clivus. This exposure is markedly affected by sphenoid sinus pneumatization either conical, presellar, or sellar type. It was originally described for lesions involving the lateral recess of the sphenoid sinus above and lateral to the level of the vidian canal (i.e., cerebrospinal fluid

Table 2 Average measurements, standard deviation, and confidence intervals of foramen ovale and rotundum in males and females

Approach	Sex	Average distance, cm	SD, cm	95% confidence interval, range, cm	95% confidence interval, cm
Columella to foramen ovale	Male (right)	7.60	0.595	7.29–7.91	0.311
	Male (left)	7.47	0.618	7.15–7.80	0.324
	Female (right)	7.23	0.434	7.00–7.46	0.227
	Female (left)	7.28	0.350	7.10–7.46	0.183
Pterygoid prominence to foramen ovale	Male (right)	1.720	0.150	1.64–1.80	0.079
	Male (left)	1.709	0.197	1.61–1.81	0.103
	Female (right)	1.69	0.207	1.58–1.80	0.109
	Female (left)	1.67	0.131	1.60–1.74	0.069
Columella to foramen rotundum	Male (right)	6.98	0.855	6.53–7.43	0.448
	Male (left)	6.93	0.887	6.47–7.40	0.465
	Female (right)	6.58	0.488	6.32–6.83	0.256
	Female (left)	6.62	0.436	6.40–6.85	0.228

Abbreviation: SD, standard deviation.

Table 3 Summary of combined, left, and right measurements for both males and females

Approach	Sex	Average distance (cm)	SD, cm	95% confidence interval, range, cm	95% confidence interval, cm
Columella to foramen ovale	Male	7.52	0.597	7.30–7.74	0.221
	Female	7.25	0.387	7.11–7.40	0.144
Pterygoid prominence to foramen ovale	Male	1.714	0.172	1.65–1.78	0.064
	Female	1.68	0.170	1.62–1.74	0.063
Columnella to foramen rotundum	Male	6.957	0.855	6.64–7.27	0.317
	Female	6.599	0.454	6.43–6.77	0.168

Abbreviation: SD, standard deviation.

leaks of the lateral Sternberg canal). In addition, this approach allows for efficient and excellent exposure of the foramen rotundum, maxillary nerve (V2), nerve of the pterygoid canal and foramen ovale, and mandibular nerve (V3) via drilling of lateral pterygoid plate and dissection of lateral pterygoid muscle. Bleeding from the pterygoid venous plexus is expected; therefore, chemical agents, bipolar cautery, and warm saline irrigation should be available for hemostasis.¹⁰

The exposure offered by the endoscopic endonasal transpterygoid approach to the ITF is more extensive than that of the microscopic sublabial transmaxillary approach, providing improved access to treat larger, more extensive lesions. It is also equivalent to the preauricular subtemporal approach.¹¹ Furthermore, endoscopic endonasal transpterygoid approaches avoid morbidities associated with traditional surgical approaches such as cosmetic problems related to skin incisions, zygomatic osteotomies, or temporalis muscle manipulation; TMJ problems; paralysis of the facial nerve or its branches; as well as morbidity related to craniotomy and or brain retraction. Potential detractors to endoscopic endonasal approaches include trismus, resulting from scarring of the pterygoid muscles, and palatal numbness, related to sacrifice or damage of the palatine nerve or dental branches of V2.

The transpterygoid approach to the ITF allows dissection of the foramen ovale and V3, which is important for management of benign tumors such as schwannomas and juvenile angiofibromas. However, some malignant tumors such as low-grade adenocarcinomas and adenoid cystic carcinomas that displace rather than invade neurovascular structures in the ITF, can also be removed through this approach. Invasive tumors most often need a traditional approach that enables proximal ICA control and manipulation of the soft tissues of the ITF.¹²

Moreover, one of the most important anatomical landmarks that help locate the parapharyngeal segment of ICA from the endonasal endoscopic approach is the mandibular nerve at the level of the foramen ovale, which is a reference point anterior to the vessel. The extracranial mandibular nerve, at the level of the foramen ovale, lies on the antero-lateral surface of the eustachian tube. The cartilaginous

eustachian tube may be used as the most medial reference point.

The intimate relationship between the ICA, the eustachian tube, and V3 is well studied for their importance to detect the superior portion of the parapharyngeal ICA and consequently poststyloid part of the parapharyngeal space. From the surgical point of view, the variability of the position of the parapharyngeal portion of the ICA represents a great challenge for the surgeon. ICA ectasia places the vessel in close relation with the lateral pharyngeal wall or even behind the posterior pharyngeal wall. During a lateral approach, this issue is of lesser significance because the vessel is under visual control. Conversely, surgeons should rely on certain landmarks during the endoscopic dissection.

As emphasized by several publications, the vidian nerve is a crucial landmark to identify the ICA during endoscopic skull base surgery.^{13,14} This could be identified easily from the endoscopic transpterygoid approach by dissection just medial and inferior to the maxillary nerve. Visualization of the maxillary nerve and consequently foramen rotundum could be achieved by tracing the infraorbital nerve in the roof of maxillary sinus. Moreover, it is possible to access the Meckel cave endoscopically by passing between the vidian canal and V2.^{13–15}

Knowledge regarding distances to endoscopic endonasal and landmarks such as foramen ovale, foramen rotundum, and foramen spinosum help to estimate and understand the depth of dissection, especially when the extensive pathologic processes obscure critical structures and their relationships with one another. The distance from foramen ovale to the pterygoid process estimates the extent of drilling of the pterygoid process that can be achieved while avoiding the transection of the lateral pterygoid muscle; therefore allowing less postoperative pain and trismus. This also helps to identify V3 as a landmark to ICA during other extended endonasal procedures such as endoscopic nasopharyngectomy.

Conclusion

Endonasal endoscopic transpterygoid approaches are very effective for the treatment of selected lesions affecting the ITF. The most important landmarks during the endonasal

endoscopic approach to the ITF and poststyloid space are the pterygoid plates, V3, and the eustachian tube. Measurements of these anatomical landmarks enhance the understanding of the endoscopic anatomy of the ITF, allowing a safe and complete resection of lesions arising or extending to that area.

References

- 1 Carrau R, Kassam A, Arriaga M. Anterior and subtemporal approaches to the infratemporal fossa. In: Brackmann DE, Shelton C, Arriaga MA, eds. *Otologic Surgery*. 3rd ed. Philadelphia, PA: Saunders Elsevier; 2010
- 2 Hitotsumatsu T, Rhoton AL Jr. Unilateral upper and lower subtotal maxillectomy approaches to the cranial base: microsurgical anatomy. *Neurosurgery* 2000;46(6):1416–1452; discussion 1452–1453
- 3 Isolani GR, Rowe R, Al-Mefty O. Microanatomy and surgical approaches to the infratemporal fossa: an anaglyphic three-dimensional stereoscopic printing study. *Skull Base* 2007;17(5):285–302
- 4 Tiwari R, Quak J, Egeler S, et al. Tumors of the infratemporal fossa. *Skull Base Surg* 2000;10(1):1–9
- 5 Robinson S, Patel N, Wormald PJ. Endoscopic management of benign tumors extending into the infratemporal fossa: a two-surgeon transnasal approach. *Laryngoscope* 2005;115(10):1818–1822
- 6 Gupta AK, Rajinikanth MG, Gupta AK. Endoscopic approach to juvenile nasopharyngeal angiofibroma: our experience at a tertiary care centre. *J Laryngol Otol* 2008;122(11):1185–1189
- 7 Fisch U. Infratemporal fossa approach to tumours of the temporal bone and base of the skull. *J Laryngol Otol* 1978;92(11):949–967
- 8 Vilela MD, Rostomily RC. Temporomandibular joint-preserving preauricular subtemporal-infratemporal fossa approach: surgical technique and clinical application. *Neurosurgery* 2004;55(1):143–153; discussion 153–154
- 9 Leonetti JP, Anderson DE, Marzo SJ, O'Gratano TC, Schuman R. The preauricular subtemporal approach for transcranial petrous apex tumors. *Otol Neurotol* 2008;29(3):380–383
- 10 Kassam A, Snyderman CH, Carrau RL, Gardner P, Mintz A. Endoneurosurgical hemostasis techniques: lessons learned from 400 cases. *Neurosurg Focus* 2005;19(1):E7
- 11 Fahmy CE, Carrau R, Kirsch C, et al. Volumetric analysis of endoscopic and traditional surgical approaches to the infratemporal fossa. *Laryngoscope* 2014;124(5):1090–1096
- 12 Hosseini SM, Razfar A, Carrau RL, et al. Endonasal transpterygoid approach to the infratemporal fossa: correlation of endoscopic and multiplanar CT anatomy. *Head Neck* 2012;34(3):313–320
- 13 Vescan AD, Snyderman CH, Carrau RL, et al. Vidian canal: analysis and relationship to the internal carotid artery. *Laryngoscope* 2007;117(8):1338–1342
- 14 Kassam AB, Vescan AD, Carrau RL, et al. Expanded endonasal approach: vidian canal as a landmark to the petrous internal carotid artery. *J Neurosurg* 2008;108(1):177–183
- 15 Kassam AB, Prevedello DM, Carrau RL, et al. The front door to Meckel's cave: an anteromedial corridor via expanded endoscopic endonasal approach—technical considerations and clinical series. *Neurosurgery* 2009;64(3, Suppl):ons71–ons82; discussion ons82–ons83