Finding the Petroclival Carotid Artery: The Vidian–Eustachian Junction as a Reliable Landmark

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J Neurol Surg B 2018;79:361–366.

Abstract

Keywords

- ▶ endoscopic surgery
- ▶ skull base
- ▶ internal carotid artery
- ▶ anatomy
- ▶ vidian nerve
- ▶ eustachian tube

Introduction Identifying the internal carotid artery (ICA) when managing petroclival and infratemporal fossa pathology is essential for the skull base surgeon. The vidian nerve and eustachian tube (ET) cartilage come together at the foramen lacerum, the vidian–eustachian junction (VEJ). The ICA position, relative to the VEJ is described.

Methods Endoscopic dissection of adult fresh-frozen cadaver ICAs and a case series of patients with petroclival pathology were performed. The relationship of the VEJ to the ICA horizontal segment, vertical segment, and second genu was assessed. The distance of the ICA second genu to VEJ was determined in coronal, axial, and sagittal planes. The length of the vidian nerve and ET was measured from the pterygopalatine fossa (PPF) and nasopharyngeal orifice to the VEJ.

Results In this study, 10 cadaver dissections (82.3 ± 6.7 years, 40% female) were performed. The horizontal petrous ICA was at or behind VEJ in 100%, above VEJ in 100%, and lateral to VEJ in 80%. The vertical paraclival segment was at or behind VEJ in 100%, above in 100%, and medial in 100%. The second genu was at or behind VEJ in 100% (3.3 ± 2.4 mm), at or above in 100% (2.5 ± 1.6 mm), and medial in 100% (3.4 ± 2.0 mm). The VEJ was successfully used to locate the ICA in nine consecutive patients (53.3 ± 13.6 years, 55.6% female) where pathology was also present. The VEJ was 15.0 ± 6.0 mm from the ET and 17.4 ± 4.1 mm from the PPF.

Conclusion The VEJ is an excellent landmark as it defines both superior and posterior limits when isolating the ICA in skull base surgery.

received

June 15, 2017

accepted after revision

September 10, 2017

published online

November 27, 2017

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Stuttgart · New York

DOI <https://doi.org/10.1055/s-0037-1608650>.
ISSN 2193-6331.

Introduction

The increasing use of endoscopic techniques for the resection of benign or malignant sinonasal pathology of the skull base has been possible due to improved surgeon understanding and comfort with complex skull base anatomy, advances in endoscopic instrumentation, and improved skull base reconstruction strategies. Various endoscopic approaches are being used to access lesions of the petrous apex, petroclival, cavernous sinus, middle cranial fossa, and infratemporal fossa regions.^{1,2} All of these approaches demand the identification and management of the internal carotid artery (ICA), a challenging step for any skull base surgeon.

Fixed and consistent anatomic landmarks are important to locate vital structures, and this concept is particularly true with respect to the ICA. Due to its complex course and varied anatomic relationships, the ICA has previously been studied in segments (parapharyngeal, petrous, paraclival, parasellar, paraclinoid, and intradural),³ with the petrous segment consisting of the petrous vertical segment, posterior genu (first genu), horizontal segment, and anterior genu (second genu),⁴ followed by the vertical paraclival segment. The eustachian tube (ET)^{1,5–8} and vidian nerve^{1,5,9} have been identified in prior studies as landmarks to safely locate the petrous ICA endoscopically. Techniques described include drilling medially and inferiorly to the vidian nerve proceeding in a posterior direction until a fibrocartilaginous tissue is identified, which marks the attachment to the foramen lacerum and the anterior border of the second genu of the ICA.^{5,6} Moving medial to lateral along the anteroinferior border of the horizontal ICA, along with removal of the cartilaginous ET, exposes the first genu.^{5,6}

Although it has been noted that the fibrocartilaginous tissue attaching to the foramen lacerum serves as a landmark for the petrous ICA, it is the junction point of the vidian nerve and cartilaginous ET (vidian–eustachian junction [VEJ]) that is easy to follow as a surgeon. An objective analysis of the relationship of these structures from an endoscopic ap-

proach is described both in a cadaver model and through a case series of patients with central skull base pathologies.

Methods

An anatomical dissection of the VEJ and its relationship was undertaken in an approved anatomy laboratory. In addition, a retrospective case series of patients who had surgery to identify the ICA utilizing the VEJ is described. Ethics approval was obtained from the St. Vincent’s Hospital Human Research Ethics Committee (SVH09/083 [Translational Research Centre, 97–105 Boundary St, Darlinghurst, NSW 2010]). The anatomy laboratory is an approved facility for the use of human anatomical specimens.

Cadaver Specimens

Adult fresh-frozen cadaver heads were used. Data collected from the cadaver specimens included age, gender, weight, and side of dissection. Zero-degree 4 mm Karl Storz endoscopes (Karl Storz & Co., Tuttlingen, Germany) and Medtronic high-speed drills with 15-degree 5 mm diamond burr (Medtronic, Minneapolis, Minnesota, United States) were used for dissection. Images and video were captured using a Karl Storz Image 1 high-definition 3-chip camera and viewed on a 21-inch high-resolution monitor.

Surgical Patients

Consecutive skull base surgical patients from June 2015 through June 2016, in which the landmarks and VEJ described in this study were used to identify and manage the ICA, were included. The surgical technique used for these patients to identify the ICA was replicated in the cadaver dissection (described later). The pathology of each case determined if the ICA was fully exposed, from the vertical paraclival segment, to the second genu, to the horizontal petrous segment, or if only a portion was exposed. Patient pathology, location, and current status are illustrated in ►Table 1.

Table 1 Consecutive patients in which the VEJ was used to identify and manage the ICA during surgical resection of skull base tumor

	Age (y)	Pathology	Location	Current status
Patient 1	45	Chordoma	Right petrous apex	DOD
Patient 2	70	Nasopharyngeal carcinoma	Left clivus, infratemporal fossa, nasopharynx	NED
Patient 3	68	Atypical meningioma	Right sphenopetroclival, infratemporal fossa, orbital areas	DOD
Patient 4	34	Chondrosarcoma	Right petroclivus	AWD
Patient 5	64	SCC	Left infratemporal fossa	NED
Patient 6	49	Chondrosarcoma	Right petrous apex	AWD
Patient 7	52	Chondrosarcoma	Left petroclivus	AWD
Patient 8	64	Giant pituitary adenoma	Sella, suprasella, nasal cavity	NED
Patient 9	36	Meningioma	Right petroclivus	NED

Abbreviations: AWD, alive with disease; DOD, dead of disease; ICA, internal carotid artery; NED, no evidence of disease; VEJ, vidian–eustachian junction.

Fig. 1 The length of the vidian canal is shown following careful drilling along its medial and inferior borders (white arrows), beginning at its opening in the posterior PPF (black arrow). LSS, left sphenoid sinus; NP, nasopharynx; PPF, pterygopalatine fossa; RSS, right sphenoid sinus.

Surgical Dissection

A strictly endonasal endoscopic single surgeon approach was used for all cadaver dissections. A wide maxillary antrostomy and complete sphenoidectomy were performed unilaterally. This was followed by a medial maxillectomy, consisting of inferior turbinectomy and resection of the medial wall of the maxillary sinus down to the nasal floor. The posterior wall of the maxillary sinus was then removed, exposing the pterygopalatine fossa (PPF) contents, which were divided just prior to the sphenopalatine foramen and then displaced laterally. The vidian nerve was identified where it entered the PPF. The pterygoid process was drilled and the vidian nerve was followed posteriorly (► **Fig. 1**). The medial pterygoid plate and medial pterygoid muscle were resected to expose the cartilaginous portion of the ET. The point where the cartilaginous ET and vidian nerve came together identified the posterior end point of the vidian canal and the fibrocartilaginous tissue attaching to the foramen

lacerum and second genu of the ICA (► **Fig. 2**). This point is primarily a crossing of the two vectors, but the structures are generally attached by a fibrous tissue. The vertical segment of the paraclival carotid was then exposed, followed by the horizontal petrous segment drilling in a medial to lateral fashion from the second genu. The length of the ET from nasopharyngeal orifice to the VEJ was left intact. Similarly, the opening of the vidian canal into the PPF was preserved along with the connection of the vidian nerve to the VEJ. These landmarks and relationships are demonstrated in ► **Figs. 3 and 4**.

Measurements

A customized millimeter scale ruler was used with endoscopic instruments to measure the length of the ET from the nasopharyngeal orifice to the junction point with the vidian nerve at the fibrocartilaginous tissue (► **Fig. 5**). The length of the vidian nerve was then measured from the level of its entrance into the PPF to the VEJ (► **Fig. 5**). The position of the VEJ was determined with respect to the vertical paraclival segment of the ICA, with the horizontal petrous segment, and with the second genu in coronal, axial, and sagittal planes. Measurements were also taken of the position of the VEJ to the position of the second genu in the coronal, axial, and sagittal planes (► **Fig. 6**).

Statistical Analysis

Statistical analyses were performed using SPSS v22 (IBM SPSS Statistics for Windows, Version 22; Armonk, New York, United States). Descriptive data, including measurements and positioning, were represented as percentages and means $\pm$ standard deviations or median (interquartile range). Student's *t*-test (two-tailed) was used for comparison of parametric data. Chi-squared analysis and Kendall's tau-b was used for the analysis of nominal values and ordinal values, respectively. Results with a *p*-value of <0.05 were considered significant.

Results

Ten cadaver dissections (82.3 ± 6.7 years, 40% female) were performed on six total cadaver heads. Four heads were dissected bilaterally and two unilaterally (40% right side). The horizontal petrous segment of the ICA was positioned at or

Fig. 2 The left internal carotid artery and VEJ are shown. The black star marks the vertical segment of the paraclival ICA just distal to the second genu and the thin black arrow marks the vidian canal (A). The eustachian tube from nasopharyngeal orifice through its cartilaginous portion (green shading) as it tracks superolaterally toward the skull base (blue arrow) is shown (B). Both vidian nerve and eustachian tube landmarks shown together (green shading with blue arrow) as they come together at the VEJ anterior to the second genu of the ICA (C). ICA, internal carotid artery; VEJ, vidian-eustachian junction.

Fig. 3 In this cadaveric dissection, the left vidian canal is shown where it enters the PPF (A). The vidian nerve is dissected posteriorly on its medial and inferior surface, and the J curette demonstrates how the junction of the vidian nerve (B) and the cartilaginous portion of the eustachian tube (C) lies just anterior to the second genu of the ICA (D). ICA, internal carotid artery; PPF, pterygopalatine fossa.

Fig. 4 A plain (A), colored (B), and labeled (C) schematic of the relationships of the VN, ET, and ICA at the junction point (marked by curette). ET, eustachian tube; ICA, internal carotid artery; VN, vidian nerve.

Fig. 5 Measurements are taken in a cadaver specimen of the length of the eustachian tube from the nasopharyngeal orifice to the junction point with the vidian nerve at the fibrocartilaginous tissue (A). The length of the vidian nerve is measured from the VEJ to its opening at the posterior PPF (B). The vertical paracaval segment of the ICA is marked (black asterisk). ICA, internal carotid artery; PPF, pterygopalatine fossa; VEJ, vidian–eustachian junction.

Fig. 6 Demonstrations of the measurements taken in a cadaver specimen of the distance from the VEJ to the position of the second genu in the coronal (A), axial (B), and sagittal (C) planes. VEJ, vidian–eustachian junction.

behind the VEJ in 100% of cases, was above the VEJ in 100%, and was lateral to the VEJ in 80%. The vertical paraclival segment of the ICA was at or behind the VEJ in 100%, above in 100%, and medial in 100%. The second genu was at or behind the VEJ in 100% by 3.3 ± 2.4 mm, at or above in 100% by 2.5 ± 1.6 mm, and medial in 100% of cases by 3.4 ± 2.0 mm. The length of the ET from the nasopharyngeal orifice to the VEJ was 15.0 ± 0.6 mm. The length of the vidian nerve from its opening at the posterior PPF to the VEJ was 17.4 ± 4.1 mm. There was no significant difference in results based on the side of dissection.

The VEJ was successfully used to locate the ICA in nine consecutive patients (53.3 ± 13.5 years, 55.6% female) where pathology was situated in a location that required identification and management of the ICA for surgical access. None of these patients had a smoking or chronic rhinosinusitis history. Malignant skull base pathology had been diagnosed in 66.7% but with no metastases, and 55.5% had received treatment prior to presenting for endoscopic resection (33.3% surgery, 11.1% chemoradiation, and 11.1% combination of surgery and radiation). ▶**Table 1** illustrates the specific patient tumor pathology and location. There were no ICA complications in any of these patients. The vidian nerve was resected as part of the procedure in 33.3%. Twenty-two percent had neurologic sequelae (permanent sixth nerve palsy and hemiparesis in one patient and hemiparesis in the other). The expectation at the time of surgery was that a gross total resection had been performed in 55.6% of cases and a near total resection in 44.4%. Following surgical resection, adjuvant therapy was undertaken by 33.3% of patients (22.2% radiation therapy and 11.1% chemoradiation). At a median follow-up time of 7.0 (9.0) months, 22.2% ($n = 2$) were dead of disease, 33.3% ($n = 3$) were alive with disease, and 44.4% ($n = 4$) had no evidence of disease. No patient had any bleeding or vascular complications. There were no adverse effects from the vidian neurectomy, with only one patient aware of loss of emotional tearing on the side of the surgery. No dry eye symptoms were reported. The resection of the ET was uneventful. The middle ear remained ventilated and no episodes of otitis media or effusion occurred.

Discussion

The surgical approach and philosophy to the ICA should be similar to that of the facial nerve in temporal bone surgery. When close to pathology, instead of avoiding it for fear of

causing injury, it should be actively sought out and identified to ensure its safety and guide surgery in the area. Having the ICA identified in the surgical field can give the surgeon tremendous confidence in his/her orientation and maximize the chance for a complete resection.

We have shown that the vidian nerve and ET can be used in combination to consistently and safely locate the ICA. The VEJ is an accurate landmark for the surgeon, building upon excellent prior research;^{1,7,9,10} our descriptions aim to simplify the technique of locating the junction point. The horizontal and vertical segments and the second genu of the ICA are located posterior and superior to the VEJ in all cases. Therefore, this junction point acts as a fixed limit for posterior and superior dissection. Superior to this point, the medial–lateral position of the ICA is more variable; therefore, drilling should not proceed superior to the VEJ until the second genu has been identified. It can then be safely followed superiorly to expose the vertical paraclival segment of the ICA, or medial to lateral to expose the horizontal petrous segment. Resection of the cartilaginous portion of the ET, and following the line of the lateral pterygoid plate will assist in exposing the entry point of the ICA to the petrous bone at the carotid foramen (first genu).¹¹

Our findings are supported by those of Kassam et al with respect to the petrous ICA never being inferior to the vidian canal.⁹ In addition, radiographic evaluation of computed tomography scans reported a median length of the vidian canal of 18 mm.¹⁰ This is similar to our intraoperative findings of 17.4 ± 4.1 mm, although this was specifically for the nerve itself from the PPF to the VEJ rather than the canal. In addition, studies have demonstrated the use of the ET as a landmark for the ICA, even specifically naming segments of the ICA according to the corresponding segments of ET.^{5,6} However, we feel that the use of the two fixed landmarks in combination by their junction point (VEJ) is reliable and specific for the localization of the second genu and provides a guide for the progression of drilling to completion of ICA exposure according to the needs of the case. Although measurements from various landmarks based on radiographic analysis or histologic specimens have been reported in the literature, such as the foramina rotundum, ovale, spinosum, and bony–cartilaginous junction of the ET,^{7,10,12} it was felt that measurements in all three planes based on a standard endoscopic approach and perspective regularly utilized by the skull base surgeon may translate as a more useful guide.

The importance of using fixed anatomic landmarks cannot be overstated in any endoscopic skull base surgery, but this is especially true when operating around the ICA. The VEJ is a robust guide to the second genu of the petroclival ICA in both cadaver and operative anatomy. There can be surgical confidence that the horizontal and vertical segments and the second genu of the ICA will always lie posterior and superior to the VEJ. Once the second genu and subsequent vertical and horizontal segments of the ICA are identified and exposed based on the needs of the case, the surgeon can progress to quicker and safer dissection of central skull base pathology.

Note

This study was presented as a poster at the American Rhinologic Society Fall Meeting, San Diego, CA, September 17, 2016.

Financial Disclosures

Gretchen M. Oakley is a consultant with Stryker. Richard J. Harvey is a consultant with Medtronic, Olympus, and NeilMed, Advisory Board for Seqiris and has received grant support from ENTtec, Stallergenes, and NeilMed. Raymond Sacks is a previous and Arturo Solares a current consultant with Medtronic. Charles Teo is a consultant for Aesculap.

Conflict of Interest

Dr. Harvey reports personal fees from Medtronic, Olympus, NeilMed, Seqiris, Teva, and Astrazeneca, outside the submitted work. Dr. Sacks reports personal fees from Medtronic, outside the submitted work. All other authors report no conflict of interest.

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