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Clinical implications of the anatomical relationships of the pterygopalatine fossa and Vidian canal: an endonasal endoscopic cadaveric study

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Abstract

Objectives: The aim of our study was to describe a surgical access to pterygopalatine fossa and Vidian canal using an endonasal endoscopic approach. We also intend to reveal the anatomical relations of the neurovascular structures in the surgical corridors and to determine the relationships between previously defined reference points in order to prevent surgical complications during surgical access to these regions.

Methods: Our study was carried out between October-December 2016 in Cerrahpaşa Faculty of Medicine Microneurosurgery and Neuroanatomy Laboratory. A total of 7 silicon dye-injected cadavers (4 males and 3 females) were studied. 3D images were obtained by photographing the approaches applied to the pterygopalatine fossa and Vidian canal and related anatomical structures.

Results: We succeeded in exposing and examining the pterygopalatine fossa and Vidian canal endoscopically in all samples. First, the posterior wall of the maxillary sinus was opened to reach the pterygopalatine fossa. The pterygopalatine fossa was divided into 3 anatomical compartments. The first layer encountered was the periosteum covering the pterygopalatine fossa. After removing the periosteum, the fat layer was revealed. Under the fat layer, the vascular compartment and finally the neural compartment were encountered.

Conclusion: Our study revealed three-dimensional anatomical data related to the surgical margins involved in approaches to the pterygopalatine fossa and Vidian canal; and specifically defined various neurovascular structures encountered in these approaches. Our study provides information to decrease potential complications that may develop during endonasal endoscopic surgery. We conclude that as the anatomy of the pterygopalatine fossa and Vidian canal is known in details, the endonasal endoscopic approach is likely to become the standard method to access lesions in these regions.

Keywords: endonasal endoscopic surgery; pterygopalatine fossa; Vidian canal

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Introduction

Endoscopic endonasal approaches were initially used to treat only sellar lesions, particularly pituitary gland tumors.[1–6] Surgical approaches to midline pathologies, which are the most common among skull base lesions, can be applied by neurosurgeons frequently with endonasal methods. The development of endoscopic endonasal skull base approaches has increased markedly over the past 20 years compared to the traditional open approaches. However, approaching lesions of the anterior and anterolateral skull base seems to be more challenging due to the region's complex anatomy and the close relationship of its neurovascular structures.[7–10] Over time, the anatomical relationships became more understandable, so did endoscopic equipment and technological developments. The addition of neurophysiological monitoring and neuronavigation systems have brought new approaches to various lesions involving the central cranial base extending from the crista galli to the foramen magnum.[11–13]

With the expansion of endoscopic endonasal approaches (EEA), methods of access to midline pathologies and then to lateral region pathologies were developed.[14] Endoscopic approaches to the cavernous sinus, clivus, odontoid process, pterygopalatine fossa (PPF), petrous apex, and middle cranial fossa were described previously.[15–17] With these approaches, there is no need for brain retraction or neurovascular manipulation, there is early revascularization of the lesion, and there is easy access to the deeply located supradiaphragmatic, retrosellar and clival sections of the brain, which are usually particularly difficult to access.[11,13,16] Recent studies have observed that low morbidity has been achieved with endoscopic approaches in skull base surgeries and with minimally invasive methods in pterygopalatine fossa and Vidian (pterygoid) canal (VC) access.[4,17]

The PPF is a difficult area to access surgically because it is located in the deep part of the middle cranial fossa and has complex neurovascular relationships. The PPF contains the maxillary artery and its branches, maxillary nerve and its branches, pterygopalatine ganglion (PPG) and the Vidian nerve.[18–26] It connects laterally with the infratemporal fossa (ITF) via the pterygomaxillary fissure, medially with the nasal cavity via the sphenopalatine foramen, and anteriorly with the orbita via the inferior orbital fissure.[27] The location and neighborhood of the PPF and its close connections with the orbit and nasal cavity increase its clinical importance. The spread of tumors and inflammatory diseases occurring in the skull base to the middle cranial fossa is of great importance due to the structures and anatomical localization of the PPF.[8]

VC is a bony tunnel located in the skull base, anterior to the foramen lacerum, above the pterygoid processes of the sphenoid bone. This canal links the Vidian artery, vein, and nerve to the PPF.[2] The aim of our study was to describe the anatomy of the PPF and VC in details and to define surgical access to these areas using the endonasal endoscopic approach. At the same time, we aimed to reveal the anatomical relations of the neurovascular structures in the surgical corridors and to determine the relationships between previously defined reference points in order to prevent iatrogenic complications during endonasal endoscopic access to these regions.

Materials and Methods

This study was carried out between October and December 2016 in Cerrahpaşa Faculty of Medicine Microneurosurgery and Neuroanatomy Laboratory, Istanbul. A total of 7 cadaveric heads (4 males and 3 females) were dissected. Before starting the study, red and blue colored silicone was prepared and injected into the common carotid artery and internal jugular vein respectively. The injection was given with a 50-cc syringe into one side of the main vessels, with the contralateral vessels left open. Injection continued until a free flow of mixture escaped from the open vessel. The cadavers have not undergone any previous craniofacial or endonasal surgery, the integrity of the skull base was preserved, had no impaired mucosa and bony tissue and were older than 18 years old.

The cadaveric heads were first fixed on the table by giving the head 15 degrees of flexion. After the Medtronic high speed drill and aspirator were placed, the procedure was initiated. Dissections were performed under a microscope (Zeiss OPMI Pico) at 4× and 40× magnification using a microsurgery kit. A surgical drill (Medtronic Midas Rex Legend, Minneapolis, MN, USA) and an angled drill bit were used for the drilling process. When choosing AT10 and ATT12 attachments, 2-5 mm torque tip was preferred.

PPF and VC were exposed by endoscopic endonasal method using transmaxillary approach. The superior concha, the inferior border of the maxillary sinus, and the skin and subcutaneous tissue up to the malar eminence were passed superiorly, inferiorly and laterally. The nostrils were retracted preserving the nasal septum (**Figure 1**). Then, the anterior wall of the maxillary sinus was drilled superiorly from the level of the maxillary nerve. The maxillary sinus mucosa was removed. The medial wall of the maxillary sinus was elevated, preserving the inferior concha. The nasal septum was removed. The parts of the conchae other than the bone attachment sites were excised to increase surgical exploration (**Figure 2**). The posterior wall of the maxillary sinus was removed with the help of a drill and the PPF and VC were finally reached.

The skull base images of the cadavers were photographed using a macro lens camera (Canon EOS 650 D, Tokyo, Japan) and 3D shooting technique with 55-100 mm lenses. Tripod and sled were used for 3D shooting. The photos were converted into optimized anaglyph 3D photos in the computer program.

Figure 1. Dissection procedure on a cadaveric head. The external nose was removed, the bony septum was preserved. **IC:** inferior concha; **IO.N:** infraorbital nerve; **MC:** middle concha; **NS:** nasal septum.

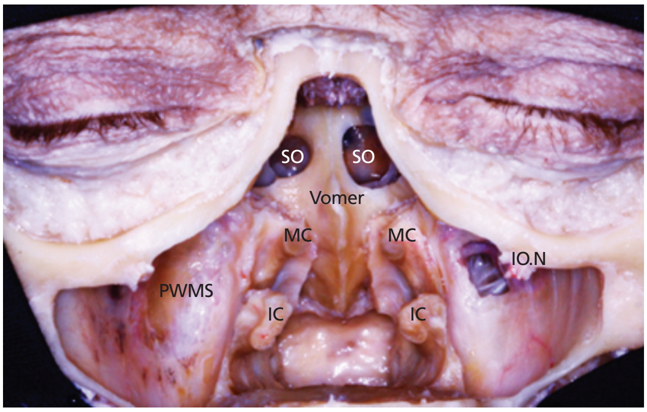

Figure 2. Further steps of dissection procedure. Anterior wall of the maxillary sinus was drilled superiorly from the level of the maxillary nerve. The maxillary sinus mucosa was removed. The medial wall of the maxillary sinus was lifted, preserving the inferior concha. The nasal septum was removed. **IC:** inferior concha; **IO.N:** infraorbital nerve; **MC:** middle concha; **PWMS:** posterior wall of the maxillary sinus; **SO:** sphenoid ostium.

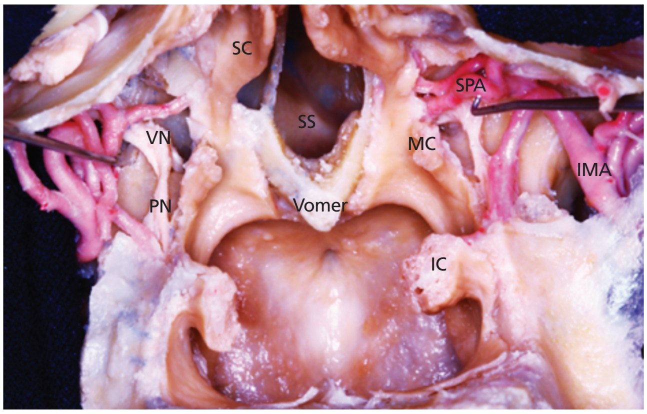

Figure 3. After removing the posterior wall of the maxillary sinus completely, the pterygopalatine ganglion and palatine nerve was exposed. **IC:** inferior concha; **IMA:** (internal) maxillary artery **MC:** middle concha; **PN:** palatine nerve; **SC:** superior concha; **SPA:** sphenopalatine artery; **SS:** sphenoid sinus; **VN:** Vidian nerve.

Results

We succeeded in exposing and examining the PPF and VC endoscopically in all samples. First, the posterior wall of the maxillary sinus was opened to reach the PPF. The PPF contained 3 anatomical compartments. The first layer encountered was the periosteum covering the PPF. After removing the periosteum, the fat layer was revealed. Under the fat layer, the vascular compartment and finally the neural compartment were encountered. In the vascular compartment layer, fat dissection exposed the arteries, including the sphenopalatine artery and descending palatine artery, which are the distal branches of the maxillary artery reaching from the ITF to the PPF through the pterygomaxillary fissure. This main branch and two terminal branches were different in each cadaver. The neural layer was encountered in the posterior part of the vascular layer and the PPG was found first in this layer. The PPG is associated with many neural structures and its relationship with the Vidian nerve entering the VC medially was noted (**Figure 3**). When the VC was followed posteriorly from the PPG, the lacerum segment of the internal carotid artery (ICA) was reached; proceeding backward from this point, it was noted as the union of greater and lesser petrosal nerves. When the greater petrosal nerve followed backwards, it was seen to merge with the geniculate ganglion. Continuing inferiorly from the PG, the greater petrosal nerve was entering the greater palatine foramen. PPG was defined as the anterolateral part of the VC, superior to the greater palatine foramen, and posterior to the sphenopalatine artery and its branches. The PPF occupied the oral cavity inferiorly, the lateral sphenoid sinus supero-medially, the nasal cavity medially, the orbital apex supero-laterally, the ITF laterally, the maxillary sinus anteriorly, and the pterygoid process posteriorly.

The most important landmark in the transpterygoid approach to the lateral skull base was the petrous segment of ICA. During drilling of the pterygoid process, the structure that would guide the surgery up to the ICA petrous segment was the Vidian nerve and the Vidian artery passing through the VC (**Figure 4**). Thus, the most important step after opening the PPF was to find the Vidian nerve. The VC was found with the “H-shape”

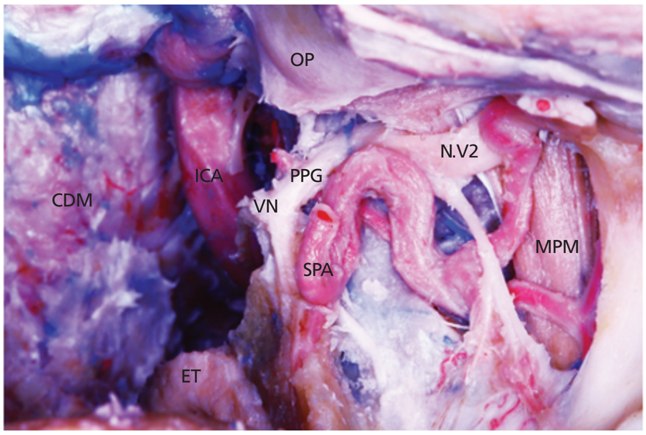

Figure 4. During drilling of the pterygoid process, the structure that guided the surgery up to the petrous segment of the internal carotid artery is the Vidian nerve and the Vidian artery passing through the Vidian canal. **CDM:** clival dura mater; **ET:** Eustachian tube; **ICA:** internal carotid artery; **MPM:** medial pterygoid muscle; **N.V2:** maxillary nerve; **OP:** orbital periosteum; **PPG:** pterygopalatine ganglion; **SPA:** sphenopalatine artery; **VN:** vidian nerve.

technique used by Kassam et al.[21] by defining the pterygoid triangle to locate the canal. At the intersection of the "H-shape", a bony triangle was exposed at the root of the pterygoid process, with its apex facing the base of the sphenoid sinus. Medially to the pterygoid triangle, the Vidian nerve was found in all cadavers and the Vidian artery in one cadaver (**Figure 5**). The areas medial and inferior to the VC were drilled posteriorly. It was observed that the VC terminated at the junction of the petrous and paraclival ICA at the level of the foramen lacerum in all cadavers. While the medial pterygoid process was drilled along the Vidian nerve trace, the lateral pterygoid process was drilled along the maxillary nerve trace. The petrous ICA was reached by drilling the medial pterygoid process, and the middle cranial fossa was reached by drilling the maxillary nerve.

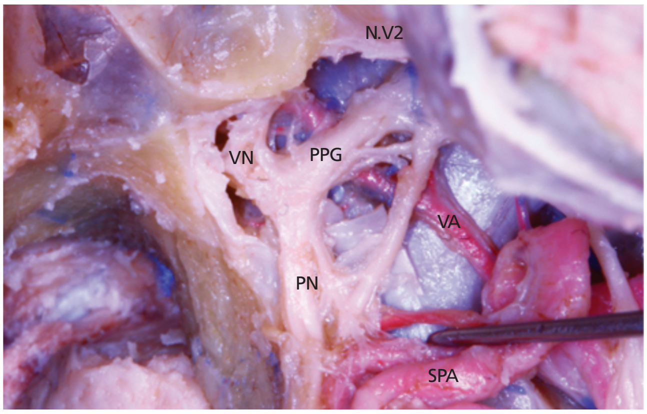

Figure 5. Medially to the pterygoid triangle, the Vidian nerve was found in all cadavers and the Vidian artery in one cadaver. **N.V2:** maxillary nerve; **PN:** palatine nerve; **PPG:** pterygopalatine ganglion; **SPA:** sphenopalatine artery; **VA:** vidian artery; **VN:** vidian nerve.

Discussion

Technological developments have defined new approaches to surgeries using endonasal skull base endoscopy. Today the endonasal techniques are used for reaching all midline lesions from the frontal sinus to the odontoid process.[15,20,21] In addition, close and high-resolution images were obtained from different angles despite narrow anatomical corridors.[13] From the patient's perspective, an important advantage to endoscopic surgery is the reduced manipulation of the brain parenchyma and neurovascular structures, which may reduce the causes of morbidity such as contusion due to tissue damage, brain edema and bleeding. Thus, faster recovery can be achieved, and hospital stay, and health care costs can be reduced.[5,9] Given these factors, the field of endoscope-based anatomy becomes an important area for research.[28–32]

The PPF is an important junction between narrow anatomical corridors containing complex neurovascular structures. Depending on the localization of the lesion, the transpterygoid approach can be applied with a combination of transmaxillary, transsphenoidal, transethmoidal and transnasal methods.[20] In approaches to this region, after reaching the maxillary sinus, if the posterior wall of the maxillary nerve medial to the infraorbital nerve is opened, the PPF is reached, and if the lateral wall of the maxillary sinus lateral to the infraorbital nerve is opened, the ITF is reached. Though few in number, endoscopic endonasal approaches to PPF have also been reported.[1,15] This region can be accessed by the central or transpalatine route with an endonasal approach.[8] Although this approach is minimally invasive and has a clear field of view, the narrow surgical corridor, the difficulty of orientation with 30 and 45 degree telescopes, and the presence of complex neurovascular structures under the adipose tissue are disadvantages of this approach. In our study, the fat layer covering the neurovascular structures was carefully dissected; at this point, knowing the anatomy and the anomalies and variations of the region will greatly benefit the surgery.

Alfieri et al.[1] described three approaches for transpterygoid surgery; *(1)* the medial transpalatine approach for reaching the medial PPF; *(2)* the middle meatal transantral approach for reaching the lateral PPF; and *(3)* the transantral approach with inferior turbinectomy for reaching the PPF and ITF. With the transpalatine approach, only the medial part of the PPF can be partially reached without opening the posterior wall of the maxillary sinus, and this approach is not applicable in skull base lesions. With the middle meatal transantral approach, a wider field of view is provided and it is possible to reach as far as the lateral infraorbital nerve. Among the described methods, the middle meatal approach is the most suitable method because it has sufficient field of view in skull base lesions and does not require resection of the inferior concha.

The PPF is a quadrangular pyramidal space extending from the ITF posteriorly to the nasal cavity anteriorly by the sphenopalatine foramen. Its surgical importance stems from its being an important junction point between different skull base regions containing complex neurovascular structures. The sphenoid bone body on the superior surface, the perpendicular lamina of the palatine bone on the medial surface, the posterior wall of the maxillary sinus on the anterior surface, the pterygoid process root on the posterior surface, and the ITF on the lateral surface of the inverted quadrangular pyramid-shaped structure. The apex of the pterygoid fossa is associated with the oral cavity. The central approach to PPF with facial incision was described in 1858 and is still applied microscopically.[18] However, in this approach, the risk of damage to the arteries and nerves of the teeth in the oral plexus is high, since the anterior and posterior maxillary walls are opened.

Since inferior turbinectomy is not performed with the middle meatal trans-central approach, phonation disorder does not develop.[22] In this method, after excision of the uncinate process and enlargement of the maxillary ostium, the ethmoid bulla and suprabullar cells are removed, the basal lamella is passed, and posterior ethmoidectomy is performed. The fovea ethmoidalis should be identified and preserved and the sphenopalatine artery should be controlled. The sphenoid sinus should then be exposed. After the maxillary sinus ostium has been enlarged, the sinus mucosa must be stripped from the posterior wall of the maxillary sinus. The posterior wall of the maxillary sinus is removed and the PPF is exposed.[30] At this point, care should be taken not to injure the greater palatine nerve in the infero-medial part of the PPF. After reaching the lateral recess of the sphenoid sinus, interventions can be applied to structures such as the cavernous sinus, Meckel cave, middle cranial fossa, petrous apex or infrapetrous according to the localization of the lesion (**Figure 1**).[12,18] A study by Prevedello et al.,[29] reported that the pterygoid process can be drilled by preserving the Vidian nerve. However, Pinherio-Neto et al.[28] reported that the Vidian nerve transposition was not sufficient for removal of the pterygoid process, and the greater descending palatine artery and greater palatine nerve had to be sacrificed. Although ipsilateral hard palate anesthesia occurs in the damage of these structures, patients can tolerate this situation. In addition, the Vidian nerve, located at the junction of the medial pterygoid process and the inferior wall of the sphenoid sinus, is an important landmark for locating the petrous ICA but can be sacrificed if necessary.[18] Furthermore, there is no proof that resection of a malignant tumor in the PPF/ITF is more efficient by an external approach than an EEA, because en-bloc resection is rarely feasible in this area and piecemeal tumor removal is not less efficient if resection is complete at the end of surgery.[19]

The VC has a close relationship with the anterior genu of the petrous ICA. Vertical part of the cavernous segment of the ICA can be reached by drilling the sphenoid corpus along the Vidian nerve.[31,32] The Vidian nerve joins the deep petrosal nerve from the ICA sympathetic trunk and enters the VC and courses together towards the PPG. This nerve, which had not previously attracted the attention of neurosurgeons, became one of the cornerstones of endoscopic surgery after Kassam.[20] Kassam et al.[21] reported the Vidian nerve to be the key anatomical point in the transpterygoid approach. In the same study, the authors suggested transpterygoid approach to be performed by drilling the VC and the canal can be found using the "H" shape method. In the light of this information, it has been determined that the Vidian nerve is an important anatomical structure in detecting the lacerum segment of the ICA. The most effective method for the preservation of the Vidian nerve has been reported as the "clock concept".[19,21] This method was applied by drilling the inferior of the VC from medial to lateral. Vidian nerve stimulates lacrimation through its parasympathetic fibers, but it is not the only nerve responsible for lacrimation. Dry eye rarely develops as a result of damage to the Vidian nerve, but when it does develop, dry eye causes complications such as keratitis. Overall the Vidian nerve should be protected if possible. In addition, especially during EEA to Meckel's cave, petrous apex, or middle cranial fossa, the Vidian nerve can be sacrificed to avoid damage to important neurovascular structures and difficulties in imaging deep structures.[31]

At this point, it should be kept in mind that corneal ulcer and ocular complications are inevitable if loss of corneal sensation due to ophtalmic nerve damage and dry eye due to Vidian nerve damage are seen together.[15] The petrous and paraclinoid segments of the ICA are an important landmarks for determining the junction of the vidian nerve and the ICA. This junction is lateral to the region where the petrous ICA passes through the foramen lacerum. For this reason, the safe surgical site is inferior to the VC.

Conclusion

Our study elucidates and explains anatomical and surgical access to the PPF and VC with the EEA. We suggest that the three-dimensional anatomical data revealed in our study may help understanding of the surgical margins of the approaches to the PPF and VC and identification of the different neurovascular structures. Detailed knowledge of these regions has outmost importance to prevent iatrogenic complications during endonasal endoscopic access to these regions.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

HK: conceptualization, data acquisition, data analysis or interpretation, drafting the manuscript, approval of the final version of the manuscript; KÇK: drafting the manuscript, critical revision of the manuscript, approval of the final version of the manuscript; ID: conceptualization, critical revision of the manuscript, approval of the final version of the manuscript.

Ethics Approval

This cadaveric study involving human participants complies with the ethical standards of the institutional and national research committee and the 1964 Declaration of Helsinki and subsequent amendments or comparable ethical standards. This study was approved by Ethics Committee of Bakırköy Mazhar Osman Mental and Neurological Diseases Training and Research Hospital (protocol 571, 06 September 2016).

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