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INTRODUCTION
The well-described endoscopic endonasal approach to the petrous apex region is still a challenge for the experienced skull base surgeon. It involves extensive drilling and dissection around the petrous, lacerum, and cavernous (paracaval) segments of the internal carotid artery (ICA). The vidian nerve has been previously described, and it is the main reference to the anterior genu of the horizontal segment of the petrous ICA and lacerum ICA.1

Although the vidian nerve has proven to be a consistent anatomical landmark, following it proximally by drilling the vidian canal until the lacerum ICA is time consuming and poses high risk of nerve damage. This is particularly evident when operating on patients with poor sphenoid sinus pneumatization2 or when dealing with distorted-anatomy secondary tumor displacement or previous surgery.

The surgical experience led us to identify the usefulness of another constant landmark to the lacerum ICA, the pharyngobasilar fascia (PBF). Used solely or in combination with other landmarks, the PBF is very helpful for reducing time and increasing the accuracy in the localization of the lacerum ICA.

METHODS
Three cadaveric specimens (six sides), without obvious intracranial disease, fixed in formalin and perfused with colored silicone, were dissected at the ALT-VISION Skull Base Laboratory of The Ohio State University. Before dissection, the specimens were rigidly fixed in a Mayfield head-holder recreating the surgical positioning. The standard endoscopic endonasal transsphenoidal approach to the petrous apex region was done. The procedures were performed using standard endoscopic and powered instruments, and rod lens endoscope (4 mm, 18 cm, 0° Hopkins II; Karl Storz Endoscopy, Tuttingen, Germany) attached to a high definition camera for visualization.

The anatomical landmarks were identified, and still images were captured and recorded using an AIDA digital video recorder system (Karl Storz Endoscopy) for further qualitative analysis. The clinical application and anatomical relationships were reproduced in vivo as shown with the illustrative case.

RESULTS
Anatomical Considerations of the PBF
The PBF or pharyngeal aponeurosis is a dense thickening of the submucosa, a ridge membrane, originating at the pharyngeal tubercle. The superior pharyngeal constrictor muscle provides fibers and is the inferior limit of the PBF. Hence, the PBF serves as the skull base attachment for the superior pharyngeal constrictor muscle. Superiortly, the PBF is attached to the pharyngeal raphe, the occipital bone, and the petrous portion of the temporal bone. At this location, above the superior pharyngeal constrictors muscle, the PBF has also the role of maintaining the patency of the nasopharynx lumen.

The PBF runs lateral and anterior to the longus capitis muscle. It extends from the posterior hamulus of the medial pterygoid plate to the petrous temporal bone anterior to the carotid foramina, dividing the superficial mucosal and deep fascial spaces (Fig. 1). The PBF is deficient ventrally, at the sinus of Morgagni, allowing passage of the cartilaginous ET and levator veli palatini muscle.3,4

Triangulation Technique
The endoscopic endonasal approach to the petrous apex region and the creation of the mucosal nasal septal flap have been extensively described in the literature.5–7
In brief, the exposure is initiated with a middle turbinectomy, harvesting of a contralateral mucosal nasal septal flap, posterior septectomy, wide bilateral sphenoidotomies, and posterior ethmoidectomies. Next, the sphenopalatine artery is isolated, ligated, and cut at the level of the sphenopalatine foramen to allow subsequent lateralization of the pterygopalatine fossa contents and identification of the medial pterygoid wedge.1

Once the initial exposure is done, it is crucial to identify the PBF, vidian nerve, and eustachian tube (ET). The PBF, as described above, has an oblique trajectory from the pharyngeal crest (anterior–medial–inferior) to the petrosal part of the temporal bone (posterior–lateral–superior).3 Its identification starts by dissecting the nasopharyngeal mucosa downward toward the clivus and exposing the bone of the inferior aspect of the sphenoid rostrum, just above the choanal arch. Drilling the sphenoid rostrum and the floor of the sphenoid sinus will lead to the exposure of the PBF. The dissection of the fibroconnective tissue attaching the PBF to the foramen lacerum should progress in a posterior–lateral–superior direction until identification of the inferior aspect of the lacerum ICA.

The vidian nerve and artery bundle may be identified in the vidian canal along the base of the pterygoid plates. The vidian canal opens anteriorly into the pterygopalatine fossa, and it is usually located at the insertion of the medial pterygoid plate on the pterygoid process of
the sphenoid bone. The vidian canal can be found by following the sphenoid floor from a medial to lateral direction. Intraoperative image guidance is helpful to confirm the location of the vidian canal (Fig. 2) that frequently is mistaken by the palatovaginal canal.

From an endoscopic endonasal perspective, the ET is oriented obliquely from posterior–lateral–superior position proximally to an anterior–medial–inferior position distally. Anteriorly, its cartilaginous portion and torus tubarius are inserted in the posterior border of the medial pterygoid process. Posteriorly, the cartilaginous ET is attached to the clivus and foramen lacerum (Figs. 2 and 3).

The triangulation technique consists in identifying these three anatomical landmarks (PBF, vidian nerve, and cartilaginous ET) and understanding that they form a three-sided pyramid, with the vertex at the lacerum foramen/ICA fibrocartilaginous tissue (Figs. 2 and 3). Hence, drilling of the bone located between the inferior–medial aspect of the vidian nerve, the superior aspect of the cartilaginous ET, and the superior–lateral aspect of the PBF may be done aggressively and safely. As the drilling progresses posteriorly, and the bone within this

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**Fig. 2.** (A) Endoscopic endonasal anatomical dissection of the ventral skull base after removal of the sphenoid rostrum and posterior wall of the right maxillary sinus. The relationships of the right side pterygopalatine fossa, medial pterygoid plate, eustachian tube, choanal arch, and sphenoid sinus may be appreciated. (B) Initial dissection of the pharyngobasilar fascia and its anatomical relationships with the vidian canal and eustachian tube. (C) Anatomical exposure after partial drilling of the right pterygoid wedge and increased exposure of the pharyngobasilar fascia. (D) Anatomy after complete bone removal of the region of interest showing the convergence point (red circle) of the pharyngobasilar fascia, vidian nerve, and the attachment of the eustachian tube at the lacerum foramen. CA = choanal arch; ET = eustachian tube; ICA = internal carotid artery; IT = inferior turbinate; MPP = medial pterygoid plate; PBF = pharyngobasilar fascia; pc.ICA = paracalveal internal carotid artery; PPF = pterygopalatine fossa; PW = pterygoid wedge; SS = sphenoid sinus; vid.C = vidian canal; vid.N = vidian nerve.

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**Fig. 3.** Panoramic view of the ventral skull base showing the pharyngobasilar fascia (yellow), vidian nerve (blue), and the attachment of the eustachian tube (green) converging to the lacerum foramen (red circle). cav.ICA = cavernous internal carotid artery; ET = eustachian tube; IT = inferior turbinate; PBF = pharyngobasilar fascia; pc.ICA = paracalveal internal carotid artery; PPF = pterygopalatine fossa; SS = sphenoid sinus; vid.N = vidian nerve.
three-sided pyramid reduces, it means we are closer to the apex of the pyramid, and drilling should be performed more carefully due to the proximity to the lacerum ICA. It is important not to exceed superiority the inferior margin of the vidian nerve to avoid the ICA.10

Given the fact that the vidian artery always inserts along the lower margin of the transition curve between the petrous/lacerum ICA to the cavernous/paraclival ICA, the inferior–medial aspect of the vidian canal is a safe zone for drilling.1 Once the bone within the triangular pyramid is removed, the lacerum ICA can be easily identified and the superior lateral and/or superior medial bone overlying the paraclival ICA may be drilled in a sequential fashion, depending on the ultimate surgical goal and origin/anatomical constraints of the pathological entity at hand.7

Case Illustration

A 32-year-old female patient presented to the James Comprehensive Skull Base and Pituitary Center for consultation related to a history of nasal congestion and difficulties breathing. Her past medical and surgical histories were significant for previous adenoidectomy and sinonasal inverted papilloma resection. Physical examination and neurological exam were unremarkable with no cranial nerve deficits.

Investigation with computed tomography (CT) and magnetic resonance imaging showed the presence of two lesions. One lesion located in the right maxillary sinus was suggestive of sinonasal polyposis blocking the nasal passage.

The second lesion, located at the right petrous apex/ petroclival region, was hyperintense in T2-weighted images, iso/hypointense on T1-weighted images, and heterogeneous contrast enhancement. Head CT showed skull base bone erosion. Those findings were suggestive of chondrosarcoma, and surgical resection was indicated (Fig. 4).

The patient underwent a right endoscopic endonasal transpterygoid approach for tumor resection as described above. The PBF was used as the main landmark, and the triangulation technique was used to safely identify the

Fig. 4. Preoperative magnetic resonance imaging. (A) Axial T1W with contrast image. (B) Coronal T1W with contrast image. (C) Sagittal T1W with contrast image. (D) Axial T2W image. T1W = T1 weighted; T2W = T2 weighted.
lacerum ICA (Fig. 5). The localization and control of the ICA were essential in this surgery. Additional paraclival ICA exposure and extension of the approach to the petrous apex were performed, making it possible to achieve a gross total tumor resection.

The postoperative course was uneventful, and final pathology confirmed chondrosarcoma grade 2/3. The patient was seen in clinic neurologically intact and with no complaints. Despite the complete tumor resection, we recommended proton beam radiation therapy due to the natural history of chondrosarcomas grade 2/3. Last follow-up at 10 months after surgery showed no signs of tumor recurrence (Fig. 6).

**DISCUSSION**

Our experience with the expanded endoscopic endonasal approach (EEA) through the pterygopalatine fossa has shown that the PBF is consistently identified intraoperatively during the detachment and downward reflection of the posterior nasopharyngeal mucosa, as a firm fibrous tissue that fuses laterally to the lacerum foramen and lacerum ICA. Likewise, the relationships between the PBF, the vidian nerve, and the cartilaginous ET have also been consistent. These findings are corroborated in our cadaveric dissections.

Numerous radiological and in cadaveric studies have demonstrated the variability of the vidian nerve trajectory in its course from the pterygopalatine fossa posteriorly to the foramen lacerum. Although not frequent, it increases the challenge for the skull base surgeons of an already complex procedure. In addition, having more than one landmark or anatomical reference has the potential to improve safety, especially with the lack of depth perception generated by the two-dimensional view of the endoscope.
CONCLUSION
We have been using the triangulation technique in the EEA to the middle clivus and petrous apex region, and found that it improved the safety of ICA dissection and reduced the time of this surgical step. Of note, the EEA to the petrous apex and infrapetrous region are not anatomically obvious and commonly used surgical corridors. It does require familiarity and experience with the ventral skull base anatomy and commonly used endoscopic approaches to the ventral skull base.

BIBLIOGRAPHY

Fig. 6. Postoperative images. (A) Axial T1W with contrast image. (B) Coronal T1W with contrast image. (C) Axial computed tomography bone window. (D) Axial T2W image. T1W = T1 weighted; T2W = T2 weighted.