

# Endoscopic Endonasal Surgical Approach to the Oculomotor Trigone from the Cavernous Sinus

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## Abstract

Knowledge of anatomy visualized endoscopically is necessary to perform endoscopic surgical procedures safely. The cavernous sinuses are complicated structures with major blood vessels and nerves seated deeply in the center of the skull base. Anatomical orientation during surgery is essential for deep and narrow skull base surgery. While performing surgery involving the cavernous sinuses, understanding of the structures identifiable via a transsphenoidal view can allow comprehension of the relationship between a lesion and the surrounding structures, thus preventing intraoperative complications. The objective of this study was to dissect the neurovascular structures in the cavernous sinus deeply inside the oculomotor trigone through a transsphenoidal view, and to determine the relationships among anatomical landmarks in the path of surgery. Ten fresh silicone-injected cadaveric heads were evaluated. Four millimeter-diameter rigid endoscopes with 0° and 30° rod-lenses were utilized to perform an endonasal transsphenoidal approach. The detailed position and course of the major components in each cavernous sinus were assessed under panoramic view. We also validated the utility of this approach by successfully excising a huge pituitary adenoma.

Key words: cavernous sinus, oculomotor trigone, endoscopic anatomy, fresh cadaveric specimens

## Introduction

Endoscopic skull base surgery has transcended the limits of conventional transsphenoidal surgery and been utilized for reaching challenging lesions in the cavernous sinus.<sup>1)</sup> The cavernous sinuses are complicated venous structures that include various important neurovascular structures, including the oculomotor, trochlear, ophthalmic, and maxillary nerves in their walls, and the internal carotid artery (ICA) and abducens nerve within the cavernous sinuses themselves.<sup>2)</sup> Injury to these structures can lead to severe neurovascular complications and even to death. Recent advances in endoscopic instruments and navigational systems have allowed greater access to this deep surgical field. Because of the risk of additional injury, however, unnecessary extensions of surgical procedures should be avoided. Moreover, despite preoperative imaging, deformities in surrounding structures may limit the surgeon's ability to determine the correct target location or direction. Thus, basic knowledge of the

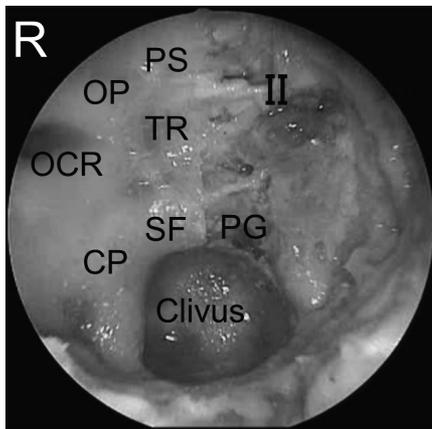
normal anatomical orientation in an endoscopic transsphenoidal view of the cavernous sinus is fundamental to avoid unacceptable complications.

The oculomotor nerve enters the roof of the cavernous sinus through a triangular dural patch called the oculomotor trigone, which is formed by the anterior petroclinoid fold, posterior petroclinoid fold, and interclinoid fold.<sup>3)</sup> This is one of the deepest and most challenging parts of the cavernous sinus when approached transsphenoidally. Using fresh cadaveric specimens, we have assessed the surgical anatomy of the route to the oculomotor trigone via the cavernous sinus using an endonasal endoscopic route. We also show the utility of our findings in removing a huge pituitary adenoma from a patient.

## Materials and Methods

Ten fresh adult cadaveric heads were anatomically dissected in the Laboratory of Microsurgical and Endoscopic Anatomy of the Medical University of Vienna. The common carotid artery of each specimen was isolated and cannulated with flexible tubing, and

the arterial system injected with red silicone. The specimens were positioned on the dissecting table to simulate the position they would be in during surgery, and a rod lens endoscope (4-mm-diameter, 18 cm long, rigid endoscope with 0° and 30° rod-lenses; Karl Storz GmbH, Tuttlingen, Germany) was used to examine each one via a direct endonasal trans-sphenoidal approach. The endoscope was attached to a light source through a fiberoptic cable and to a high definition (HD) camera with a control unit to allow visualization on an HD wide flat screen (two million pixels). An AIDA compact HD System (Karl Storz) was used to record the images. The



**Fig. 1** Endoscopic view of the posterior wall of the sphenoid sinus and bony landmarks on the right side and exposed medial wall of the cavernous sinus around the intracranial ICA on the left side. CP: carotid prominence, ICA: internal carotid artery, OCR: optocarotid recess, OP: optic prominence, PG: pituitary gland, PS: planum sphenoidale, SF: sellar floor, TR: tuberculum recess, II: optic nerve.

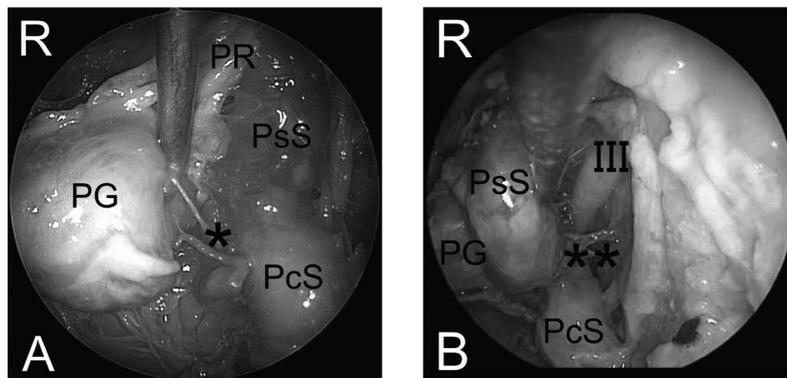
endoscope was used to view each specimen via an expanded endonasal approach in a stepwise manner and via a cavernous sinus approach.

## Results

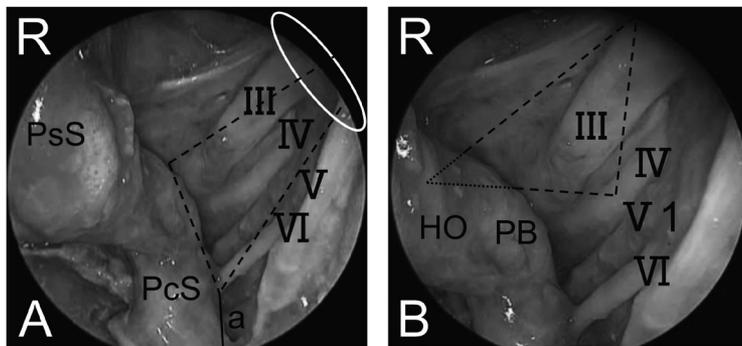
The sphenoid ostium was identified through the neuroendoscope, after which a nasoseptal flap was created<sup>4)</sup> and bilateral sphenoidotomies was performed to expose the sphenoid sinus widely. The posterior wall of the sphenoid sinus was exposed by removing the intersinus sphenoid septums and key bony structures as anatomical landmarks were identified (Fig. 1). The bony walls were removed using a high-speed drill and Kerrison punch (Fig. 1) and the periosteum and connective tissue covering the ICA revealed. In well pneumatized cases, the course of the ICA could be identified by the shape of the carotid prominences.

The covering tissues and medial wall of the cavernous sinus were then dissected, exposing the ICA, which divides into parasellar and paraclival segments<sup>5)</sup> (Fig. 2A, B), and its branches. In all of our cadaver heads, the artery of the inferior cavernous sinus runs from the horizontal segment to the lateral side, and the meningo-hypophyseal trunk and its three branches arise on the medial side of the posterior bend (Fig. 2A, B). The distal border of the intracavernous ICA is the distal dural ring (Pernecky's ring).<sup>6)</sup>

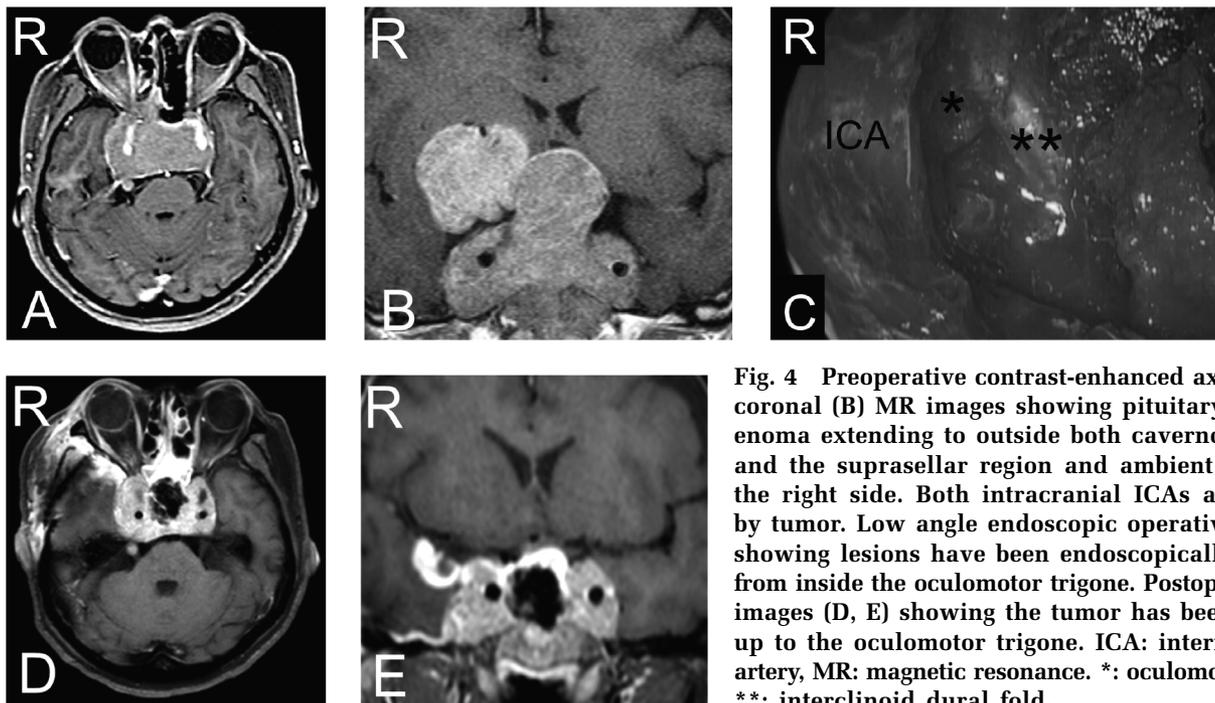
Additional dissection was then performed to reveal the oculomotor and abducent nerves lying close to the ICA, whereas the trochlear, ophthalmic, and maxillary nerves are on the outer side of the lateral wall of the cavernous sinus (Figs. 2B, 3A, B). As a landmark for the oculomotor trigone, the abducent



**Fig. 2** A: Endoscopic view of the medial side of the intracavernous ICA. B: Endoscopic view of the lateral side of the intracavernous ICA. ICA: internal carotid artery, PcS: paraclival segment of the ICA, PG: pituitary gland, PR: Pernecky's ring (this dural ring being the distal border of the intracavernous ICA), PsS: parasellar segment of the ICA, III: oculomotor nerve. \*: meningo-hypophyseal trunk (MHT) and its branches, \*\*: artery of the inferior cavernous sinus.



**Fig. 3** A: Endoscopic intracavernous sinus view showing course of cranial nerves and neurovascular relationships. B: Close-up endoscopic view around the entry point of oculomotor nerve into the cavernous sinus. a: distance between abducens nerve and lower limit of the lacerum segment, Circle: superior orbital fissure (SOF), HO: horizontal segment of intracavernous internal carotid artery (ICA), PB: posterior bend of intracavernous ICA, PcS: paraclival segment of the ICA, PsS: parasellar segment of the ICA. IV: trochlear nerve, V: trigeminal nerve, V1: ophthalmic nerve, VI: abducens nerve.



**Fig. 4** Preoperative contrast-enhanced axial (A) and coronal (B) MR images showing pituitary macroadenoma extending to outside both cavernous sinuses and the suprasellar region and ambient cistern on the right side. Both intracranial ICAs are encased by tumor. Low angle endoscopic operative view (C) showing lesions have been endoscopically removed from inside the oculomotor trigone. Postoperative MR images (D, E) showing the tumor has been removed up to the oculomotor trigone. ICA: internal carotid artery, MR: magnetic resonance. \*: oculomotor trigone, \*\*: interclinoid dural fold.

nerve, which travels in the innermost layer behind the paraclival segment of the ICA to the superior orbital fissure,<sup>7)</sup> is an important structure. The abducent nerve attaches to the posterior vertical segment of the ICA. Its mean distance above the lower limit of the lacerum segment is 13.2 mm ( $\pm$  0.8) at 20 part in 10 cadaver heads (Fig. 3A, a). The abducent nerve contributes to forming the triangular area defined by the abducent nerve, oculomotor nerve, and posterior vertical segment of the ICA, which leads to the oculomotor trigone (Fig. 3A).

With medialization of the ICA, the entry point of the oculomotor nerve was observed near the posterior superior edge of the cavernous sinus where it is the most distant location in a transnasal endoscopic view. Then the oculomotor trigone was exposed, which was identified by interclinoid fold and two borderlines between the roof of the cavernous

sinus and posterior or lateral wall of the cavernous sinus (Fig. 3B).

In addition, we here present a case of a huge pituitary adenoma that illustrates the benefits of our findings. A 43-year-old woman presented with progressive visual field disturbance for 6 months. On admission, lethargy, logorrhea, and mild left hemiparesis were evident. Preoperative ophthalmologic evaluation revealed visual loss and visual field disturbance, including central scotoma and inferior hemianopsia, in the right field and temporal hemianopsia in the left field. Magnetic resonance imaging showed a huge pituitary tumor extending to the right prepontine and ambient cisterns through the oculomotor trigone (Fig. 4A, B). Endocrinological testing showed high concentrations of prolactin (23.4 ng/mL; normal 3.4–19.4 ng/mL) and follicle stimulating hormone (60.9 mIU/mL; normal 5.0–20.8 mIU/mL),

and low concentrations of luteinizing hormone (< 0.1 mIU/mL; normal 9.1–74.2 mIU/mL), growth hormone (0.04 ng/mL; normal 0.28–1.64 ng/mL), and insulin-like growth factor-1 (91 ng/mL; median 147 ng/mL). All other serum hormone concentrations were normal. After verifying the anatomy endoscopically, synchronous surgery, consisting of a combination of microscopic transcranial and endoscopic transnasal surgery, was performed to improve her neuropsychiatric state and decompress the cranial nerves. The tumor, which filled the sphenoid and cavernous sinuses, was removed with endoscopic transnasal surgery followed by transcranial surgery (Fig. 4C–E). Then, the oculomotor trigone was revealed, which was identified by interclinoid fold and the roof and walls of cavernous sinus. The thinned optic and oculomotor nerves were preserved and decompressed. The sphenoid sinus wall was reconstructed with fat, fibrin glue, and a nasoseptal flap. The patient had diabetes insipidus, panhypopituitarism, and right ptosis postoperatively. These changes had started to resolve by 6 months postoperatively and her preoperative symptoms had also improved.

## Discussion

Endoscopic exposure of the sphenoid sinus was first described in 1997.<sup>8)</sup> As endoscopes, surgical instruments, and supportive devices have developed, the indications for endoscopic surgery have expanded to include parasellar lesions previously treated by microscopic surgery. An important advantage of the endoscopic endonasal technique is that, compared with traditional transcranial approaches, it provides direct, minimally invasive access to the cavernous sinus.<sup>9–12)</sup> Endoscopic angled vision provides better visualization than microscopic surgery for approaching structures on the lateral side, including the cavernous sinus.<sup>13,14)</sup> Furthermore, use of a closed panoramic view allows excellent visualization of the narrow operative field in the cavernous sinus.

Although the endoscopic anatomy of different parts of the cavernous sinus has previously been reported,<sup>15,16)</sup> in view of the above considerations we believed it was necessary to further explore the endoscopic surgical anatomy of this region. We, therefore, systematically dissected the cavernous sinuses of 10 cadavers and ascertained the relationships between the complicated neurovascular structures in this sinus and the oculomotor trigone through an endoscopic view.

The information we obtained by our dissections included observation around the entry point of the oculomotor nerve in the cavernous sinus through the endoscope. Posteriorly and laterally, we visualized

narrow spaces limited by the posterior petroclinoid fold and posterior wall of the cavernous sinus and by the closely adjacent trochlear nerve and lateral wall of the cavernous sinus. The medial space leading to the dura mater covering the pituitary gland and clivus behind the genu of the ICA was relatively wide. These findings made it possible to reach areas inside the oculomotor trigone in the cavernous sinus via a medial approach, as illustrated by our case whose ICA was lateralized by tumor. Meanwhile, approaching there, lateral route via outside of the ICA was recommended in cadaver heads. Although the intracavernous ICA does indeed take a basically S-shape course,<sup>2,17)</sup> this space may be limited by the convex curve of the posterior bend, which we found varied from case to case.

Cavernous sinus tumors have previously been excised by endoscopic surgery.<sup>18,19)</sup> Our anatomical evaluation may be useful for treatment of parasellar neoplasms that have infiltrated the cavernous sinus. Our anatomical findings enabled us to safely remove a huge pituitary adenoma that had invaded the cavernous sinus behind of the oculomotor trigone.

While narrow operative field may avoid bleeding from and injury to normal structures, it results in more blind working space. The larger the space occupied by a lesion, the wider the working space and operative view would become. The invasive lesions compress normal anatomical structures in the cavernous sinus, thus changing the relationships between landmarks. Appropriate decisions about the safest surgical procedure require preoperative radiological assessment to determine the structural relationships in the cavernous sinus. The anatomic information presented here may be useful in assisting recognition of the radiologically invisible structures in the cavernous sinus. Knowledge of endoscopically visualized neurovascular structures in the operative field may prevent unnecessary mortality and morbidity.

## Conflicts of Interest Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices used in this study.

## References

- 1) Cappabianca P, Cavallo LM, Esposito F, De Divitiis O, Messina A, De Divitiis E: Extended endoscopic endonasal approach to the midline skull base: the evolving role of transsphenoidal surgery. *Adv Tech Stand Neurosurg* 33: 151–199, 2008
- 2) Inoue T, Rhoton AL, Theele D, Barry ME: Surgical

- approaches to the cavernous sinus: a microsurgical study. *Neurosurgery* 26: 903–932, 1990
- 3) Harris FS, Rhoton AL: Anatomy of the cavernous sinus. A microsurgical study. *J Neurosurg* 45: 169–180, 1976
  - 4) Kassam AB, Thomas A, Carrau RL, Snyderman CH, Vescan A, Prevedello D, Mintz A, Gardner P: Endoscopic reconstruction of the cranial base using a pedicled nasoseptal flap. *Neurosurgery* 63(Suppl 1): ONS44–ONS52; discussion ONS52–ONS53, 2008
  - 5) Alfieri A, Jho HD: Endoscopic endonasal cavernous sinus surgery: an anatomic study. *Neurosurgery* 48: 827–836; discussion 836–837, 2001
  - 6) Day JD, Tschabitscher M: Microsurgical dissection of the cranial base, chapter 2, in: *Neurosurgical Dissection of the Cranial Base*, ed 1. London, Churchill Livingstone, 1996, pp 39–42
  - 7) Barges-Coll J, Fernandez-Miranda JC, Prevedello DM, Gardner P, Morera V, Madhok R, Carrau RL, Snyderman CH, Rhoton AL, Kassam AB: Avoiding injury to the abducens nerve during expanded endonasal endoscopic surgery: anatomic and clinical case studies. *Neurosurgery* 67: 144–154; discussion 154, 2010
  - 8) Yaniv E, Rappaport ZH: Endoscopic transseptal transsphenoidal surgery for pituitary tumors. *Neurosurgery* 40: 944–946, 1997
  - 9) Cavallo LM, Cappabianca P, Galzio R, Iaconetta G, de Divitiis E, Tschabitscher M: Endoscopic transnasal approach to the cavernous sinus versus transcranial route: anatomic study. *Neurosurgery* 56(2 Suppl): 379–389; discussion 379–389, 2005
  - 10) Cook SW, Smith Z, Kelly DF: Endonasal transsphenoidal removal of tuberculum sellae meningiomas: technical note. *Neurosurgery* 55: 239–244; discussion 244–246, 2004
  - 11) de Divitiis E, Cappabianca P, Cavallo LM: Endoscopic transsphenoidal approach: adaptability of the procedure to different sellar lesions. *Neurosurgery* 51: 699–705; discussion 705–707, 2002
  - 12) de Divitiis O, Conti A, Angileri FF, Cardali S, La Torre D, Tschabitscher M: Endoscopic transoral-transclival approach to the brainstem and surrounding cisternal space: anatomic study. *Neurosurgery* 54: 125–130; discussion 130, 2004
  - 13) Catapano D, Sloffer CA, Frank G, Pasquini E, D'Angelo VA, Lanzino G: Comparison between the microscope and endoscope in the direct endonasal extended transsphenoidal approach: anatomical study. *J Neurosurg* 104: 419–425, 2006
  - 14) Lanzino G, Laws ER: Pioneers in the development of transsphenoidal surgery: Theodor Kocher, Oskar Hirsch, and Norman Dott. *J Neurosurg* 95: 1097–1103, 2001
  - 15) Couldwell WT, Sabit I, Weiss MH, Giannotta SL, Rice D: Transmaxillary approach to the anterior cavernous sinus: a microanatomic study. *Neurosurgery* 40: 1307–1311, 1997
  - 16) Komatsu F, Komatsu M, Inoue T, Tschabitscher M: Endoscopic supraorbital extradural approach to the cavernous sinus: a cadaver study. *J Neurosurg* 114: 1331–1337, 2011
  - 17) Fortes FS, Pinheiro-Neto CD, Carrau RL, Brito RV, Prevedello DM, Sennes LU: Endonasal endoscopic exposure of the internal carotid artery: an anatomical study. *Laryngoscope* 122: 445–451, 2012
  - 18) Ceylan S, Koc K, Anik I: Endoscopic endonasal transsphenoidal approach for pituitary adenomas invading the cavernous sinus. *J Neurosurg* 112: 99–107, 2010
  - 19) Zhao B, Wei YK, Li GL, Li YN, Yao Y, Kang J, Ma WB, Yang Y, Wang RZ: Extended transsphenoidal approach for pituitary adenomas invading the anterior cranial base, cavernous sinus, and clivus: a single-center experience with 126 consecutive cases. *J Neurosurg* 112: 108–117, 2010

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