Endonasal Endoscopic Approaches to the Paramedian Skull Base

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Key words

- Endoscopy
- Endonasal approach
- Infratemporal fossa
- Middle cranial fossa
- Posterior fossa
- Pterygopalatine fossa
- Skull base

Abbreviations and Acronyms

CN: Cranial nerve
CSF: Cerebrospinal fluid
EEA: Endoscopic endonasal approach
ET: Eustachian tube
ICA: Internal carotid artery
V2: Second branch of the trigeminal nerve
V3: Third branch of the trigeminal nerve

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OBJECTIVE: **To describe the technical and anatomic nuances related to endoscopic endonasal approaches (EEAs) to the paramedian skull base.**

METHODS: **Surgical indications, limitations, and technical aspects pertaining to EEAs designed to access areas oriented in the coronal plane are systematically reviewed with special attention to caveats, pitfalls, and common complications and how to avoid them. Case examples are presented.**

RESULTS: **The paramedian skull base may be divided into anterior (corresponding to the orbit and its contents), middle (corresponding to the middle cranial, pterygopalatine, and infratemporal fossae), and posterior (includes the craniovertebral junction lateral to the occipital condyles and the jugular foramen) segments. EEAs to the anterior segment offer access to the intraconal orbital space and the optic canal. A transpterygoid corridor typically precedes EEAs to the middle and posterior paramedian approaches. EEAs to the middle segment provide wide exposure of the petrous apex, middle cranial fossa (including cavernous sinus and Meckel cave), and infratemporal and pterygopalatine fossae. Finally, EEAs to the posterior segment access the hypoglossal canal, occipital condyle, and jugular foramen.**

CONCLUSIONS: **Approaches to the paramedian skull base are the most challenging and complex of all endoscopic endonasal techniques. Because of their technical complexity, it is recommended that surgeons master endoscopic endonasal anatomic approaches oriented to median structures (sagittal plane) before approaching paramedian (coronal plane) pathologies.**

INTRODUCTION

Endoscopic endonasal approaches (EEAs) have become a feasible option for the management of benign and malignant cranial base pathologies, bringing a new perspective to the treatment of skull base disorders (1, 10). Expanded endoscopic approaches can be classified according to the orientation of the surgical field (target area) under 2 main categories: 1) approaches to the median skull base (access to structures in the sagittal plane) and 2) approaches to the paramedian skull base (access to more lateral structures, located in the coronal plane) (5, 9, 12).

Traditionally, middle and posterior cranial fossa pathologies have been treated through lateral routes, such as transpterional, transpetrosal (anterior and posterior), and retrosigmoid/far lateral approaches. These approaches are well established, and they are effective in well-selected patients, especially in patients whose lesions extend to the lateral aspect of the middle and posterior fossae. However, when lateral approaches are used for lateral lesions that extend medially to the ventral brainstem, they may require undesirable manipulation and retraction of neural tissue (16). Under these circumstances, paramedian EEAs can be a great alternative to avoid neural tissue and vascular retraction (10, 20).

Modular EEAs are defined based on the anatomy of the corridor and their target areas and their relationship with critical structures. In the coronal plane, the most critical and defining structure is the internal carotid artery (ICA). The ICA can be divided into segments that have their own distinct landmarks (**Table 1**) (10, 12). Additional important anatomic landmarks include the pterygoid plates, the vidian canal, and foramina rotundum and ovale (with the second and third branches of the trigeminal nerve [V2 and V3], respectively) (15, 22).

PARAMEDIAN EEAS

Paramedian EEAs must be considered in 3 different depths as the working corridor advances from an anterior to posterior. In general, the anterior coronal plane relates to the anterior cranial fossa and orbits, the middle coronal plane relates to the middle cranial fossa and temporal lobe, and the posterior coronal plane relates to the posterior cranial fossa (1, 10). Based on their relationship to different segments of the ICA, the middle and posterior

Table 1. Endoscopic Landmarks to Segments of the ICA

Segment	Anatomic Landmark
Parasellar	mOCR
Vertical ICA	Medial pterygoid
Horizontal ICA	Vidian nerve
Carotid canal	ET (bony)
Ascending ICA	ET (cartilaginous)

ICA, internal carotid artery; mOCR, medial opticocarotid recess; ET, eustachian tube.

paramedian approaches may be classified as follows: zone 1 or medial petrous apex approach (posterior to the paraclival ICA), zone 2 or infrapetrous approach (inferior to the petrous ICA), zone 3 or suprapetrous approach (superior to the petrous ICA and lateral to the paraclival ICA), zone 4 or lateral cavernous sinus approach (superior to Meckel cave approach, i.e., Meckel cave), zone 5 or middle fossa/infratemporal fossa approach (lateral to the petrous ICA and anterior to the parapharyngeal ICA), zone 6 or occipital transcondylar approach (posterior to the eustachian tube [ET] and medial to the parapharyngeal ICA), and zone 7 or jugular foramen approach (posterior and lateral to the parapharyngeal ICA) (9, 10, 12). A transpterygoid corridor is the initial step to gain endonasal access to most of the zones in the middle and posterior coronal plane (9).

Anatomic Considerations

As with any other surgical technique, a flawless EEA is based on a profound understanding of the ventral skull base anatomy. A complex group of bones, fissures, foramina, and neurovascular structures must be taken into consideration. The sphenoid bone is located in the center of the cranial base in intimate contact with many important arterial, venous, and neural structures, such as the internal carotid and basilar arteries, the cavernous sinuses, and associated cranial nerves (CNs). Pneumatization of the sphenoid bone and sphenoid sinus creates a natural corridor, allowing the surgeon to approach various neurovascular structures with minimal drilling or manipulation of intracranial structures (1, 16).

The body of the sphenoid bone forms part of the medial wall of the orbital apex and superior orbital fissure. The medial wall of the orbit is also formed by the ascending process of the palatine bone, the lamina papyraceae of the ethmoid bone, the lacrimal bone, and the frontal process of the maxilla (from posterior to anterior). The orbital medial wall is extremely thin at the level of the lamina papyraceae, which separates the ethmoid sinus cells and the orbit. At the junction of the roof and the medial wall of the orbit is the frontoethmoidal suture. This suture represents an important landmark as the anterior and posterior ethmoidal foramina, in which the respective anterior and posterior ethmoidal arteries and nerves traverse (7, 14).

The greater wing of the sphenoid bone forms a large part of the lateral wall of the orbit, the floor of the middle fossa, and the roof of the infratemporal fossa. The infratemporal fossa is an anatomic space located under the floor of the middle cranial fossa and posterior to the maxilla that contains the parapharyngeal and masticator spaces. It communicates medially with the pterygopalatine fossa through the pterygomaxillary fissure, which is continuous with the inferior orbital fissure (3, 5). These fissures form a half-moon–shaped pathway and can be used as a surgical landmark because they delimit surgical boundaries between the pterygopalatine (medially) and the infratemporal fossae (laterally) (3, 6).

The pterygopalatine fossa is bound by the pterygoid process posteriorly, the palatine bone anteromedially, and the maxilla anterolaterally (**Figure 1**) (3, 15, 18). It contains a superficial (i.e., anterior) vascular compartment that contains the maxillary artery (also known as internal maxillary artery) and its terminal branches. A posterior neural compartment includes the pterygopalatine ganglion, which receives parasympathetic and sympathetic fibers through the vidian nerve, and sensory fibers from the descending palatine nerve and the maxillary nerve (V2).

The vidian nerve, formed by the union of the greater superficial petrosal nerve and the deep petrosal nerve, is one of the most important surgical landmarks when navigating on the coronal plane. It consistently marks the level of the horizontal ICA in the petrous bone.

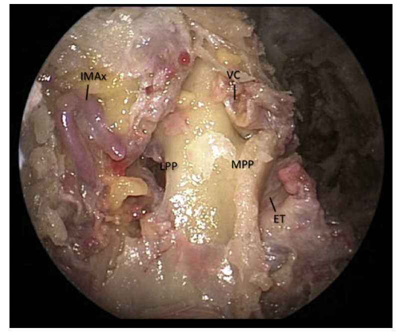

Figure 1. Endoscopic view of a cadaveric dissection of the pterygopalatine fossa. ET, eustachian tube; IMAx, internal maxillary artery; LPP, lateral pterygoid plate; MPP, medial pterygoid plate; VC, vidian canal (sectioned).

Intraoperatively, the nerve can be followed posteriorly up to the level of the foramen lacerum allowing the surgeon to identify the ICA safely (12, 16, 17, 22).

Pneumatization of the sphenoid sinus extending into the greater sphenoid wing bears a lateral sphenoid recess (i.e., pterygoid recess), which projects under the middle fossa. The anteromedial portion corresponds to Meckel cave, containing the trigeminal (gasserian) ganglion (4, 7, 16). Removal of the lateral wall of the sphenoid sinus exposes the periosteum of the middle fossa. CN VI is the most vulnerable structure intradurally. Understanding its anatomy is paramount to avoid an accidental injury. CN VI exits the brainstem at the level of the vertebrobasilar junction (level of the sphenoid sinus floor), pierces the clival dura mater posterior to the paraclival ICA, and advances between the dural layers superolaterally toward Dorello's canal; it angulates anteriorly under Gruber ligament to enter the cavernous sinus immediately lateral to the parasellar ICA. CN VI goes into the superior orbital fissure running parallel to the horizontal segment of the cavernous ICA and first branch of the trigeminal nerve. CN VI must be monitored, carefully identified, or avoided to prevent postoperative palsy (8, 10).

Anterior Coronal Plane

Transorbital Approach. Transorbital EEAs are designed to reach both extraconal and intraconal lesions. The most common