Section I Endoscopic Endonasal (EN) Combined Approaches

Chapter 1

Combined Endonasal Transethmoidal, Transcribriform, and Endoscope-Assisted Supraorbital Craniotomy

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Introduction and Indications

Traditional transcranial approaches to the anterior skull base provide wide exposure but often require significant retraction of the brain and manipulation of neurovascular structures that lie between the surgeon and the pathology. The bifrontal, extended-subfrontal, or frontobasal approaches necessitate the sacrifice of the superior sagittal sinus, which can lead to brain edema or venous infarct. Minimally invasive routes have been developed to curtail the practice of brain retraction and provide a means of access to the pathology that, in well-selected cases, may reduce the need to cross the plane of cranial nerves or arteries.

The *extended endonasal approach* (*EEA*) is a global term used to describe a variety of approaches that utilize the nasal sinuses as corridors to reach a variety of locations along the midline and parasagittal skull base (1). When exposing the anterior skull base or frontal fossa, the ethmoid sinuses and the frontal sinus can be opened by removing the cribriform plate. This so-called transethmoidal, transcribriform approach allows for the resection of midline anterior skull base lesions without the need to sacrifice the superior sagittal sinus or retract the frontal lobe (2, 3). Other benefits of this approach include direct visualization and cauterization of the ethmoidal arteries for tumor devascularization, direct exposure of the cribriform plate (which is often invaded by tumors), and direct access and wide exposure to lesions that may have invaded the nasal sinuses. A vascularized nasal septal flap is easily obtained from this approach and helps decrease the rate of cerebral spinal fluid (CSF) leaks. However, given the breadth of the anterior skull base and the large size of the defect created, additional support may be needed to prevent CSF leaks in this area.

The transethmoidal, transcribriform approach is limited anteriorly by the frontal sinus, laterally by the lamina papyracea, and posteriorly by the planum sphenoidale (Table 1.1; Figure 1.1).

Table 1.1 Indications and limitations of the endonasal transethmoidal, transcribriform approach, supraorbital approach, and combined approach

Approach	Indication	Advantage	Disadvantage	Medial-to-lateral limitation	Anterior-posterior limitation
Endonasal transethmoidal, transcribriform	Medially centered anterior skull base lesions with nasal extension	Direct visualization of tumor, access to blood supply	CSF leak risk, patient loss of smell	Lateral to middle orbital line	Frontal sinus, posterior planum sphenoidale
Supraorbital	Anterior skull base tumors with lateral extension and without nasal extension	Direct visualization of tumor	Lack of access to vascularized flap, difficulty if pathology invades into the diploë of the skull base	Cribriform plate, crista galli, lateral and inferior sphenoid wing	Frontal sinus, invasion into frontal sinus, posterior to sphenoid wing
Combined	Extension beyond the lamina papyracea, extension into nasal sinus	Increased direct access to tumor, minimal brain retraction	Long operative time, patient loss of smell, CSF leak	Lateral and inferior sphenoid wing	frontal sinus, invasion into frontal sinus, posterior to sphenoid wing

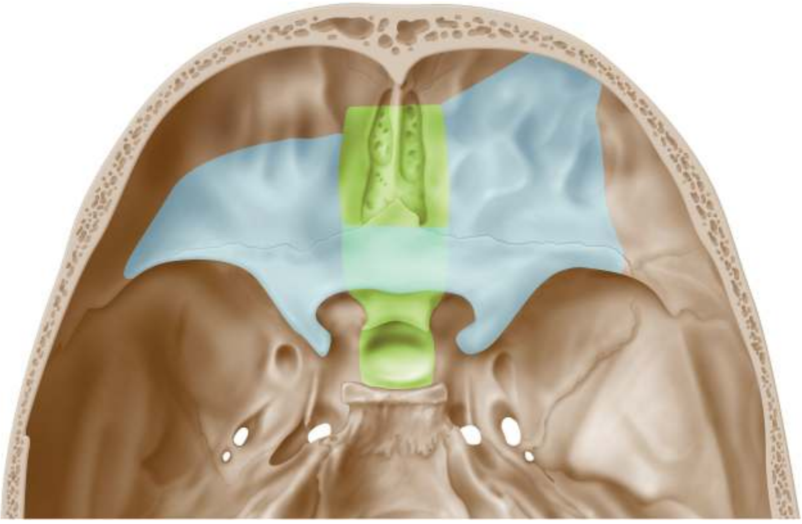

Figure 1.1 Axial overview of the cranial skull base outlining the area reached using the combined extended endonasal approach (EEA) and endoscopic-assisted supraorbital approach. The green shaded area represents the area exposed during an EEA, and the blue shaded area represents the area directly exposed during a supraorbital approach. The area with color overlap represents areas exposed equally well with either approach.

Complete removal of the lamina papyracea combined with a limited superomedial orbitectomy can provide further lateral extension, but the orbit itself cannot be mobilized beyond a few millimeters (4). Expansion of the approach through the sphenoid can aid in improving visualization of lesions that extend posteriorly. Removal of the tuberculum sellae provides further access to the medial optic nerve, chiasm, and lesions that expand into the third ventricle (5).

For pathology that does not lie completely within the confines of the area exposed by the transethmoidal, transcribriform approach, additional exposure can be provided by combining the EEA with a separate transcranial approach (6). In some cases, depending on the pathology and its location, only a supraorbital approach is required, which can be further expanded using endoscopic assistance. This approach provides direct access to the anterior cranial fossa floor and decreases the need for brain retraction. Using angled endoscopes, access to the anterior olfactory groove, intrasellar space, inferior optic nerve, interpeduncular space, medial middle fossa, and anterior third ventricle can be obtained through the supraorbital approach (7).

For some anterior cranial fossa lesions, the supraorbital approach is limited. Lesions extending far to the contralateral side can be difficult to resect, even with angled endoscopes. Laterally extending the frontal sinuses can limit the medial portion of the craniotomy. This can be overcome by cranializing the frontal sinus or packing the open portion of the sinus; however, the risk of pneumocephalus or CSF leak may not warrant this approach if sinus repair or packing is necessary. Lesions extending far anterior into the frontal sinus can also be difficult to reach, as are lesions that are either lateral or inferior to the sphenoid ridge. In addition, lesions that grow through the cribriform plate cannot be resected solely using the supraorbital approach, due to limitations on drilling the cribriform plate and crista galli (4).

Combining supraorbital endoscope-assisted craniotomy with the transethmoidal, transcribriform approach can help overcome some of the limitations of using a single approach. The EEA is the best approach for the removal of lesions that extend intranasally and are located along the cribriform plate, and for repairing the defect. The supraorbital approach can then be added to remove lesions extending anteriorly to the frontal sinus or extending laterally beyond 1 cm of the lamina papyracea (LP). Pathologies that most commonly fall into this category include olfactory groove meningiomas, esthesioneuroblastomas, and squamous cell carcinomas.

Other operative concerns to consider before choosing a combined approach include the extent of the lesion into the frontal sinus. Bilateral frontal sinus invasion still would be best removed with a bifrontal craniotomy. This would allow for a large pericranial flap harvest for skull base repair. Frontal sinuses are difficult to repair with a nasal flap.

Histology should also be considered during this process. For instance, en bloc resections, which may be necessary for some malignancies, cannot be obtained through this route. If the pathology is highly vascular, preoperative embolization should be considered. In addition, an EEA will likely eliminate olfaction and gustation, and patients should be counseled on this sensory loss.

Patient Positioning and Preparation

When conducting the combined approach, the surgeon can choose to perform the individual approaches sequentially or perform both approaches simultaneously. Typically, with either sequence, the patient will be placed in a rigid Mayfield head holder. The head can be fixed in a single position for both approaches with 15–30 degrees of extension, ipsilateral rotation, and abduction toward the contralateral shoulder (Figure 1.2A). The amount of rotation should be just enough to center the operative eyebrow at the highest point of the surgical field and permit comfortable endonasal access. The navigational system is then registered. The patient receives perioperative antibiotics with a broad enough spectrum to cover the nasal sinus flora. We generally use vancomycin and a second-generation cephalosporin. Perioperative antiepileptics and dexamethasone can also be administered. A lumbar drain may be placed, depending on the size of the expected defect, and intrathecal fluorescein (0.2 ml of 10% fluorescein with 10 ml of CSF or preservative-free saline) can help identify intraoperative CSF leaks (8, 9). If fluorescein is injected, the patient should be premedicated with 50 mg of intravenous diphenhydramine in addition to dexamethasone. Areas near the umbilicus and also near the lateral portion of the thigh are prepped for the harvesting of fat and fascia lata grafts, respectively.

Surgical Technique

Endonasal Transethmoidal, Transcribriform Approach

In preparation for the sinus procedure, the middle turbinates and the ethmoidal arteries are injected with 1% lidocaine with epinephrine (1:100,000 dilution). A large nasal septal flap should be harvested at the beginning of the dissection, as previously described (10). Bilateral, or "Janus," flaps may be helpful, depending on the expected size of the defect (11). There are five vertical structures in the nasal cavity that can be removed in a graded fashion, depending on the required size of the exposure. These include the septum in the midline, each of the middle turbinates, and each lamina papyracea. An uncinectomy is performed to reveal the maxillary sinus ostium using a sickle blade. This fully exposes the ethmoid bulla, allowing for dissection lateral to the lamina papyracea. If even further lateral resection is needed, the lamina papyracea can be resected if the periorbita is not violated. Once lateral dissection of the ethmoids to the lamina papyracea is completed

(a)

(b)

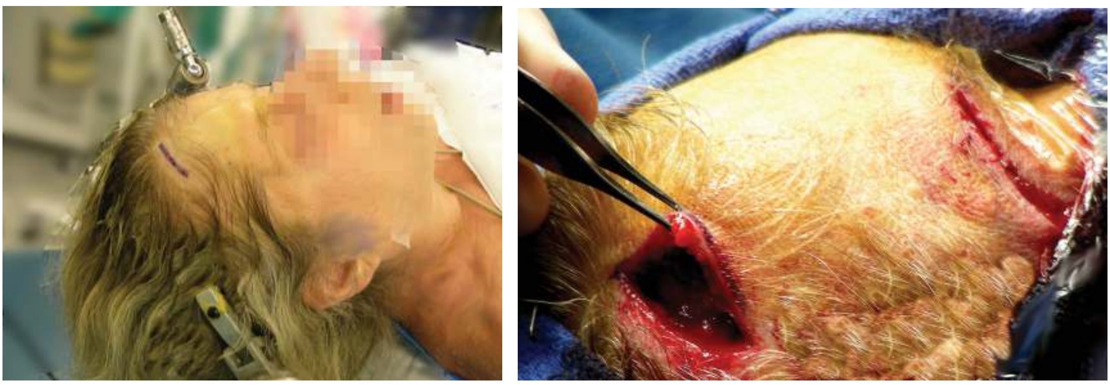

Figure 1.2 (A) Intraoperative photo showing the head position for combined supraorbital and EEA. Typical positioning requires 15–30 degrees of extension, ipsilateral rotation, and abduction toward the contralateral shoulder. (B) Visualization of a superior forehead incision for a pericranial graft along with a typical supraorbital incision.

bilaterally, submucosal dissection and resection of the upper third of the nasal septum are completed to form a large, single cavity. The anterior and posterior ethmoidal arteries are identified and coagulated. The olfactory epithelium and mucosa are removed following cauterization. High-speed drills are used to remove the fovea ethmoidalis, beginning anteriorly at the frontoethmoidal recess and progressing posteriorly to the sphenoid sinus. If the lesion overlies the planum sphenoidale or tuberculum sellae, the sphenoid sinus is then opened bilaterally. Laterally, the cribriform plate is drilled at the border with the lamina papyracea. The thick bone of the crista galli is drilled in the midline. The thin bone is then freed with curettes and removed with Kerrison and pituitary rongeurs. If the pathology is intradural, the dura can be opened once maximum exposure is obtained.

The lesion is then debulked internally, typically using bimanual suction. For firmer lesions, an ultrasonic aspirator (Cavitron, Valleylab, CO) or monopolar (Elliquence, Oceanside, NY) may be used. After adequate debulking, the capsule of the lesion is mobilized. Sharp dissection and cautery are used to free the capsule from vascular and neural structures such as the A2 branches.

Several options exist to close the defect. If bony margins are present, a "gasket-seal" closure can be performed (12, 13). An inlay of Duraform (Natus Neuro, Middleton, WI) can be used as a first layer. A fascia lata graft or Dura-Guard (Synovis Surgical, St. Paul, MN) piece is then cut so that it has a diameter about 1 cm larger than the skull defect. This graft is then laid over the opening. A piece of MEDPOR (Stryker, Kalamazoo, MI) is then cut to the size of the defect and countersunk into the defect just beyond the edge of the bone. The previously harvested nasoseptal flaps are laid so that they extend beyond the margin of the fascia lata or Dura-Guard (14). A sealant such as DuraSeal (Integra, Plainsboro, NJ) or Adherus (Stryker, Kalamazoo, MI) is then placed over the gasket seal. If the defect is large with no boney margins, an inlay-onlay of fascia lata can be performed and buttressed with a Foley balloon to provide extra support. The balloon stays in place for a few days and is then removed. The nasal cavity is then filled with Floseal (Baxter, Deerfield, IL), and NasoPore (Stryker, Kalamazoo, MI) is inserted into the nasal cavity.

Supraorbital Approach

The incision for the supraorbital approach is made from within the eyebrow, extending from the supraorbital notch to just past the insertion of the temporalis muscle, with care taken not to injure the supraorbital nerve. The exposure must be lateral to the frontal sinus and extend far enough to allow a burr hole to be made in the key hole of the pterion.

The side chosen depends on the location of the pathology. Approaching ipsilaterally to the greatest lateral extent of the pathology can be advantageous, particularly if the pathology extends laterally to the optic nerve. However, the medial optic canal can often be hidden given the low angle of approach. Therefore, if the pathology extends into the medial optic canal, a contralateral approach can often be advantageous (Figure 1.1) (15). An incision is made with a 15 blade in the middle of the eyebrow. Dissect sharply down through the frontalis and orbicularis oculi to the pericranium. The pericranium is incised in a U-shape fashion with the base of the "U" at the orbital ridge. Longer pericranial flaps can be harvested by dissecting the pericranium further posterior and making a second incision on the forehead (Figure 1.2B). This flap is useful when there is a large frontal sinus violation or inadequate closure from the EEA. The skin incision is then retracted with elastic stay retractors. The temporalis is dissected widely enough to reveal the key hole. A single burr hole is made in the key hole. A craniotome is then used to make as large a craniotomy as is allowed by the incision, which is typically 3 × 3 cm (Figure 1.3). The craniotome is stopped along the medial and lateral edges of the orbital bar. Thereafter, the orbital bar is removed with a chisel or an ultrasonic knife, while the periorbita is retracted and protected with a brain retractor. The bone flap is then removed. Some authors do not routinely remove the orbital rim, although this can increase the size of the opening, improve maneuverability, and increase upward exposure to reach the top of larger tumors.

The frontal lobe and dura are retracted and a microscope is used to view the orbital floor. A diamond drill is used to remove any prominent bone. The dura is then opened and flapped in a U-shape fashion with the base of the "U" at the orbit. CSF is evacuated to assist with brain relaxation. (One accessible area for CSF is the opticocarotid cistern.) Another option for brain

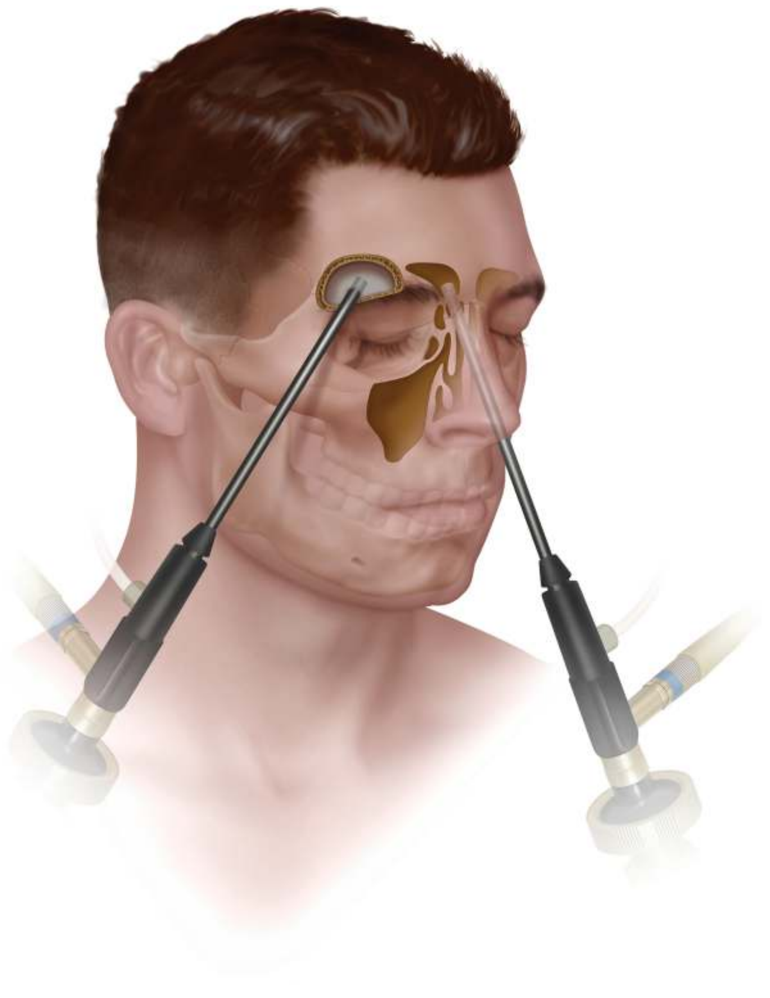

Figure 1.3 Schematic of size and location of supraorbital craniotomy along with the trajectory of the EEA

relaxation is to open the lumbar drain that was placed before the operation, although this is generally not necessary.

Depending on the surgeon's preference, initial dissection to the pathology can be performed with the aid of either a microscope or an endoscope. Endoscopic views, especially with a 45° scope, can provide a much wider view of the pathology. The scope can be held by a second surgeon or placed in a scope holder. At the very least, the endoscope can be used to inspect the surgical cavity for residual tumor if a microscopic resection is preferred. Once the lesion is resected, hemostasis is obtained in the cavity. The pericranial graft can be laid over any opening made in the frontal sinus.

The dura is closed and made watertight. If necessary, extra Duragen or Gelfoam can be placed over the dura to help with watertight closure. The bone flap is affixed with low-profile plates. The temporalis muscle is reapproximated by placing small tack-up holes along the superior temporal line. Bone cement can be used to cover any remaining gaps in the bone. The galea is closed with 3–0 vicryl sutures. The skin is closed with a 5–0 Prolene stitch in a subcuticular fashion without knots along the incision. The two ends of the Prolene stitch are knotted together over a Telfa dressing. The Prolene stitch is removed in 5–7 days.

Postoperative Care

Immediately post-surgery, the head of the patient's bed is elevated 30 degrees. Patients are given typical sinus precautions: no blowing of the nose, no use of straws, and a strict bowel regimen to prevent straining. Patient diets are advanced slowly to reduce the risk of vomiting. If a lumbar drain was placed, it is drained depending on the severity of intraoperative CSF leakage. For lesions extending into the sellar space, patients are placed on diabetes insipidus watch. In such cases, postoperative cortisol and pituitary function labs are also obtained. Patients without a CSF leak may get out of bed on the first day postoperation.

Case Presentation

A 53-year-old woman presented with nasal congestion. She was initially diagnosed with nasal polyp disease but began having tooth pain leading to a CAT scan of the head. This revealed a mass in the anterior skull base. A brain MRI further elucidated an enhancing mass of the anterior skull base on the right side (Figure 1.4). The mass extended intracranially from the back of the frontal sinus, anteriorly over the crista galli along the cribriform plate, and back to the anterior margin of the planum. The mass also extended down through the olfactory bulb and into the nasal cavity medial to the middle turbinate. Although esthesioneuroblastoma was considered in the differential diagnosis, the imaging was most consistent with olfactory groove meningioma.

A lumbar drain was placed before final positioning, and fluorescein (0.25 mL in all of 4% fluorescein diluted with 10 mL of CSF) was injected. The patient was placed supine with the head in a Mayfield head holder and registered with frameless stereotactic navigation. The planned approach was a right supraorbital craniotomy with orbital osteotomy performed simultaneously with an EEA and transethmoidal, transcribriform approach. The supraorbital approach allowed for a complete removal of the supratentorial intradural portion of the mass. This was accomplished by using both a microdissection technique as well as a 45-degree endoscope to see into the olfactory groove. A piece of autologous pericranium was used for a secondary repair of the dura. The previously harvested pericranium and frontalis muscle were used to cover the frontal sinus. The bone was replaced with low-profile plates and the skin was closed as previously described.

Next, the endoscopic approach commenced. A nasoseptal flap was developed on the left side and was tucked into the nasopharynx. The ethmoid was exposed so that the roof of the nasal cavity and the olfactory groove could be viewed bilaterally. Next, bilateral partial inferior turbinectomies and

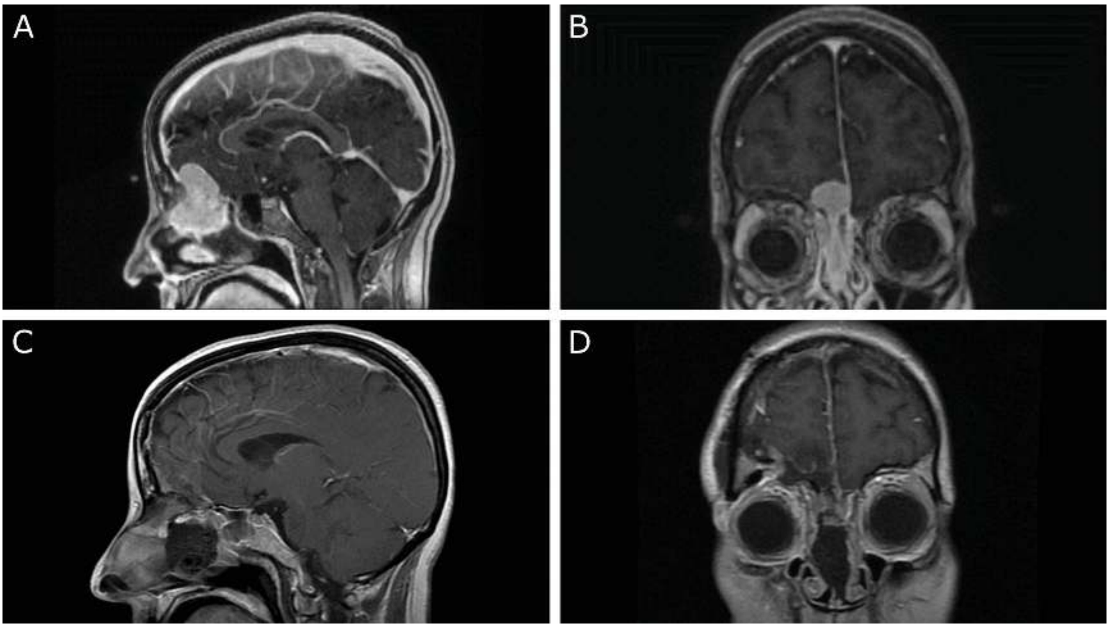

Figure 1.4 (A) Sagittal and (B) coronal view of a preoperative T1-weighted post-contrast image depicting a large enhancing mass compatible with an olfactory groove meningioma. The tumor extended far anterior against the frontal sinuses with extension into the nasal cavity. Patient underwent a combined approach. Postoperative post-contrast T1-weighted (C) sagittal and (D) coronal planes depict a complete resection.

bilateral uncinectomies were performed. A complete right-sided ethmoidectomy was then performed. The perpendicular plate of the ethmoid was removed under direct vision. The tumor was removed from the olfactory groove bilaterally. The dura was exposed all the way to the planum sphenoidale to ensure all the mass had been removed. A dural defect was noted. After removal of the perpendicular plate and the lateral lamella of the roof of the ethmoid sinus, the nasoseptal flap was rotated into the area of the defect. DuraSeal was sprayed into the area around the flap, followed by FloSeal. CSF/fluorescein leak was not observed after the repair. NasoPore splints were inserted into each nostril. Postoperative MRI films of the brain showed a gross tumor resection (Figure 1.4), and final pathology confirmed olfactory groove meningioma.

Conclusion

The combined endoscopic endonasal transethmoidal, transcribriform approach with endoscope-assisted supraorbital craniotomy is a minimally invasive approach that can be used as an alternative to the classic transcranial, transfacial, or combined craniofacial approaches to lesions of the anterior cranial fossa. This approach is best used for lesions that extend anteriorly to the frontal sinus, laterally beyond the lamina papyracea, and inferiorly into the ethmoid sinus. There are several methods for closing the skull base defect both from above and below with this approach, including pericranial graft, a vascular nasal septal flap, and a gasket seal with fascia lata.

Key Points

- The combined endoscopic endonasal transethmoidal, transcribriform approach with endoscope-assisted supraorbital craniotomy can be used for lesions that extend laterally beyond the lamina papyracea and inferiorly into the ethmoid sinus.
- This combined approach can be completed in one operative sitting or done sequentially, depending on the location of the lesion.
- The combined approach is limited anteriorly by the frontal sinus and posteriorly by the sphenoid wing.
- There are many different methods used to close the post-operative defect, including a pericranial flap, a vascular nasal flap, and a gasket seal closure.
- Patients must be counseled on the risk of CSF leak and the high likelihood of decreased olfaction following surgery.

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Chapter 2

Combined Endonasal and Transorbital Approach

Darlene Lubbe and Hamzah Mustak

Introduction

The concept of using endoscopy in the orbit was first proposed by Norris in 1983 (6). The inability to safely insufflate and create a working space, coupled with the available technology at the time, led to a loss of interest in this approach. Advances in imaging technology, illumination sources, and instrumentation have resulted in a renewed interest and the adoption of these technologies in orbital surgery.

Combining endoscopic transnasal and transorbital approaches allows for multiportal surgery, where instruments can reach difficult-to-access skull base areas with minimal collateral damage to normal tissues. Different surgical trajectories can be obtained and the use of standard zero-degree endoscopes and instruments allows for easier manipulation of the target lesion. Multistage surgery can often be avoided and lesions can often be removed en-bloc. Endoscopic transnasal approaches offer access to the central and medial areas of the skull base; however, the orbit limits access to the lateral skull base through this approach. Kris Moe popularized the concept of transorbital portals that overcome the obstacle of the orbital contents allowing for access to the superior and inferior lateral areas of the skull base (4,5). The transorbital approach takes advantage of the natural tissue planes and displacement of the globe and orbital soft tissues to create a portal for introduction of the endoscope and operating instruments. The drive for the development of minimally invasive surgery has seen a renewed interest in exploring the transorbital corridors, along with their advantages, limitations, and role in addressing intra-orbital pathology.

Endoscopic surgery involving the orbit can therefore be categorized according to whether the target lesion is within the orbit, adjacent to the orbit, and extradural or located intracranially requiring intradural dissection (Figure 2.1).

A combination of portals can often be used to approach a lesion and allows for the manipulation of the target from different directions and angles. (Figure 2.2).

Indications for Endoscopic Orbital and Multiportal Endonasal and Transorbital Approaches

Endoscopic Orbital Surgery: Intraconal and Extraconal Surgery

The endoscope is a useful tool for addressing lesions within the orbit and for managing disease affecting the bony walls of the orbit. The surgery is extradural and breaching the dura during these cases would be a complication of surgery, similar to breaching the dura during endoscopic sinus surgery. Endoscopic approaches for addressing orbital tumors are best suited for lesions that are extraconal and in the mid to posterior orbit. These lesions are approached in the subperiosteal plane and the periorbita is opened only once the tumor is identified tenting it. This approach limits orbital fat prolapse which would make surgical exposure more difficult. Transorbital surgery avoids the need for a craniotomy and removal of the roof of the orbit and reconstruction of the defect. The decision on which transorbital portal to use and whether to combine it with an endonasal approach depends on the location of the orbital lesion. If the lesion is located within the superior, lateral, or inferior orbit, a single portal transorbital approach is indicated. If the lesion is located within the medial orbit, a precaruncular or endonasal approach can be utilized, or a multiportal approach using both portals can be used to assist in lesion manipulation (Figure 2.3).

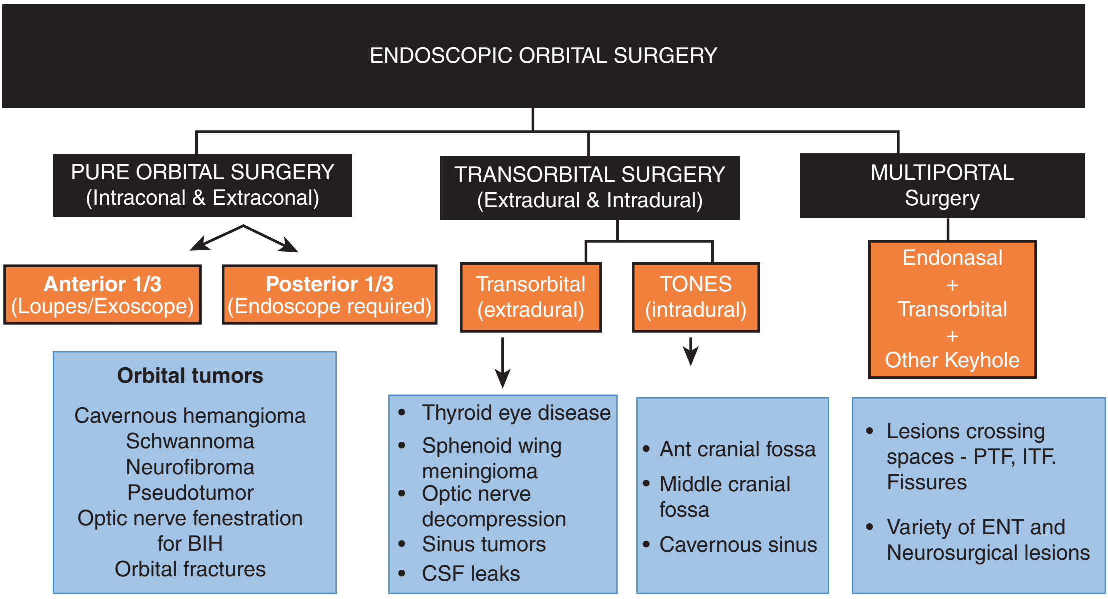

Figure 2.1 Algorithm showing endoscopic surgery involving the orbit categorized according to whether the target lesion is within the orbit, adjacent to the orbit, and extradural or located intracranially requiring intradural dissection

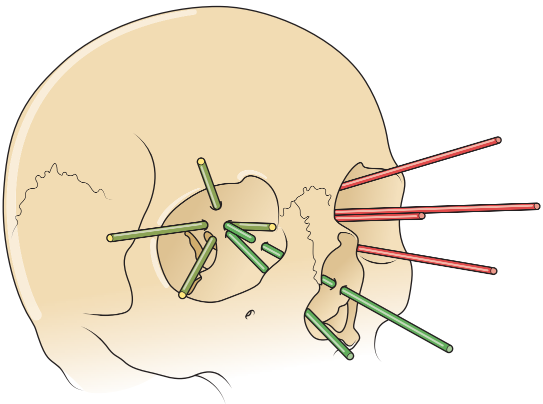

Figure 2.2 A combination of 10 portals can be used to approach a lesion and allows manipulation of the target from different directions and angle

Figure 2.3 Multiportal approach using the precaruncular and binostril portals

Cavernous hemangiomas are one of the most common orbital tumors and often patients present with proptosis as the main complaint. The transorbital portal allows for a minimally invasive approach to these lesions, avoiding a craniotomy, an orbitotomy, or an extensive endonasal dissection, depending on the location of the lesion. Other advantages are that the patients can be discharged the same day, avoid the need for post-operative intensive care monitoring, and have no visible scar except for the temporary blepharoplasty incision, when used. These lesions can often be approached by at least two different transorbital portals and the approach selected