# Minimally Invasive Surgery (Endonasal) for Anterior Fossa and Sellar Tumors

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**KEYWORDS**

• Endoscope • Endonasal approach • Meningioma
• Adenoma • Craniopharyngioma

## HISTORICAL PERSPECTIVE

The primary goal of any surgical approach is to adequately visualize and treat the pathologic condition with minimal disruption to adjacent normal anatomy. During the past 200 years, rapid advances have been made in endoscope technology and instrumentation. In 1806, Philipp Bozzini demonstrated the use of a device consisting of a tube that was illuminated by a candle and mirror to visualize structures within the human body.[1,2] In the mid-1880s, the term endoscope was coined by the French urologist Antonin Jean Desormeaux.[1] One of the key limitations of early endoscopes was poor illumination. The invention of the incandescent light bulb by Thomas Edison in 1879, followed by the development of fiberoptic technology beginning in 1926 by John Logie Baird, paved the way for greatly improved illumination systems.[1] Revolutionary advances in rod-lens technology through the mid-1990s greatly expanded visualization. Finally, progress in video and display technologies has made it possible to view exquisite real-time images on large screens in high definition (HD) and, in some cases, in 3 dimensions, in addition to video documentation for teaching and cataloging purposes.

Whereas initial endoscopes were only used for visualization, concurrent advances were being made in the development of new instruments to allow endoscopic procedures to be performed as well. Maximilian Nitze was an early pioneer in endoscopic surgery. He published the *Textbook of Cystoscopy* in 1889 and was the first to use movable loops for urological procedures.[2] The subsequent development of microinstruments and electrocautery made a wide range of endoscopic procedures possible. Although pioneers in urology and otolaryngology made rapid advancements in endoscopic approaches, it was many years later before neurosurgeons began to recognize its potential for the treatment of pathologic conditions of the anterior skull base and sella.

The first steps toward the eventual development of endonasal endoscopic neurosurgery came with the early work by Harvey Cushing, demonstrating the feasibility of transsphenoidal techniques for resection of the sellar lesion. In the late 1800s, attempts made by other researchers to access the sella through subfrontal or temporal approaches were associated with high perioperative mortality rates, with some reports approaching 80%.[3] Cushing's technique required first

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Neurosurg Clin N Am 21 (2010) 607–620
doi:10.1016/j.nec.2010.07.010

making a sublabial incision followed by exposing the submucosa and then resecting the nasal septum to allow direct access to the sphenoid sinus. The posterior wall of the sinus was opened with an osteotome to provide direct access to the sella. Between 1910 and 1925, Cushing used his transsphenoidal approach on 231 patients with a mortality rate of 5.6%. However, improvements in the safety and the greater exposure provided by intracranial approaches, compounded by problems with persistent spinal fluid leaks and meningitis, ultimately cooled the enthusiasm for the transsphenoidal approach, and the approach was all but abandoned.

However, one of Cushing's students, Norman Dott, recognized the advantages of the transsphenoidal approach and continued to refine this technique. Gerard Guiot, a French neurosurgeon who worked with Dott, was impressed by the approach and went on to perform more than 1000 transsphenoidal pituitary adenoma resections.[3] He and his fellow, Jules Hardy, further improved the technique. With the introduction of the operating microscope, Hardy reported his ability to treat pituitary adenomas, craniopharyngiomas, clival chordomas, and meningiomas with morbidity and mortality rates that were less than those of transcranial approaches.[4]

With the revival and increasing popularity of the transsphenoidal approach and the development of the modern endoscope, neurosurgeons in the 1970s began to merge these techniques. Early applications used endoscopes to augment traditional microsurgical approaches to allow visualization of structures that were not within the direct line of sight. Apuzzo and colleagues[5] provided some of the first reports using 70° and 120° endoscopes to inspect the sella after a traditional microsurgical transsphenoidal resection. Finally, in the 1990s, multidisciplinary teams including neurosurgeons and otolaryngologists began to report on purely endoscopic endonasal transsphenoidal approaches. In 1997, Jho and Carrau[6] first published their experience with endoscopic endonasal transsphenoidal surgery on 50 patients. Their results revealed the promise of minimally invasive endonasal neurosurgery and paved the way for broader applications of the technology. This article discusses the current state of minimally invasive endonasal techniques to address the pathologic conditions of the anterior cranial fossa and parasellar region.

## ANATOMY

Detailed understanding of the normal anatomy is critical in any neurosurgical procedure; however, this fact becomes even more important with endoscopic approaches, in which one can easily become disoriented. Some of the key advantages of using an endoscope for transsphenoidal surgery are the ability to angle the view and inspect the tumor bed, and the superior illumination in a deep and dark cavity. This new degree of visualization is initially unfamiliar and can further contribute to surgeon disorientation. It is important to take full advantage of the improved visualization capability by having a detailed understanding of the anatomy of the sella and surrounding structures and to identify key landmarks early in the operation.

A careful review of preoperative imaging is crucial. Magnetic resonance imaging (MRI) provides critical details regarding the anatomy of both the lesion being addressed and the adjacent critical normal structures, such as the pituitary gland, carotid arteries, cavernous sinuses, and cranial nerves. Intrasellar lesions, such as pituitary adenomas or Rathke cleft cysts, can cause the sella to become greatly expanded. Also, as a sellar mass expands, the anatomy of the carotid arteries can become distorted. The cavernous portion of the carotid artery forms the lateral walls of the sphenoid sinus. In a recent cadaver study, the normal distance between the carotid arteries was 21 $\pm$ 2.5 mm.[7] However, there can be great variability in the course of the carotid artery, particularly if the artery is displaced or encircled by the lesion. In a study of normal specimens, an extreme medial course of the carotid artery was identified in 8% of cases (**Fig. 1**).[8] The flow voids of the carotid arteries are easily identified on T2-weighted MRI, and understanding the relationship of the carotid arteries with the lesion is critical in avoiding complications. Another key structure is the optic chiasm and optic nerves. As a sellar mass expands, the diaphragma sellae is forced upward and displaces the optic chiasm. The diaphragm can act as a barrier from the optic apparatus during the resection and can be observed to come into the operative field as the lesion is resected. Alternatively, suprasellar masses, such as craniopharyngiomas, can extend around the superior surface of the chiasm, making difficult a gross total resection via a transsphenoidal approach alone. It is important to recognize this relationship preoperatively to avoid injury to the optic apparatus during resection. Finally, the location of the remaining normal pituitary tissue should be determined on preoperative imaging. The normal pituitary is often identifiable on dynamic gadolinium-enhanced T1-weighted MR images. The pituitary gland takes up the gadolinium early in the postinjection phase whereas the adenoma

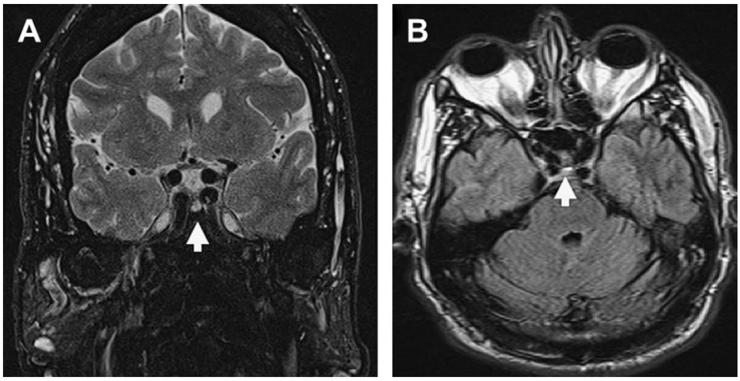


**Fig. 1.** Atypical anatomy of cavernous segment of carotid artery. As indicated by the arrows on the coronal T2-weighted magnetic resonance (*A*) and axial fluid-attenuated inversion recovery (*B*) images, this patient has unusually close cavernous carotid arteries. This variant must be recognized and considered when planning a transsphenoidal approach.

does not, and conversely, the gland shows no enhancement in the delayed scans whereas the adenoma does. Intrasellar masses often displace the normal pituitary posteriorly and to one side or the other. Understanding where the normal pituitary is located can help avoid intraoperative injury and prevent postoperative hormonal complications.

Whereas MRI provides important soft tissue detail, computed tomography (CT) provides information regarding the bony anatomy. The sphenoid sinus generally contains an intersinus septation (79% of cases)[8] and sometimes additional accessory septations. These septa most often terminate in the midline but can be present along the internal carotid artery prominence (26.7%) or along the optic prominence (19.6%).[8] Understanding the relationships between these septa and the carotid arteries preoperatively can help orient the surgeon (**Fig. 2**).

In addition, several bony landmarks can be identified intraoperatively. Typically, the carotid arteries and optic nerves are shielded by readily recognizable prominences along the roof and lateral walls of the sphenoid sinus. As the carotid artery prominence curves posteriorly along the lateral wall of the sinus, it passes just inferior to the optic nerve prominence. The depression just lateral to this junction is the lateral opticocarotid recess, which corresponds to the pneumatization of the anterior clinoid process. The prominent bulge between the carotid prominences is the sella. Identifying these structures early in the case is critical to remaining oriented, and frameless stereotaxy can be a helpful confirmatory adjunct (**Fig. 3**). An expansile mass can erode the overlying bone and obscure these landmarks, leaving them more susceptible to injury. In addition, bony dehiscences of the optic or carotid protuberances or anterior skull base are commonly identified on imaging, even without erosive pathologies. The presence of Onodi cells can also be identified on preoperative imaging, and these cells are present in approximately 8%

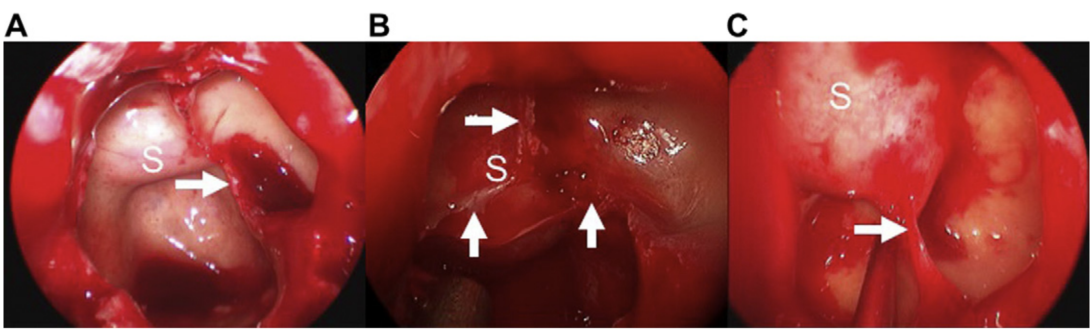


**Fig. 2.** Variations of septation encountered within the sphenoid sinus. (*A*) Paramedian vertical septation (S) attaching to the left carotid protuberance (*arrow*). (*B*) Complex 3-limbed vertical and horizontal septation (*arrows*). (*C*) Incomplete vertical midline septation (*arrow*).

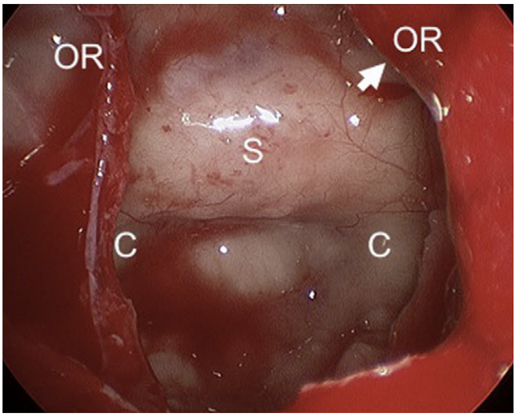


**Fig. 3.** Typical endoscopic view of posterior wall of sphenoid, with panoramic visualization of opticocarotid recesses (OR), sella (S), and carotid protuberances (C).

of cases.[8] Onodi cells are posterior ethmoid cells that can displace the sphenoid sinus posteriorly and interfere with the identification of common landmarks. More importantly, Onodi cells can contain the optic nerve, and it is important that these cells be recognized to avoid inadvertent optic nerve injury during ethmoidectomy.

Endonasal approaches were originally used to treat only sellar lesions, but now these approaches can be used to address a variety of midline skull base lesions. The nasally accessible boundaries extend from the cribriform plate anteriorly to the superior portions of the cervical spine posteriorly. The lateral boundaries are defined by the medial orbital walls anteriorly and the cavernous sinus and carotid arteries posteriorly. With proper training and experience, coupled with appropriate angled endoscopes and instruments, neuronavigation system, and preoperative planning, a wide variety of lesions can now be safely and successfully treated with the minimally invasive endonasal approach.

## INDICATIONS

Endoscopic endonasal approaches to midline skull base lesions have several advantages when compared with traditional open approaches. The lesion can be directly accessed without retraction of the brain or neurovascular structures; the blood supply of the lesion can often be controlled early in the procedure; and visualization is improved, with better illumination, higher magnification, and a larger field of view than obtained by using the operating microscope. In addition, less morbidity, less blood loss, and shorter hospital stays have been reported with endoscopic approaches.[9]

However, several critical issues need to be considered when determining whether an endoscopic approach is appropriate for an individual patient. The goal of the surgery needs to be clearly defined because achieving it will ultimately determine a successful outcome. This consideration should be the same regardless of whether an endonasal endoscopic or open approach is used. For example, some lesions may be amenable to biopsy alone, whereas in other cases patients would be better served with subtotal or gross total resection.

If the goal of the procedure is to achieve a gross total resection, several anatomic relationships should be studied on preoperative imaging to determine if this goal is feasible. The degree of pneumatization of the sphenoid bone determines the size of the operative corridor and how readily identifiable the bony landmarks within the sphenoid sinus will be.[10] With a poorly pneumatized sphenoid sinus, the bone is thicker and superficial landmarks are more difficult to identify. Thus, more drilling will be required to gain adequate access and the risk of a complication may be higher.[10] Endoscopic approaches are ideally suited for midline lesions with minimal lateral extension. In general, lesions that extend laterally beyond the medial orbital walls invade the cavernous sinus and encircle the carotid arteries or infiltrate the bone and soft tissue of the face, and these lesions may be best treated with an open approach. The presence of brain invasion or extensive intradural involvement is also an important consideration that may lead one more toward an open approach. A cerebrospinal fluid (CSF) cleft on T2-weighted magnetic resonance image, the amount of brain edema, and the size of the mass can all aid in determining if brain invasion has occurred. The relationship of the mass with large arteries and the visual apparatus also needs to be studied carefully. Often, intrasellar lesions, such as pituitary adenomas, displace the carotid arteries laterally and the optic chiasm superiorly. Even when pituitary adenomas have become large, they can often be resected using an endoscopic approach. However, predominantly suprasellar lesions can displace or encircle the optic nerves, carotid arteries, and anterior cerebral arteries in such a way as to potentially cause the endonasal approach to be more difficult and potentially more morbid. Recurrent disease with fibrosis and destruction of normal anatomic landmarks can also be viewed as relative contraindications.[11] Finally, if an en bloc resection is desired based on oncologic principles, such as for nasopharyngeal carcinomas, an open craniofacial approach is likely to be superior because endoscopic resections are generally performed piecemeal.

## PITUITARY ADENOMAS

Most of the early work demonstrating the promise of endonasal endoscopic surgery for anterior skull base lesions was performed by pioneers in pituitary surgery. Initially, the endoscope was used in conjunction with open microneurosurgical techniques. As surgeons became more comfortable with using the endoscope and as additional instrumentation was developed, it became possible to perform purely endoscopic resections with the goal of causing less damage to normal anatomy during exposure.[12] In 1992, Jankowski and colleagues[13] demonstrated the feasibility of performing purely endoscopic pituitary adenoma resections in their report on 3 patients. This report was followed by one by Jho and Carrau[6] in 1997, which described resection of pituitary adenomas by an endoscopic endonasal transsphenoidal approach in 44 patients. Of these patients, 13 had microadenomas, 16 had intrasellar macroadenomas, 9 had macroadenomas with suprasellar extension, and 6 had macroadenomas with invasion into the cavernous sinus. Among the patients with secreting tumors, 21 of 25 improved clinically. Of the 19 patients with nonsecreting adenomas, postoperative imaging revealed total resection in 16 and residual disease within the cavernous sinus in 3. More than 50% of the patients required an overnight hospitalization only, and all patients had clear nasal airways with minimal discomfort.

Since these early reports, large series have recently been reported, further verifying that pure endoscopic endonasal transsphenoidal resection of pituitary adenomas is a safe and effective procedure. Dehdashti and colleagues[14] reported on 200 patients with pituitary adenomas treated with purely endoscopic endonasal resection. Total resection was reported in 96% of the patients with suprasellar extension and 98% of those with intrasellar lesions. With regard to functioning adenomas, the investigators achieved remission rates of 71% for growth hormone–secreting, 81% for adrenocorticotropic hormone–secreting, and 88% for prolactin-secreting adenomas.[14] In the series by Gondim and colleagues[15] on 228 pituitary adenomas treated by a purely endoscopic approach, a gross total resection in 79% of all cases was achieved, with a remission rate of 83% for nonfunctioning and 76% for functioning adenomas. These cases were not further classified by cavernous sinus invasion or suprasellar extension. In addition, the tumors treated by Gondim and colleagues were larger than in most previous reports, which would also influence resectability.

It is controversial as to whether purely endoscopic resections are associated with lower complication rates than traditional microneurosurgical techniques. CSF leak and meningitis are the most common complications for transsphenoidal surgery, regardless of the approach. The rate of CSF leak and meningitis is comparable between endoscopic and microsurgical approaches at 1.5% to 3.5% and 0.5% to 1%, respectively.[14,16] The risk of permanent diabetes insipidus (1%–7.6%), pituitary insufficiency (3%–13.6%), visual loss (0%–0.9%), ophthalmoplegia (0%–0.9%), and death (0%–0.9%) are also similar between the approaches.[14,16] It does seem clear that the purely endoscopic approach causes less injury to nasal tissues, resulting in fewer nasal complications and improved nasal outcome.[17] Recognized nasal complications associated with microsurgical exposures include nasal septum perforation, saddle nose deformity, anesthesia of the upper lip and anterior maxillary teeth, fracture of the hard palate, anosmia, fracture of the orbit or cribriform plate, and bleeding (**Fig. 4**). In a review of 150 pure endoscopic transsphenoidal resections, 10% of the patients had hyposmia and 2% had anosmia, 0.7% had a serious postoperative bleeding complication, and no other nasal complications were recorded.[18] However, it has been argued that most patients recover quickly with few nasal complications after the microsurgical resections as well.[16] Identifying small differences in complication rates are not possible without large randomized trials. Nevertheless, published results confirm that the purely endoscopic endonasal approach for the treatment of pituitary adenomas is at least as safe and efficacious as microsurgical techniques, and can offer faster recoveries and return to normal lifestyle (**Figs. 5** and **6**).

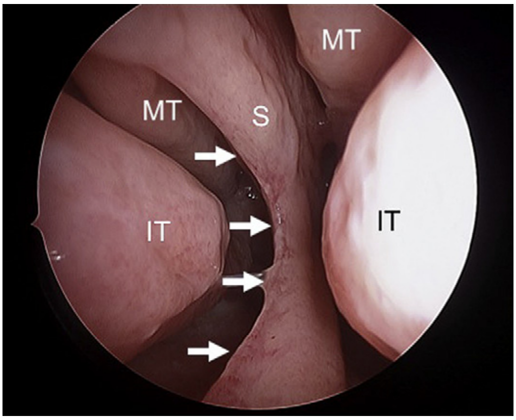


**Fig. 4.** Large nasal septal perforation (*arrows*) as a complication in a patient who was previously treated with a transseptal transsphenoidal surgery. IT, inferior turbinate; MT, middle turbinate; S, septum.

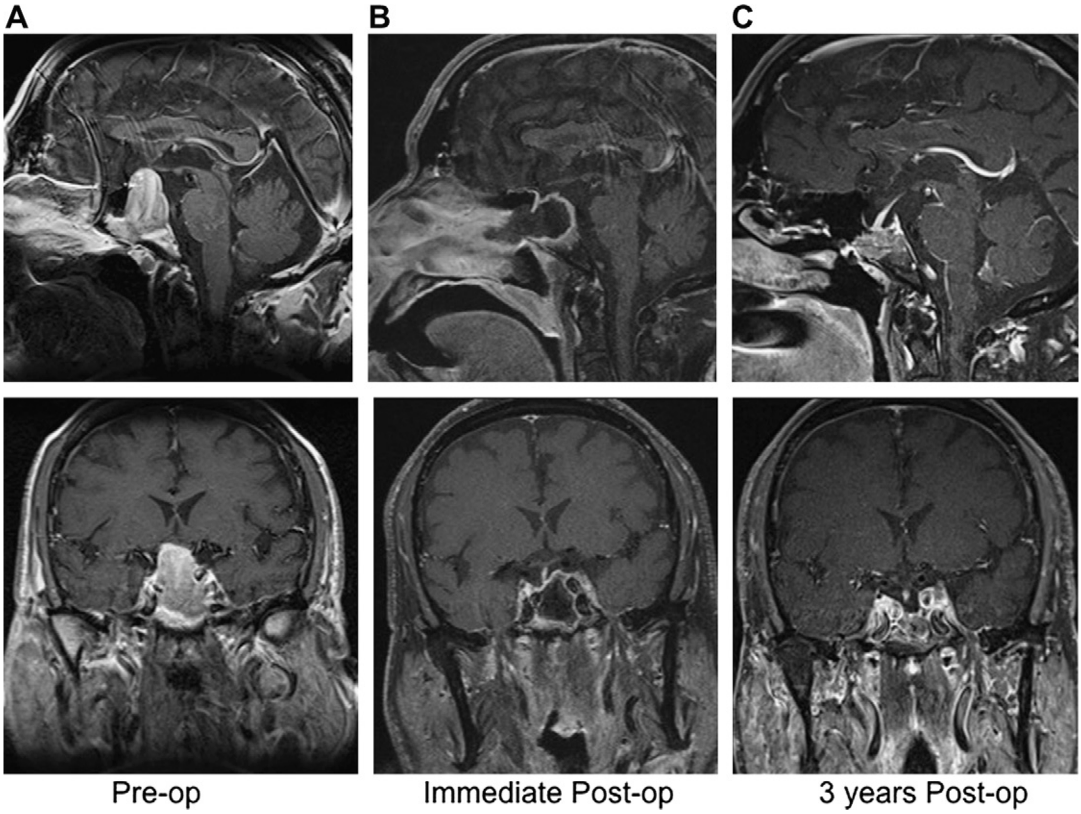


**Fig. 5.** Example case of a large pituitary adenoma with suprasellar as well as sphenoidal extensions before (*A*), immediately after (*B*), and 3 years after (*C*) endoscopic endonasal resection.

## EXTENDED ENDOSCOPIC ENDONASAL APPROACH

Emboldened by the success of treating pituitary adenomas with an endonasal transsphenoidal approach and armed with new technology including improved endoscopes, neuronavigation systems, and specialized instrumentation, surgeons began seeking to expand the potential applications of this technology. Endoscopic endonasal approaches are now being used to treat a wide range of midline anterior skull base lesions. Dehdashti and colleagues[9] recently reported on the use of the endoscopic endonasal approach to treat 22 patients with lesions extending from the frontal sinus to the inferior clivus and foramen magnum. These lesions included 6 craniopharyngiomas; 4 esthesioneuroblastomas; 3 giant pituitary macroadenomas; 2 suprasellar Rathke pouch cysts; 2 angiofibromas; and 1 each of suprasellar meningioma, germinoma, ethmoidal carcinoma, adenoid cystic carcinoma, and suprasellar arachnoid cyst. Achieving a gross total resection is clearly more difficult in these complex cases than for typical pituitary adenomas, with a reported gross total resection rate of 73% for these diverse pathologies. However, the study highlights the ever-expanding indications for endoscopic endonasal skull base surgery.

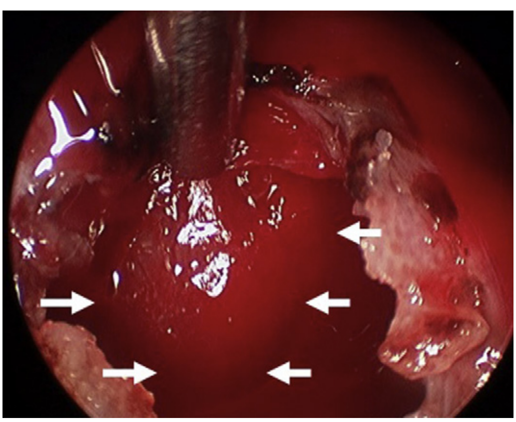

**Fig. 6.** Intrasellar view of normal pituitary gland (*arrows*) after excision of the adenoma.

The extended endonasal approach proves most advantageous in the treatment of skull base tumors in situations in which traditional open approaches are associated with significant morbidity. In particular, the authors discuss in greater detail the literature regarding the surgical management of particularly challenging anterior skull base pathologies, including craniopharyngiomas, tuberculum sellae meningiomas, and other more invasive tumors, including esthesioneuroblastoma and chordoma.

## *Tuberculum Sellae Meningiomas*

Tuberculum sellae meningiomas provide a difficult surgical challenge owing to the density of the tumor tissue and adherence to vital structures including the anterior circulation arteries, pituitary gland and stalk, and cranial nerves. Classically, the pterional transsylvian approach is used, often in conjunction with an orbitofrontal osteotomy. An endonasal approach offers the opportunity to avoid potential cosmetic challenges, including postoperative enophthalmos, temporal wasting, and a large surgical scar, while also allowing for early obliteration of the tumor's vascular supply, thereby minimizing blood loss, and elimination of the need for brain retraction.

A detailed description of the endoscopic endonasal surgical approach has been recently reported.[19] One of the unique challenges to resecting tuberculum sellae meningiomas using an endonasal endoscopic approach is to first achieve adequate bony exposure of the ventral surface of the mass. The posterior border of the planum sphenoidale is identified by the sharp angle created at the junction with the anterior surface of the sella, while the medial opticocarotid recesses identify the lateral borders. After the mucosa is elevated, the bone is removed with a drill and rongeurs. Once the ventral surface of the mass is exposed, the ventral blood supply of the tumor can be obliterated with electrocautery. Being able to attack the blood supply of the mass early in the procedure allows for a near bloodless field. The dura can then be opened and the tumor debulked from within. After debulking the mass, the arachnoid plane around the tumor can typically be identified, and the lesion can be carefully dissected away from the ventral forebrain with no brain retraction. The magnified view that the endoscope provides allows for careful microdissection of the tumor capsule away from vital structures. After the mass has been resected, the anterior skull base is reconstructed using strategies described later.

de Divitiis and colleagues[19] reported their experience using the extended endoscopic trans sphenoidal approach to treat 6 patients with tuberculum sellae meningiomas. Of these patients, 2 had tumors less than 2 cm in size and 4 had tumors 2 to 4 cm in size. A gross total resection was achieved in 5 patients. More than 90% of the tumor was resected in the sixth patient, who had residual tumor within the optic canal on postoperative imaging. Four of the patients who complained of preoperative visual deficits had complete resolution of their symptoms postoperatively. The complications cited included new diabetes insipidus in 1 patient and CSF leak in 2 patients; of these 2 patients, 1 ultimately had an intraventricular hemorrhage during the third revision of the leak repair and died. These results demonstrate the promise of the endoscopic endonasal approach and the importance of careful preoperative patient selection, and illustrate the importance of skull base reconstruction and dural repair.

An alternative minimally invasive approach for resection of tuberculum sellae meningiomas is the supraorbital craniotomy via an eyebrow incision. This technique is discussed in detail elsewhere in this issue. This method is effective to safely and completely remove these tumors, while still achieving excellent cosmetic results and minimizing recovery time. As such, surgeons have several good options as to which operation is likely to be the most effective and least morbid for each particular patient. A recent study that addressed this issue found that visual improvement and tumor extent of resection rates were similar between endonasal and supraorbital treatment groups; however, the complication rate was higher in the endonasal treatment group because of postoperative CSF leak.[20] These investigators suggest that tumors larger than 3 cm or extending beyond the supraclinoid carotid arteries should be approached via craniotomy (**Fig. 7**). The senior author (C.T.) uses the location of the anterior cerebral vessels as the main criterion for approaching these tumors from above or below. If there is a "cortical cuff" of gyrus rectus separating the posterosuperior dome of the meningioma from the anterior cerebral vessels, the authors favor an endonasal approach. Most olfactory groove and small tuberculum sellae meningiomas are grouped into this category. If the anterior cerebral vessels are intimately involved or indeed surrounded by tumor, a transcranial approach is recommended, of which the eyebrow minicraniotomy is the authors' preferred option.

Other reports do not separate supraorbital approaches from other transcranial approaches, but note similar results overall. For example, one series suggested a lower risk of visual worsening in patients treated with an endonasal approach compared with those treated transcranially.[21]

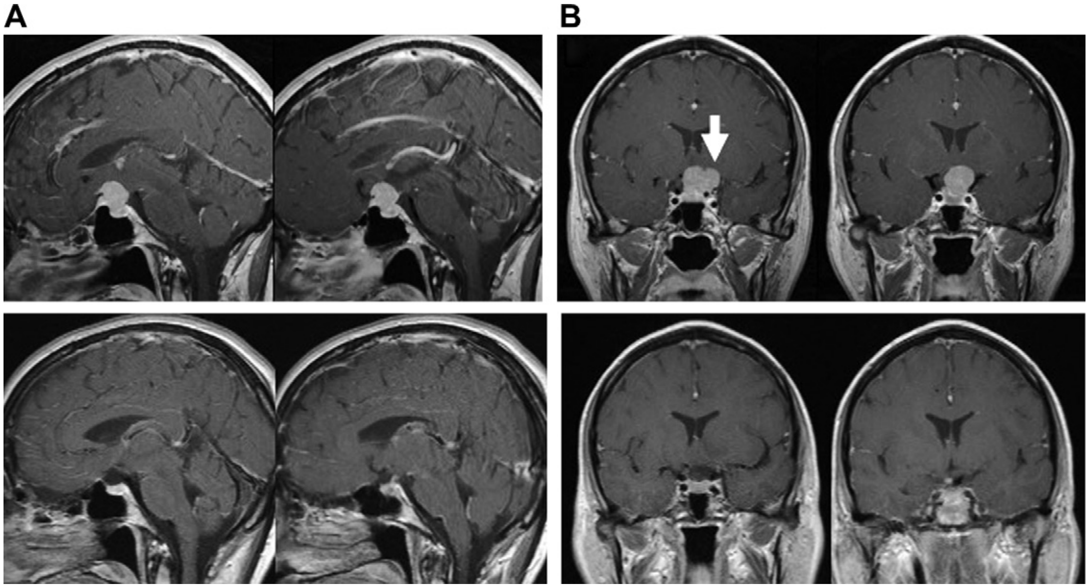


**Fig. 7.** Example case of tuberculum meningioma—which approach to use? This patient underwent a supraorbital craniotomy, given the lateral extent of the tumor (*arrow*). A complete excision was achieved as shown in the sagittal (*A*) and coronal (*B*) T1 postgadolinium images. Top row: preoperative; bottom row: postoperative.

These investigators, like Fatemi and colleagues,[20] further acknowledge the difficulties of skull base repair and CSF leak after an extended transsphenoidal resection. A different small case series reported improved visual acuity in patients treated with the endonasal approach compared with those treated with a transcranial approach, yet there was no difference in visual field outcomes between the different techniques.[22]

## *Craniopharyngioma*

Craniopharyngiomas are neoplasms derived from squamous epithelial remnants of the Rathke pouch, and can have both sellar and suprasellar components. The extended endonasal approach allows for direct early tumor visualization without brain retraction. Further, these tumors often recur after initial subtotal resections. Reoperation, irrespective of the approach used, in this setting is treacherous because of arachnoidal scarring and gliosis with increased rates of incomplete resection and a higher complication rate.[23] [Teo CNS] For patients requiring re-resection, the transsphenoidal approach is particularly appealing because it allows for an unaltered path to the tumor in those patients who have previously undergone resection via craniotomy. Furthermore, many patients with recurrent tumors have panhypopituitarism, so the preservation of the pituitary gland and pituitary stalk are not concerns during transsphenoidal reoperation. Another factor that lends itself toward endonasal treatment is a primarily retrochiasmatic tumor location (**Figs. 8** and **9**). These tumors, if approached via a subfrontal or transsylvian approach, require dissection around and under the optic nerves and chiasm, with the resultant risks of postoperative visual decline caused by manipulation or vascular compromise. The endonasal approach avoids such difficult dissection by its natural trajectory below and behind the optic apparatus, which is often elevated and displaced anteriorly by the tumor.

Cavallo and colleagues[23] described their experience using the extended endoscopic transsphenoidal approach to treat 22 patients who had previously undergone surgical resections of craniopharyngioma. A gross total resection was achieved in 9 patients and more than 95% of the tumor was resected in 8. Adherence to the optic nerves, perforating vessels, invasion of the hypothalamus, and parasellar or retroclival extension were identified as factors leading to a subtotal resection. Of 18 patients, 11 who had visual field deficits preoperatively experienced marked improvement and 6 reported that the defect normalized or had no change during follow-up, whereas 1 patient reported decreased vision in one eye and improvement in the other. CSF leak was reported in 13.6% of the patients. New-onset panhypopituitarism was identified in 2 patients. These results certainly compare favorably with the results of previous reports that used traditional open approaches.[24]

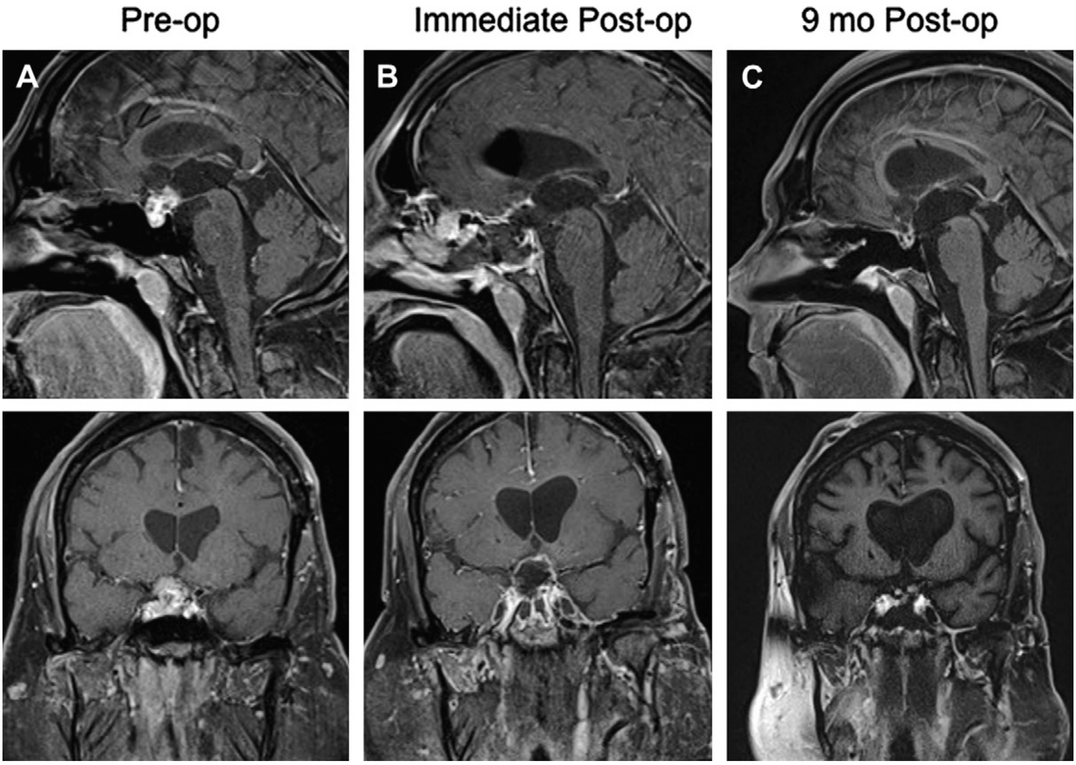


**Fig. 8.** Example case of a recurrent craniopharyngioma excised via an endoscopic endonasal approach. Column (*A*) shows preoperative images, column (*B*) shows immediate postoperative images demonstrating total resection, and column (*C*) shows images 9 months after surgery. Top row: sagittal T1 postgadolinium image; bottom row: coronal T1 postgadolinium image.

Like for tuberculum sellae meningiomas as discussed earlier, as well as for other suprasellar lesions, an alternative surgical option for craniopharyngioma removal is the supraorbital craniotomy. This minimally invasive approach is known to be safe and effective [Teo CNS], but only a single case series compares this technique directly with endonasal approaches in a cohort of patients with craniopharyngioma.[20] These investigators found a greater extent of resection and improved visual outcome in the cohort of patients treated with the endonasal approach, and

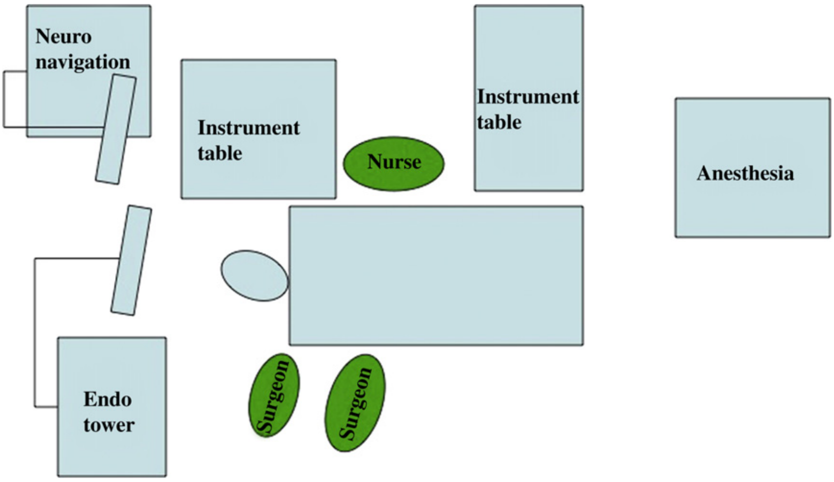


**Fig. 9.** Typical operating room setup for endoscopic endonasal surgery.

therefore recommended endonasal resection of retrochiasmal tumors over craniotomy. Conversely, the incidence of CSF leak and pituitary insufficiency was higher in patients treated with the endonasal approach than in those who underwent craniotomy. This series highlights the important considerations when choosing an approach for these difficult neoplasms, which are: lateral extent of the tumor—the more lateral the extent the more likely to approach the neoplasm transcranially; location of the chiasm—the more prefixed the more likely to approach transsphenoidally; preoperative hormonal and visual functions; and dural reconstruction. These issues require further study and additional case-control studies.

### *Esthesioneuroblastoma*

Esthesioneuroblastomas are malignant sinus tumors arising from the olfactory epithelium. These invasive neoplasms typically involve the superior nasal vault and anterior skull base. The traditional surgical approach involves a craniofacial resection, which carries with it significant morbidity, including tension pneumocephalus, extra-axial fluid collections, anosmia, and frontal lobe retraction injury.

However, the midline location of these tumors and lack of intradural invasion has led investigators to explore the role of the endonasal endoscopic approach in resecting these complex lesions. Folbe and colleagues[11] described their multicenter results on 23 patients with esthesioneuroblastoma treated with this minimally invasive technique. Of these patients, 19 presented with primary disease and 4 had recurrent disease. All but one patient was treated successfully with a purely endoscopic approach, and 16 patients were treated with postoperative radiation. All patients with primary disease and 3 of 4 with recurrent disease were tumor free at a mean follow-up of 45.2 months. Spinal fluid leak was reported in 4 patients. No new neurologic deficits or perioperative fatalities were reported. In their recent report on 10 patients with esthesioneuroblastoma treated with endonasal endoscopic resection, Castelnuovo and colleagues[25] reported no local or regional recurrence in 9 patients and a recurrence in the neck in 1. The investigators were also able to preserve the sense of smell on the unaffected side in all patients, something that they thought was only possible because of the improved visualization that the endoscope affords. The average hospital stay of 5 days further speaks to the advantages of this less invasive approach.

Additional support for the use of endoscopic approaches for the treatment of esthesioneuroblastoma comes from a recent meta-analysis by Devaiah and Andreoli,[26] who reviewed the outcome data for 361 patients with esthesioneuroblastoma and found that endoscopic surgery compared favorably with open surgery in terms of survival for less invasive tumors.

### *Chordomas*

Chordomas are another pathologic condition in which endoscopic endonasal approaches could greatly decrease the morbidity of resection. Chordomas are also discussed in another article elsewhere in this issue. Traditional approaches, including anterior transfacial, extended subfrontal transbasal, and lateral transtemporal approaches, are associated with significant morbidity. Hwang and Ho[27] described the use of the endoscopic endonasal approach coupled with neuronavigation to successfully treat 3 patients with large chordomas. Two of the patients underwent a single endoscopic procedure, and both were discharged home without complication on hospital day 3. The third patient had first undergone a craniotomy for resection of the superior portion of the mass and later underwent an endoscopic endonasal procedure to resect the residual inferior portion of the tumor. Fraser and colleagues[28] have subsequently reported their experience with endoscopic resection of chordomas in 7 patients. In 6 patients, a gross total resection was attempted. More than 95% resection was achieved in 5 patients, and 80% resection was achieved in the remaining case. One patient with multiple recurrent tumors underwent 2 intentionally subtotal palliative debulking procedures. No new neurologic deficits, intraoperative complications, or spinal fluid leaks were reported. Most of the patients received adjuvant radiation therapy, and all but the patient who underwent palliative surgery were alive and progression free at a mean follow-up of 18 months. These reports demonstrate the promise that the endoscopic approaches hold for the treatment of midline skull base lesions.

## LEARNING CURVE

One of the major challenges that neurosurgeons face in performing purely endoscopic endonasal resections of anterior skull base tumors is the learning curve associated with using the endoscope. The endoscope gives a magnified panoramic view of the sella and surrounding structures; however, standard endoscopes only provide a 2-dimensional (2D) view, making depth perception difficult. This technical limitation along with the unfamiliar ergonomics of operating while looking up at a screen can also initially be awkward for surgeons who are used to standard bimanual microsurgical techniques. Furthermore, neurosurgeons have historically had limited training and exposure to basic handling and use of endoscopes. Thus, working with an experienced team of otolaryngologists who often use nasal endoscopy on a daily basis in clinic and surgery can shorten the learning curve of neurosurgeons acquiring new skills.[29] It is well documented that the complication rate decreases, the operative time decreases, and the extent of the resection increases as the surgeon becomes more familiar with the use of the endoscope.[18,30]

Recently, 3-dimensional (3D) endoscopes have been developed to provide improved depth perception and potentially shorten the learning curve for less experienced surgeons. Tabaee and colleagues[31] have described their experience using a 3D endoscope manufactured by Visionsense Ltd, Petach-Tikva, Israel, to perform 13 endonasal endoscopic transsphenoidal surgeries. The investigators have reported improved depth perception without physical discomforts, such as headache, nausea, or ocular fatigue. The authors have used a similar 3D endoscope and have had a similar experience.

## TECHNICAL CONSIDERATIONS

### *Equipment*

Multiple types of endoscopes and supporting equipment are commercially available for use in endoscopic endonasal surgery. Flexible or rigid endoscopes can be used. Rigid endoscopes are most commonly used because they are readily available in most hospitals, afford excellent high-resolution images, often in HD, are straightforward for surgeons to maintain and change viewing orientation, and can also serve as simultaneous intranasal retraction. The standard rod-lens endoscopes are available in several diameters and viewing angles. Typically, 0° and 30° optics are sufficient, but 45° or 70° optics are occasionally helpful. As the endoscope diameter decreases their fragility increases, and small telescopes (eg, 2 mm) can be easily damaged or broken entirely by improper handling or cleaning. The 4-mm-diameter, 18-cm-long telescopes afford excellent viewing image size, are robust to tolerate manipulation without breaking easily, are strong enough to retract structures such as the turbinates, allow excellent working space around the scope for other instruments, and do not block access to the nares. A lens cleansing or irrigating system (ie, sheath) is helpful to quickly clear blood or debris from the lens and increase efficiency.

Several manufacturers produce cameras that easily clip-mount to endoscopes, and there are options for standard or HD resolution. The same cameras can be used for other types of endoscopic surgery, such as thoracoscopy or laparoscopy, increasing the use and compatibility within hospitals. Likewise, light cables and sources are prevalent, interchangeable, and in some cases built into operating rooms. Standard liquid crystal display flat-screen monitors are used. Finally, a recording system or hard drive is helpful to save photographs and videos taken during surgery, for cataloging in the patient's medical record, for using for study purposes, or for instructional use. This equipment is ideally situated on a portable cart for easy transfer from one operating room to another, or can be boom-mounted within a given operating room to use space efficiently. Overall, viewing technology is advancing quickly, and video "chip-on-the-tip" scopes, smaller diameter scopes, and 3D systems are now being investigated.

Regarding surgical instruments, length, diameter, and physical size (ie, the ability of an instrument to fit in the endonasal corridor) are the only constraints to instrument suitability in endonasal surgery. Therefore, many standard microneurosurgical instruments can be used. However, because the view from endoscopes is at the tip and working instruments are passed along the shaft of the endoscope, bayoneted instruments are not required. In fact, straight instruments are preferred because they allow 360° rotation and tip usability without the bayoneted shaft impeding or affecting an adjacent instrument. This fact also obviates the need and expense of having multiple "right-" and "left-" or "up-" and "down-" angled instrument tips relative to the shaft.

Nevertheless, there are shortcomings in endonasal surgical instrumentation. Specifically, the ability to suture is extremely difficult. In addition, standard bipolar forceps are fairly ineffective and difficult to use because of their size and the tips being forced closed or prevented from opening by the surgical corridor. Longer and thinner diameter forceps are available, but these are limited by scissoring of the tips. Pistol-grip bipolar forceps are being developed to circumvent these problems, but they still require refinement.

### *Neuronavigation*

Nowhere is it more critical to have a clear understanding of the relevant anatomy than during extended endonasal endoscopic surgery. Poor sphenoid sinus pneumatization or distortion of the anatomy from an expansile mass can further complicate the anatomy. Modern systems allow for navigation to be based off CT images to allow for high resolution of bony anatomy and on MR images to detail soft tissue and vascular structures. Neuronavigation can provide critical information before beginning the exposure to allow precise identification of the carotid arteries and optic nerves. The tumor margins can also be identified early in the case. This information allows for a wide bony exposure with less chance of injuring vital structures. Further, because most lesions treated using the endoscopic approach are intimately associated with the skull base, brain shift during surgery has little impact on the accuracy of neuronavigation during the procedure, improving its usefulness during tumor resection. Thus, neuronavigation should be routinely used in extended endonasal endoscopic cases.

### *Basic Operating Room Setup*

Proper setup of the operating environment is important for effective and comfortable endonasal surgery. Of utmost importance are positions of viewing screens such that they can all be viewed comfortably from the surgeons' working position. As illustrated in **Fig. 9**, the endoscope screen and neuronavigation system are behind the patient's head to allow straight-on viewing by the surgical team. The scrub nurse should be directly opposite the surgeon to facilitate instrument transfer without the surgeon having to look away from the screen. The patient's head can be tilted away from and rotated toward the surgeon to aid access to the nares and improve surgeon comfort.

## SPHENOIDAL APPROACH

The endonasal approach to the sphenoid sinus can be accomplished using a unilateral or bilateral nares technique. The binaris approach generally affords an improved opportunity for the surgeon to work using a bimanual method. This approach is recommended when first learning, for complex tumors requiring extended transsphenoidal approaches, and for moderate- and larger-size tumors.

The usual endonasal approach begins with mucosal decongestion using topical cocaine or oxymetazoline-soaked cottonoids followed by sphenopalatine blocks using local anesthetics. Next, the middle turbinates can be lateralized or partially resected depending on the surgeon's preference. This step allows visualization of the natural sphenoid ostia, which can be entered and enlarged. The overlying mucosa can be resected with oscillating debriders, while rongeurs or a drill can be used for bony removal of the anterior sphenoid. In addition, a partial posterior septectomy can be performed to facilitate bilateral access into the sphenoid sinus. The sphenoidotomy should be large, such that multiple instruments and the endoscope itself can be passed through the sphenoidotomy without being forced against each other by the bony edges of the remaining anterior sphenoid bone.

The sella and parasellar bony structures are immediately evident on entering the sphenoid sinus. At this point, the operative techniques for an endoscopic endonasal approach are the same as those for microsurgical approaches. In brief, intrasphenoidal septations should be taken down with a drill or rongeurs to complete the sellar exposure. Normal landmarks should be identified and confirmed as needed with neuronavigation. The mucosa overlying the bony entry point (eg, the midline sella for a pituitary tumor) is opened and cauterized to expose the bony anterior face of the sella. Because the sella is often enlarged by slow growing macroadenomas, bony defects are often seen after the mucosa is opened. If no defect is present, an opening can be created with a curet, drill, or small osteotome. The bony opening is then enlarged with rongeurs or a drill to extend from the ipsilateral carotid protuberance to the contralateral carotid protuberance, and from the floor of the sella to the planum sphenoidale inferosuperiorly. The dura is incised, and tumor debulking is performed with ring curettes, followed by a capsular dissection if possible. The normal pituitary gland should be preserved if possible.

## CLOSURE TECHNIQUES

One challenging aspect of endoscopic endonasal surgery is achieving an adequate dural repair to prevent postoperative CSF leaks, which is particularly true when more complex extended endonasal procedures are attempted and bony and dural openings are larger. Several techniques have been described and are briefly reviewed here. After resection has been completed and hemostasis assured, a piece of collagen matrix or dural substitute is placed on the diaphragma sellae. A fat graft is then lodged within the dural defect such that a portion of the graft is intradural.[32] Some researchers advocate repairing the sella with autogenous bone graft.[30] The bone can be collected from the rostrum of the sphenoid, middle turbinate, or sphenoid septum, and this bone will support the fat graft. Alternatively, a sealant or tissue glue may be used. Anterior support of the dural repair may be achieved by sphenoidal packing with fat or cellulose sponges.

In cases in which a large dural defect is encountered intraoperatively or a postoperative CSF leak occurs, additional strategies have been suggested. One approach is to create a pedicled nasal septal flap based on the posterior nasal artery.[33] The flap can be positioned over the fat graft and then secured with tissue glue/sealant. The closure can be held in place with Nasopore sponges (Stryker, Kalamazoo, MI, USA) and a Foley catheter balloon. The balloon can be removed 3 to 5 days after surgery.[33] Finally, a novel technique has been reported to allow for creation of an endoscopically harvested vascularized pericranial flap that can be used to repair anterior skull base defects.[34] Two small incisions are made behind the hairline and a third along the natural skin crease of the glabella. The pericranial flap is created and passed inferiorly. After a small nasal osteotomy is created through the glabellar incision, the flap is passed into the nasal cavity. The vascularized pericranial flap is then positioned over the defect. Any time there is concern for a CSF leak, a lumbar drain can be placed and maintained for several days.

## SUMMARY

As technological advancements in endoscope technology and neuronavigation systems have made their way into the operating room, investigators have only recently begun to discover the true potential of the extended endonasal endoscopic approach for anterior skull base lesions. With improved visualization, less brain retraction, and the promise of less morbidity than traditional open approaches, the indications will certainly continue to expand as surgeons gain experience and comfort with these new techniques. Further studies are required to more clearly identify factors influencing patient selection and to compare the long-term outcomes of endoscopic endonasal surgery with craniotomy for these expanding applications.

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