Expanded Endoscopic Endonasal Approaches to Skull Base Meningiomas

J. Drew Prosser, M.D.¹ John R. Vender, M.D.^{1, 2} Cargill H. Alleyne, M.D.² C. Arturo Solares, M.D.^{1, 2}

¹Department of Otolaryngology, Georgia Health Sciences University, Augusta, Georgia

²Department of Neurosurgery, Georgia Health Sciences University, Augusta, Georgia

Address for correspondence and reprint requests C. Arturo Solares, M.D., Assistant Professor, Co-Director of the GHSU Skull Base Center, Department of Otolaryngology, 1120 15th Street, BP 4109, Augusta, GA 30912 (e-mail: csolares@georgiahealth.edu).

J Neurol Surg B 2012;73:147–156.

Abstract

Keywords

- skull base
- endoscopic
- endonasal
- meningioma

Anterior cranial base meningiomas have traditionally been addressed via frontal or frontolateral approaches. However, with the advances in endoscopic endonasal treatment of pituitary lesions, the transphenoidal approach is being expanded to address lesions of the petrous ridge, anterior clinoid, clivus, sella, parasellar region, tuberculum, planum, olfactory groove, and crista galli regions. The expanded endoscopic endonasal approach (EEEA) has the advantage of limiting brain retraction and resultant brain edema, as well as minimizing manipulation of neural structures. Herein, we describe the techniques of transclival, transphenoidal, transplanum, and transcribiform resections of anterior skull base meningiomas. Selected cases are presented.

Nearly one in four intracranial tumors are meningiomas, of which 40% arise from the base of the anterior, middle, or posterior cranial fossa.¹ Nearly half of these basal meningiomas are located in the anterior cranial fossa bounded posteriorly by the lesser sphenoid wing and the anterior margin of the chiasmatic groove.^{2,3} Meningiomas of this area typically arise from the cribriform plate, orbital roof, planum sphenoidale, anterior clinoid process, tuberculum sellae, cavernous sinus, or sphenoid wing and may extend into the orbit, paranasal sinuses, or infratemporal fossa.² Sphenoid wing meningiomas account for almost half of the anterior fossa tumors, while tuberculum sellae tumors and olfactory groove tumors account for the majority of the other half.¹ These slow growing tumors can often reach very large sizes before causing clinical symptoms despite massive displacement of the intracranial contents. However, when certain critical structures (i.e., the optic nerves) are compressed, even small tumors cause early presenting signs and symptoms. Due to the indolent nature of the majority of these tumors, as well as relative subtlety of the symptoms there is often a delay in diagnosis leading to further enlargement of the lesion. According to their origin and extension, meningiomas of the anterior

cranial fossa can be classified as olfactory groove, tuberculum sellae, sphenoid ridge, cavernous sinus, or sphenoorbital.⁴

Anterior cranial base meningiomas have traditionally been addressed by craniotomy. Various approaches exist based on tumor size, location, and relationship with surrounding structure. Traditional options include frontal, frontolateral, fronto-temporo-sphenoid, orbitozygomatic, bifrontal, unilateral subfrontal, or supraorbital approaches.⁴ However advances in surgical instrumentation, endoscopic techniques, and surgical navigation have lead to an increasing role of endoscopic endonasal surgical approaches for the operative management of skull base pathology.⁵ Driven by the revolution of endoscopic endonasal pituitary surgery, expanded endonasal approaches have been developed in an attempt to decrease morbidity. The use of the endoscope affords narrow corridor access with near-field magnification of vital structures and tissue (both tumor and normal parenchymal tissue). A variety of factors including anatomical restrictions on surgical access, the histopathology and biological behavior of the disease, technical challenges, special patient populations, expertise of the surgical team, and available resources can pose limitations.⁵

received

February 5, 2011

accepted after revision

October 11, 2011

published online

February 22, 2012

Copyright © 2012 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.
Tel: +1(212) 584-4662.

DOI <http://dx.doi.org/10.1055/s-0032-1301391>.
ISSN 2193-6331.

Unlike endoscopic endonasal approaches to sellar pathology, there is a relative paucity of literature regarding endoscopic endonasal approaches to meningiomas. Much of the literature involves the collective experience of an approach rather than experience with specific pathologies (i.e., anterior cranial base meningiomas). This is presumably due to the relative rarity of basal meningiomas, and selected centers in which the expanded endoscopic endonasal approach (EEEA) is widely utilized for nonpituitary pathologies. The EEEA has the advantage of reducing the extent of bone removal/resection, eliminating brain retraction, and minimizing manipulation of neural and vascular structures, which may reduce morbidity, shorten postoperative recovery times, and improve outcomes (such as ophthalmologic function) by approaching these tumors (which traditionally displace the optic apparatus superiorly or posteriorly) from an anteromedial and inferior trajectory.⁶ Furthermore, because of the site of origin of these tumors, the primary vascular supply is cranial base dura. Early access to this vascular supply can greatly reduce intraoperative blood loss and facilitate removal. Further advantages of this approach include removal of involved bone and dura as a part of the approach which allows a Simpson Grade I resection. Early tumor devascularization is accomplished in many cases as the anterior and posterior ethmoidal arteries are exposed and may be divided during the early steps of the approach (in the case of olfactory groove meningiomas). Finally, and perhaps most importantly, direct tumor access without exposure, retraction, or manipulation of edematous frontal lobes is accomplished, as well as relative avoidance of an ischemic, compressed optic apparatus while performing complete bilateral optic canal decompression.⁷ These advantages have led to an increased interest in the EEEA for the treatment of skull base meningiomas. Here, we describe the techniques of transclival, transphenoidal, transplanum, and transcribiform resections of skull base meningiomas.

Operative Technique

Preoperative Evaluation

Preoperative evaluation must include imaging. At our institution both magnetic resonance imaging (MRI) and fine-cut CT scans are obtained and used intraoperatively for image guidance (Medtronic Fusion, Minneapolis MN). MRI is valuable for confirming the relationship of the tumor to critical structures. Fine-cut CT details the bony anatomy and can be coupled with angiography to define the relationship to vascular structures. Preoperative evaluation should elicit any previous nasal or cranial surgeries and document a thorough ophthalmologic (including visual field testing) and cranial nerve examination.

Special Instrumentation

While the majority of the initial dissection is done with standard endoscopic sinus surgical instruments, expanded endonasal approaches to skull base meningiomas do require special instrumentation (►Fig. 1). We find a Mayfield head clamp to be particularly helpful in providing complete im-

mobilization, a requirement for fine work near critical structures. Several rigid endoscopes (0, 45, and 70 degree) are critical for addressing pathology ranging from the clivus to olfactory grooves. Multiple high-definition monitors allow for ergonomic head positioning for both operating and assisting surgeons in the 4-hand technique. Some authors find irrigating sheaths helpful, although these are not required. Multiple sizes of Kerrison rongeurs are useful for removing bony partitions of the skull base and providing a wide sphenoidotomy. A high-speed drill with extended 4 mm round course diamond burr is utilized for drilling of the sphenoid septations and skull base.

For the soft tissue dissection, the Kassam/Snyderman Take-apart® bipolar forceps (Karl Storz, Tuttlingen, Germany) are particularly useful for hemostasis in cases of skull base meningiomas. Due to the 20 cm working length, deep anatomic regions can be easily addressed. Also, microdissection instruments with extended reach are required to perform the tumor resection and mobilization. A full set of suction devices that allow for the suction intensity to be regulated such as Fukushima suctions are paramount and can be used to perform a significant portion of the dissection. The use of an endonasal ultrasonic aspirator (multiple brands) is helpful, albeit not necessary for most cases. For closure, an extended needle-tip bovie with the tip bent 70 degrees is essential to harvesting of nasal septal flap.

Patient Positioning and Preparation

The patient is positioned supine with the head in a neutral or slightly extended position. In these expanded approaches, a Mayfield head holder is utilized for complete immobilization during detailed drilling and dissection near critical structures. Neuromonitoring may be used in selected cases. Oxy-metazoline-soaked pledgets are placed bilaterally to decongest the nasal cavity. All patients are given a third or fourth generation cephalosporin (clindamycin if allergic) for antibiotic prophylaxis. The bed (which has been flipped so that the patient's head is at the foot of the bed allowing placement of pedals underneath) is then rotated 180 degrees. Placement of the video tower, additional monitor, image guidance system, surgeon, assistant, and scrub tech are shown in ►Fig. 2, facilitating a two-surgeon technique.

Initial Exposure

The initial exposure has been extensively detailed in previous publications,^{6,8,9} and serves to facilitate bimanual dissection which is the key to the two-surgeon technique. The ability to use both hands (traditionally with suction in the non-dominant hand and a drill, dissector or elevator in the dominant hand) is paramount in keeping a clear operative field and allowing safe dissection. The initial exposure for all expanded approaches begins with accessing the sphenoid sinus. A zero-degree endoscope with handheld irrigation or an irrigating sheath is used for the initial approach. Traditional sinonasal techniques are used to dissect posteriorly toward the sphenoid sinus on both sides of the nasal cavity. Depending on the degree of required exposure either a transnasal or a trans-ethmoidal route can be utilized. The sphenoid os is identified

Figure 1 Special instrumentation utilized for expanded endonasal approaches to skull base meningiomas. Microscissors including up turned, straight, right and left (right and up turned shown in top left). Fukushima suctions (shown bottom left). Endoscopic bipolar forceps (shown top right) and multiple sizes of Kerrison rongeurs (shown bottom right).

and wide bilateral sphenoidotomies are performed, extending laterally to the level of the medial pterygoid plates. It is paramount to ensure adequate exposure not only for visualization but also to ensure unhindered access for control in the event of critical bleeding. In the event of bleeding, the endoscope and instruments must be maneuverable without hindrance from bone or soft tissue. The posterior septal artery should be preserved for later use if a nasal septal flap is needed for reconstruction. A posterior septectomy is performed to facilitate the use of multiple instruments simultaneously.

Next access to the pituitary fossa is obtained. The sphenoid septations are carefully removed with a biter or drill with the understanding that these lead to the carotid canal. Dissection is extended anteriorly removing posterior ethmoid air cells which define the planum-tuberculum junction. Finally, the sphenoid floor is removed to the level of the clival recess which allows a more caudal to rostral approach into the sellar and suprasellar space. The sphenoid sinus mucosa is removed and venous bleeding controlled with bipolar or warm irrigation depending on the preference of the surgeon.

With this exposure completed vital landmarks are now readily identifiable (► **Fig. 3**), including the medial and lateral opticocarotid recesses (OCR), the carotid protuberance within the parasellar space, the sellar face, clival recess, and strut of tuberculum bone overlying the superior intercavernous sinus

(SIS). Attention is then directed toward the portion of the tuberculum which connects the two medial clinoids and mOCRs. This can be drilled eggshell-thin and then removed by gentle fracture along with the medial clinoids. This exposure now allows for access to the carotid canal, optic canal, sella, frontal fossa, and cavernous sinus. With this exposure, expanded approaches can now be performed safely to address lesions in defined locations.

Transsphenoid Approach

The initial approach as described above allows complete access to the sphenoid sinus. With this access further bony structures can be drilled egg-shell thin and then removed by careful fracture with a freer. Along with image guidance, a Doppler can be used to further identify the location of the carotid artery. For cavernous sinus meningiomas an incision is then made in the dura in a paramedian location with curved microscissors. The tumor is then identified and the intrasellar portion of the tumor is removed to decompress the pituitary gland and the optic apparatus. For intradural dissection, the principles of microsurgery are utilized as the foundation of endoscopic neurosurgery. Inherent in these principles are internal tumor debulking followed by capsule mobilization, extracapsular dissection of neurovascular structures, focal coagulation, followed by capsule removal. Debulking proceeds in several different manners depending upon tumor

Figure 2 Operating room set-up for expanded endoscopic endonasal approaches.

consistency. Mostly our group utilizes a slotted suction tip in the left or nondominant hand which provides gentle countertraction while maintaining a clean/dry operative field. The right or dominant hand manipulates a dissecting or debulking instrument. In soft lesions, a malleable 6- or 8-French suction, or pituitary ring dissectors work well. For firmer tumors, an ultrasonic aspirator or fine cutting forceps with blunt ends facilitates removal, however each of these is surgeon dependent.

These techniques are continued for internal debulking until the tumor capsule moves freely to countertraction applied with the suction. Grasping instruments should be avoided for countertraction as they have the potential to tear extracapsular vessels. Following capsule mobilization, extrac-

apsular dissection proceeds, preferably with sharp instrumentation, taking care to identify and protect critical neural structures with a neurosurgical patty. Endoscopic bipolar can then be used to coagulate the tumor capsule, avoiding thermal injury to critical neurovascular structures. If at any point in the dissection the tumor is unable to be removed while adhering to these principles, staging or conversion to open procedures should be considered. Following removal reconstruction proceeds as described below.

Transclival Approach

Once the initial exposure is complete as described above, the superior portion of the clivus is exposed by drilling the posterior wall of the sphenoid sinus starting at the sella

Figure 3 Intraoperative view of the base exposure needed to identify critical landmarks prior to initiating expanded modules. CP, the carotid protuberance; CR, clival recess; NSF, nasal septal flap; OCR, optico-carotid recess; PS, planum sphenoidale; SF, the sellar face.

and working inferiorly. Exposing the sella is needed in some cases to elevate the pituitary gland to gain access to the posterior clinoids. The vertical portions of the carotid arteries can be exposed bilaterally with the aid of surgical navigation and Doppler technology as needed, while working superiorly to inferiorly to expose the overlying dura. Adequate carotid exposure is paramount when the tumor extends laterally into the cavernous sinus. For tumors lying posterior to the pituitary, it is possible to mobilize the gland to obtain exposure and facilitate removal. For tumors extending inferiorly in the clivus below the sphenoid sinus, an inferiorly based pharyngeal flap can be made such that the anterior aspect of the inferior clivus is exposed. This bone can be drilled back until dura is exposed working as inferiorly as the tumor dictates, superiorly to the pituitary fossa and laterally to the eustachian tubes. Complete clival exposure can be obtained by drilling laterally to the vertical segment of the internal carotid arteries, exposing the bony canals of the sixth cranial nerve and medial aspects of the occipital condyles, if necessary. Generous removal of bone facilitates removal and improves safety as discussed previously. This wide exposure facilitates visualization and access in the event of critical bleeding. “Pulling” the tumor into view should be avoided for fear of neurovascular injury and inability to evaluate margins or completeness of the resection.

Once any bony obstructions are removed, a vertical incision is made in the dura in a capital “I” form to then be reflected laterally. Care should be taken to avoid the basilar artery and other vascular structures of the posterior circulation. Working from medial to lateral helps avoid damage to the sixth cranial nerves. The tumor is then identified and

removed using the techniques of intradural dissection described above. For tumors extending posterior to the carotid arteries, the carotids should be fully dissected and skeletonized. At this point they can be gently mobilized laterally. Angled scopes and instruments may be used to remove any residual disease and evaluate the completeness of resection. Once resection or debulking is completed, reconstruction proceeds as described below.

Transplanum Approach

Once the initial approach is completed the planum-tuberculum junction should be identified. Any residual ethmoid septations are then removed so that the anterior cranial base is easily seen from the sella to the posterior ethmoid artery and laterally to the lamina papyracea providing for complete exposure. To minimize the risk to olfaction, the skull base is not skeletonized anterior to the posterior ethmoid artery, the most rostral aspect of the nasal septum is left attached to the skull base and one middle turbinate is left intact if possible. Next, the planum sphenoidale is drilled thin working from anterior to posterior. Once thinned it is fractured inferiorly using a blunt elevator/dissector. Dissection is carried to the sella and the SIS is exposed. This allows for direct access to tumor in the suprasellar space. Removal of this segment of bone is sufficient to provide access to tumor in this location and it is not necessary to transect the SIS.

Next the middle clinoids/mOCRs are drilled and removed. When drilling in this area it is important to use caution and copious irrigation to protect the optic nerves from thermal injury. Bleeding in this area is common and should be controlled with pressure or gelfoam which has been coated in thrombin. Kerrison rongeurs are helpful in removing the bone overlying the cavernous carotid lateral to the sella. Small bites and clear visualization help prevent inadvertent carotid injury. Controlled removal of this bone is essential and care must be taken to avoid uncontrolled fracture. Again the principles of wide exposure necessitate removing the remainder of the medial optic strut and middle clinoid process. This allows safe and complete access to the tumor in the intradural optico-carotid recess. Again “pulling” the tumor into the field of vision should be avoided because of the risk of vascular injury and the inability to evaluate the margins of the tumor.

At this point, the optico-carotid recess should be inspected and any arterial vessels supplying the tumor should be coagulated. It is not uncommon for anterior skull base meningiomas to have an arterial feeder from the carotid at this point. The posterior ethmoid arteries can be ligated to provide additional devascularization. When this maneuver is performed, the arteries should be ligated as medial as possible to prevent inadvertent retraction of the artery into the orbit and subsequent retrobulbar hematoma. At this point, exposure of the dura should extend from the planum/cribriform junction to the clival recess and laterally from lamina papyracea to lamina papyracea. The dura is then incised and intradural resection proceeds as previously described. Once the tumor has been removed, reconstruction can proceed as described below.

Transcribiform Approach

For a transcribiform approach, the initial exposure is performed followed by the bony exposure for the transplanum approach. Following this dissection is carried anteriorly until complete total ethmoidectomies have been performed bilaterally. At this point, additional anterior exposure can be obtained to the posterior table of the frontal sinus by a frontal recess approach, with medial widening of the frontal recesses and removal of the frontal nasal septum and inferior frontal sinus septum (endoscopic modified Lothrop or Draf III).¹⁰ At this point, one should have complete exposure to the anterior cranial base from the posterior aspect of the frontal sinus to the sella, and laterally to the lamina papyracea bilaterally. The skull base should be sufficiently skeletonized such that the anterior and posterior ethmoid arteries are easily identified and may be controlled.

At this point, the superior portion of the nasal septum is removed creating a large common cavity from the frontal sinus to the rostrum of the sphenoid along the cranial base. This maneuver is likely to compromise olfaction, however, due to the location of the pathology it is unlikely that olfaction would be intact preoperatively. Now drilling proceeds from the frontal recess or posterior table of the frontal sinus working posteriorly. For tumor devascularization, the anterior and posterior ethmoid arteries are coagulated as they are encountered at their medial aspect to allow for control and prevent retraction into the orbit. Removal of the soft tissue overlying the bone of the olfactory sulcus will aid in drilling. As the crista galli is approached, patience is required as it is attached to the falx and will require a significant amount of drilling to safely remove. Dissection is carried posteriorly as until complete exposure of the dura is obtained.

With this exposure the dura can be coagulated, which will provide additional hemostasis and tumor devascularization. The dura is then incised and opened on both sides of the falx, leaving the midline intact. This is important because the anterior falcine artery and associated falcine branches (supplying the tumor and falx) may be encountered with a midline incision. This artery is the primary residual feeding vessel to the tumor, other than any cortical vessels parasitized from the anterior circulation. Once the tumor is exposed, internal debulking can proceed until the edge of the falx is identified along with the anterior falcine artery vessels. These can now be coagulated along with the falx for final tumor devascularization and hemostasis. The falx is transected forming the final step in exposure and the tumor can be removed, starting at the center and utilizing the above stated techniques of intradural dissection. One key pearl is to leave the dura intact anterior to the brain/tumor interface. This will prevent downward herniation of the brain, obscuring the surgical field.

With large tumors, subpial invasion may be present. In this case, dissection is performed to the level of the interhemispheric fissure, taking care to avoid the A2 segments and the frontopolar artery which are often draped over the surface of the tumor. Following internal debulking, the parasellar space should be exposed to identify critical landmarks including the optic nerves and anterior communicating artery. This will

make extracapsular dissection of the A2 segment in the interhemispheric fissure easier and safer as it provides control for vascular dissection. This also provides proximal control during further vascular dissection along the capsule interface. Angled scopes are particularly helpful in these cases but require the instruments to work cranial to the scope whereas the converse is true for the majority of the dissection with a zero degree scope.

Staging Dissection

With large tumors, or those with significant displacement of critical structures, a staged approach may be the best option. Intraoperatively with removal of bony and soft-tissue, image guidance will become less accurate because of shift. In these cases, partial debulking will often allow the tumor to further collapse into the surgical defect over the next few days. Repeat imaging can be obtained and used for neuronavigation during the second stage, allowing safer, more complete tumor removal. The time frame for staging is variable and will depend on the pathology, tumor consistency, amount resected/remaining, and the patient's recovery. While intraoperative CT/MRI provides a promising technology to allow for more complete single-stage resection, as of yet, this technology is not widespread and therefore, when reassessment of the tumor residual is required for further resection, staging often presents the best option.

Reconstruction

Surgical defects that are small in size (less than 5 mm) can be closed with any combination of inlayed bone, overlaid fascia, or free mucosal graft. However, for the EEAs described above, the resultant dural defects necessitate vascularized techniques for reconstruction. Devascularized, layered reconstruction techniques for large skull base defects have been extensively described; however, they often result in high incidence of CSF leak and risk of meningitis. The use of vascularized mucosal pedicled flaps has been the most significant advancement in skull base reconstruction over the past decade.^{11–13} The use of the posteriorly based pedicled nasal septal flap has become the primary mode of reconstruction following expanded endoscopic cranial base resections,¹⁴ and has resulted in decreased CSF leak rates following extensive endoscopic skull base reconstruction.¹³ This flap is raised endoscopically with a needle-tipped electrocautery device that has been bent at a small angle used to divide the mucosa and outline the flap which is based off the posterior septal artery, a branch of the sphenopalatine artery (►Fig. 4). The superior cut should be made at the approximate level of the sphenoid os and can be extended anteriorly to encompass the near entirety of the septum (►Fig. 4). The flap is elevated with a freer in a submucopericondrial/mucoperiosteal plane and can be banked in the nasopharynx for use at the end of the case. This flap is large enough to cover maximal dural defects extending from the frontal sinus to sella and from orbit to orbit (i.e., CFR defect).¹³ It has been used successfully in pediatric patients older than 14 years of age, but caution is recommended in younger patients, and it may

Figure 4 Sagittal view of the nasal septum demonstrating the posterior septal branch of the sphenopalatine artery (left). Representation of the endoscopic view of the posterior nasal cavity while harvesting the nasal septal flap (right). Dashed lines mark the location of cuts for the posteriorly based nasal septal flap. IT, inferior turbinate; SPF, sphenopalatine foramen.

not be a viable option in patients younger than 10 years due to inadequate length.¹⁵

Further advantages include the ease at which flap viability and integrity can be assessed postoperatively, which has traditionally been a challenge following endoscopic skull base reconstruction. Vascularized flaps have a characteristic appearance (mucosal enhancement) on MRI, which can cause some confusion following tumor resection as radiologists and surgeons unfamiliar with this appearance may confuse the flap with residual tumor as traditional graft material (fat, explanted muscle, and synthetics) do not

enhance. However, its appearance to the trained eye makes it ideal for monitoring the integrity of the skull base repair.¹⁶ When a nasoseptal flap cannot be used secondary to compromise of the posterior septal artery or other condition making it a nonviable option, an anteriorly based pericranial flap can be elevated using minimally invasive techniques and placed intranasally without a craniotomy.¹⁷ Other vascularized flaps available for endonasal skull base reconstruction include middle and inferior turbinate pedicled flaps,^{18–20} temporoparietal fascia flap,²¹ and palatal flap.²²

Figure 5 Preoperative T1-weighted contrast enhanced sagittal MRI image showing a clival meningioma with brainstem compression (left); postoperative image demonstrating the extent of resection via the EEA (right).

Selected Cases

Case 1

A 21-year-old healthy African American female presented to an outside hospital with worsening headaches and visual changes. A CT scan obtained showed a clival mass and she was transferred to our institution for definitive management. Repeat imaging showed a $2.7 \times 3.9 \times 3.7$ cm meningioma in the area of the prepontine cistern at the level of the clivus that compressed the pons superiorly and posteriorly as well as compressed the third ventricle and cerebral aqueduct causing mild obstructive hydrocephalus (►Fig. 5). She underwent a planned two-stage debulking via an EEEA to the clivus achieving near-total resection with residual tumor at the most caudal extent of the tumor (►Fig. 5). The defect was reconstructed with a nasal septal flap. Pathology revealed a Grade 2 petroclival meningioma. Due to aggressive pathology, she underwent a third-stage frontal-orbito-zygomatic craniotomy for residual disease and received conformal radiotherapy. Her visual symptoms improved, however, she had delayed bilateral abducens nerve palsies despite anatomic preservation of both nerves presumably due to devascularization.

Case 2

A 61-year-old white female presented to an outside ophthalmologist with visual loss in the right eye. Imaging revealed a planum mass and she was referred to our institution for definitive therapy. Further imaging revealed a sellar/suprasellar mass extending along the planum sphenoidale and tuberculum sella. The mass measured $2.1 \text{ cm} \times 1.8 \text{ cm} \times 2.5 \text{ cm}$, and superiorly displaced the optic nerves and optic chiasm more prominently on the right. There was also an

oblique dural margin with elevation of the gyrus rectus on the right, abutment of the right supraclinoid internal carotid artery encasement of the right A1 segment (►Fig. 6). She underwent an endoscopic endonasal transplanum approach and was reconstructed with a nasal septal flap (►Fig. 7). Pathology revealed a Grade 1 meningioma. Postoperative imaging revealed gross total resection (►Fig. 6). She had improvement in her visual symptoms and had no evidence of cerebrospinal fluid leak.

Discussion

Building on extensive endoscopic transnasal approaches to the sella, expanded approaches have allowed endoscopic endonasal resection of anterior cranial base meningiomas which have traditionally been approached through a frontal or frontolateral approach. These traditional approaches for midline anterior base meningiomas carry a significant risk to the optic apparatus. As these tumors are intimately associated with the optic apparatus, traditional approaches require manipulation of an already compromised structure. Expanded endonasal approaches have been developed in an attempt to eliminate brain retraction as well as improve ophthalmological outcomes by approaching the tumors from an anteromedial and inferior dissection.

One of the major concerns and critiques of the endonasal approach to anterior base or parasellar meningiomas is difficulty accessing optic canal extension medial to the optic nerve which can frequently occur in these tumors. However, the inferior approach allows for dissection of disease from the inferior medial aspect of the nerves with minimal manipulation. From a lateral approach, significant retraction is required to clear disease in this location. Further, this approach

Figure 6 Preoperative T1-weighted contrast enhanced coronal MRI scans showing a planum meningioma with an oblique dural margin with elevation of the gyrus rectus on the right, abutment of the right supraclinoid internal carotid artery, and encasement of the right A1 segment (left); postoperative image demonstrating gross total resection achieved via the EEEA (right). The black arrow denotes the enhancement of the nasal septal flap.

Figure 7 Intraoperative view during the resection of a planum meningioma. The tumor, internal carotid artery, anterior cerebral artery, and optic chiasm are labeled.

facilitates optic nerve decompression and early tumor devascularization, as most are supplied by the anterior and posterior ethmoid arteries.

As the majority of meningiomas are benign and slow-growing, it is important to approach these from the standpoint of minimizing functional deficits postoperatively. While the goal of surgery is nearly always to obtain the maximal resection that the approach allows, it should be mentioned that for many of these procedures, the primary goal should be decompression of critical structures and improvement of symptomatology. Meningioma surgery has potential complications. These can be categorized as neurological, visual, endocrine, neurologic, CSF leak, or recurrence. At present, it is not known if the EEEA will reduce the incidence of these and other complications, and thus, outcomes data studies are necessary to validate the intuitive knowledge that a more direct access to the tumor with less brain manipulation will likely reduce the incidence of complications.

Conclusion

Cranial base meningiomas, while often grouped together, encompass a wide variety of origins and extensions which makes operative management challenging. The EEEA offers a tool that, in experienced hands, has the potential to improve outcomes while maximizing resection. This approach is not for every patient or every surgeon. The learning curve is

significant and we believe a functional knowledge of open transcranial approaches is required to gain proficiency with these EEEA techniques.

It is also important to understand the criticisms and limitations of the EEEA technique, including accessibility of optic canal extension, large lesions, tumor consistency, vascular encasement, and reports of high CSF leak. With experience in these approaches, each of these can be addressed in an attempt to obtain better or equivalent results with transcranial techniques. As the collective experience continues, data on long-term outcomes will answer whether this approach is preferred. Currently, EEEA represents a viable alternative for the operative management of cranial base tumors.

References

- 1 DeMonte F, Al-Mefty O. Meningiomas. In: Kaye AH, Laws ER, eds. *Brain Tumors*. London: Churchill Livingstone; 1995:675–704.
- 2 Rubin G, Ben David U, Gornish M, Rappaport ZH. Meningiomas of the anterior cranial fossa floor. Review of 67 cases. *Acta Neurochir (Wien)* 1994;129(1-2):26–30.
- 3 Solero CL, Giombini S, Morello G. Suprasellar and olfactory meningiomas. Report on a series of 153 personal cases. *Acta Neurochir (Wien)* 1983;67(3-4):181–194.
- 4 Rachinger W, Grau S, Tonn JC. Different microsurgical approaches to meningiomas of the anterior cranial base. *Acta Neurochir (Wien)* 2010;152(6):931–939.

- 5 Solares CA, Ong YK, Snyderman CH. Transnasal endoscopic skull base surgery: what are the limits? *Curr Opin Otolaryngol Head Neck Surg* 2010;18(1):1–7
- 6 Kassam AB, Snyderman CH, Mintz A, Gardner PA, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. *Neurosurg Focus* 2005;19(1):E3
- 7 Gardner PA, Kassam AB, Thomas A, et al. Endoscopic endonasal resection of anterior cranial base meningiomas. *Neurosurgery* 2008;63(1):36–52, discussion 52–54
- 8 Kassam AB, Gardner P, Snyderman CH, Mintz A, Carrau R. Expanded endonasal approach: fully endoscopic, completely transnasal approach to the middle third of the clivus, petrous bone, middle cranial fossa, and infratemporal fossa. *Neurosurg Focus* 2005;19(1):E6
- 9 Kassam AB, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum. *Neurosurg Focus* 2005;19(1):E4
- 10 Weber R, Draf W, Kratzsch B, Hosemann W, Schaefer SD. Modern concepts of frontal sinus surgery. *Laryngoscope* 2001;111(1):137–146
- 11 El-Sayed IH, Roediger FC, Goldberg AN, Parsa AT, McDermott MW. Endoscopic reconstruction of skull base defects with the nasal septal flap. *Skull Base* 2008;18(6):385–394
- 12 Harvey RJ, Nogueira JF, Schlosser RJ, Patel SJ, Vellutini E, Stamm AC. Closure of large skull base defects after endoscopic transnasal craniotomy. *Clinical article. J Neurosurg* 2009;111(2):371–379
- 13 Kassam AB, Thomas A, Carrau RL, et al. Endoscopic reconstruction of the cranial base using a pedicled nasoseptal flap. *Neurosurgery* 2008; 63(1, Suppl 1):ONS44–ONS52, discussion ONS52–ONS53
- 14 Hadad G, Bassagasteguy L, Carrau RL, et al. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. *Laryngoscope* 2006;116(10):1882–1886
- 15 Shah RN, Surowitz JB, Patel MR, et al. Endoscopic pedicled nasoseptal flap reconstruction for pediatric skull base defects. *Laryngoscope* 2009;119(6):1067–1075
- 16 Kang MD, Escott E, Thomas AJ, et al. The MR imaging appearance of the vascular pedicle nasoseptal flap. *AJNR Am J Neuroradiol* 2009;30(4):781–786
- 17 Zanation AM, Snyderman CH, Carrau RL, Kassam AB, Gardner PA, Prevedello DM. Minimally invasive endoscopic pericranial flap: a new method for endonasal skull base reconstruction. *Laryngoscope* 2009;119(1):13–18
- 18 Fortes FS, Carrau RL, Snyderman CH, et al. The posterior pedicle inferior turbinate flap: a new vascularized flap for skull base reconstruction. *Laryngoscope* 2007;117(8):1329–1332
- 19 Harvey RJ, Sheahan PO, Schlosser RJ. Inferior turbinate pedicle flap for endoscopic skull base defect repair. *Am J Rhinol Allergy* 2009;23(5):522–526
- 20 Prevedello DM, Barges-Coll J, Fernandez-Miranda JC, et al. Middle turbinate flap for skull base reconstruction: cadaveric feasibility study. *Laryngoscope* 2009;119(11):2094–2098
- 21 Fortes FS, Carrau RL, Snyderman CH, et al. Transpterygoid transposition of a temporoparietal fascia flap: a new method for skull base reconstruction after endoscopic expanded endonasal approaches. *Laryngoscope* 2007;117(6):970–976
- 22 Oliver CL, Hackman TG, Carrau RL, et al. Palatal flap modifications allow pedicled reconstruction of the skull base. *Laryngoscope* 2008;118(12):2102–2106