The expanded endoscopic endonasal approaches for the skull base

Abordagens endonasais endoscópicas expandidas para a base do crânio

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ABSTRACT

Background: Endoscopic endonasal approach (EEA) for skull base surgery (SBS) is a significant modification of the current practice.

Methods: We reviewed our experience at the University of Pittsburgh with EEA for 800 patients from 1998 to July 2007.

Results: Modular approaches to multiple pathologies of the skull base were designed totally based on intrinsic anatomy. Stages of training were established based on the level of technical difficulty and potential risk of vascular and neural injury. Five levels were defined in an incremental manner.

Conclusions: Practice standardization with modular, incremental training is projected to facilitate the gaining of knowledge and skills to safely master EEA for SBS in an organized manner. We suggest adherence to the systematic acquisition of endoscopic skills, to work as an integrated team of surgeons and to have a thorough perspective of conventional SBS and endoscopic surgery. Therefore, the choice of approach must be a specific function of the anatomy and pathology rather than the surgeon's bias or lack of experience with alternative approaches.

Key-words: Endoscopic skull base surgery, endoscope, endonasal, endoneurosurgery, training, learning curve.
INTRODUCTION

There is a continuing transformation in multiple surgical specialties with the introduction of endoscopy. In otolaryngology, endoscopic sinus surgery has become the new standard for the treatment of multiple sinus diseases for the last 30 years. In neurosurgery, the use of endoscopes for pituitary surgery has grown impressively since the first publication on pure endoscopic pituitary surgery in 1992. A natural progression of endoscopic sinus and pituitary surgery has been the application of endoscopic techniques to the surgical treatment of pathologic conditions of the cranial base.

Endoscopic skull base surgery was only possible with the collaboration of multiple surgical specialties. Rather than working sequentially as is often done with open approaches, surgeons from different specialties work together simultaneously as a team: one person maintaining the surgical view with the endoscope and the other working bimanually to dissect the tissues. The benefits of true team surgery include improved visualization, increased efficiency, and the ability to deal with a crisis such as a vascular injury. There is added value of having a “co-pilot” for problem-solving and avoiding complications. Besides great visualization, other potential benefits of endoscopic surgery include improved cosmetic results and decreased morbidity due to less tissue trauma. The consequences of decreased morbidity are a faster recovery, shortened hospitalization, and decreased cost of medical care.

Familiarity with endoscopic ventral skull base anatomy, proper instrumentation, an experienced surgical team with adherence to endoscopic surgical principles are essential for avoiding complications. The principles of endoscopic skull base surgery are identical to standard microsurgical principles. Internal debulking of tumors is performed to allow extracapsular dissection of tumor margin with early identification of neural and vascular structures. Sharp dissection of tumor margins is performed without pulling on tumors (FIG 1). Adherence to this fundamental principle minimizes the risk of neural or vascular injury.

Since 1998, over 800 patients have undergone endoscopic skull base procedures at the University of Pittsburgh Medical Center for a wide variety of pathologies.

ENDOSCOPIC ENDONASAL APPROACH

PLANNING

Frameless stereotactic image guidance (IG) is used in all expanded (endoscopic) endonasal approaches (EEAs) to the skull base. Image guidance is of value in corroborating the visual impression of the surgical anatomy, especially critical neurovascular structures, and to help define a targeted resection. A high resolution CT angiogram is used for most skull base surgeries, as it allows for the simultaneous visualization of osseous, vascular and soft-tissue anatomy (FIG 2). An exception is that of pituitary adenomas, for which MRI is used, as soft-tissue definition is of supreme importance. Increasingly, we utilize image fusion of CT and MRI scans to take advantage of the best features of each: CT for the bony anatomy of the cranial base and MRI for intracranial tumor margins.

OPERATING ROOM SETUP

The surgeons are positioned on the right side of the patient contrary to the anesthesia team (FIG 3). The surgical technician or nurse is positioned towards the foot of the bed. This arrangement gives the surgeons unrestricted access to the nasal region. Electrical cords and suction tubing are directed away from the surgical field toward the head and foot of the bed to
minimize interference with surgical instruments.

Figure 2 - Intraoperative image from the image guidance system during an expanded endonasal approach for the petrous apex (Zone 1), for a resection of a cholesterol granuloma. Note in the axial image the probe (blue) pointing to the petrous apex immediately medial to the left carotid artery, which was transposed during the procedure.

Figure 3 - Intraoperative photograph showing the operating room setup during an expanded endonasal approach. Note that the surgeons are positioned in the right side of the patient, whereas the anesthesiologist is in the left side. One of the surgeons navigates with the endoscope with one hand and helps the dissection with another instrument with his other hand. The second surgeon, positioned in front of the face of the patient uses both hands for dissection. Either surgeon has an individual screen adjusted in the most comfortable angle of view.

Pin fixation system is used to reduce the intraoperative movement of the head, especially during drilling and neurovascular dissection. The head is fixed following endotracheal intubation, with the neck in slight extension, tilted to the left and the face is turned to the right by 10-15 degrees, and with the patient as close to the right side of the surgical bed as possible. The bed can be angulated in the room in a way that the foot of the bed goes away from the surgeons allowing for even more space.

Neurophysiological monitoring of cortical function (somatosensory evoked potentials) +/- brainstem function (brain stem evoked responses) is routinely performed in all cases dura is exposed or dissection near the carotid arteries is performed. Neurophysiological monitoring can identify changes in cerebral blood flow that may occur with blood loss or changes in blood pressure and alert the anesthesiologist to make adjustments. Cranial nerves electromyography is performed as necessary base on tumor anatomy.

A nasal decongestant, such as oxymetazoline 0.5%, is applied topically to the nasal mucosa using cottonoids. The skin of the external nose and nasal vestibule as well as the abdomen (fat graft donor site) is prepped with a povidone antiseptic solution. The patient is given a fourth generation cephalosporin for perioperative antibiotic prophylaxis.

SURGICAL EXPOSURE:

The endoscope is introduced at the “12 o’clock” position of the nostril (usually the right) and is used to retract the nasal vestibule superiorly; therefore, elongating the nostril and increasing the available space for other instruments. A suction tip is generally introduced at the “6 o’clock” position on the same side. Dissecting instruments are introduced through the left nasal cavity. A suction irrigation sheath or continual irrigation by an assistant or co-surgeon cleans the lens of the scope and preserves visualization without removing the scope for frequent cleaning. If, for any reason, a bimanual (preferably binarial) approach cannot be pursued then proceeding further is absolutely contraindicated. Furthermore, we discourage the use of an endoscopic holder for all EEAs.

Widening of the nasal corridor is achieved initially by out-fracturing of the inferior turbinates, followed by the removal of the right middle turbinate to provide room for the endoscope. Injection of vasoconstrictors is optional and is performed according to the surgeon’s preference.

For the last two years we have been using a nasoseptal vascularized mucosal flap for the reconstruction of the skull base defect. As it has to be harvested initially during the exposure, the surgical planning is crucial. For cases in which is known dura mater will be opened for tumor exposure, the decision is
simple and the flap is elevated immediately without hesitation. Recently we have noticed much less nasal morbidity during the postoperative period for patients that received a vascularized mucosa covering the exposed sphenoid sinus bone. Much less crusting has been detected and more often we are harvesting the nasoseptal flap even in cases there is minor chances of CSF leak to be encountered.\textsuperscript{11,17}

We use unipolar electrocautery with an insulated needle tip to incise the septal soft tissues. Two parallel incisions are performed following the sagittal plane of the septum. One follows the maxillary crest and a parallel incision follows a line 1 cm below the most superior aspect of the septum to preserve the olfactory epithelium and function. These parallel incisions are joined anteriorly by a vertical incision usually placed rostral to the anterior head of the inferior turbinate. Posteriorly, the superior incision is extended laterally inferior to the natural sphenoid ostium. The inferior incision extends laterally on the superior margin of the choana. Elevation of the mucoperichondrium, using a Cottle dissector, proceeds from anterior to posterior after ascertaining that all incisions have been carried through the peristeum and perichondrium. Elevation of the flap from the anterior face of the sphenoid sinus is completed preserving the vascular pedicle between the sphenoid ostium sinus and choana.

The flap can be stored in the nasopharynx (Fig 4a) or inside the maxillary sinus after an antrostomy is performed to facilitate dissection at the level of the clivus for instance until the extirpative phase of the surgery is concluded (Fig 4b).

The nasoseptal flap is pediculated in the postero nasoseptal artery. The mucosal pedicle goes from the roof of the choana to the sphenoid ostium. Inferiorly it can be extended laterally in the floor of the nasal cavity if needed, or more often it is harvested up to the transition in between the septum and the floor.

The sphenoidotomy is initiated by identifying and enlarging the natural ostium of the sphenoid sinus or by entering the sphenoid at the junction of the nasal septum and the rostrum of the sphenoid sinus. A Cottle dissector is used to incise and disarticulate the posterior septum from the rostrum of the sphenoid bone. Removal of the bony rostrum is completed using Kerrison rongeurs and/or a surgical drill. Wide bilateral sphenoidotomies are performed extending laterally to the level of the medial pterygoid plates and lateral wall of the sphenoid sinus, superiorly to the level of the planum sphenoidale and inferiorly to the floor of the sphenoid sinus. The posterior edge of the nasal septum (1-2cm) is resected with backbiting forceps or microdebrider. The posterior septectomy facilitates bilateral instrumentation without displacing the septum into the path of the endoscope, and increases the lateral angulation and range of motion of instruments. Wide bilateral sphenoidotomies and a posterior septectomy provide bilateral access and visualization of key anatomical structures.

Once the sphenoid sinus is wide exposed and all the septations are drilled, the desired module of expanded endonasal approach can be pursued.

Two concepts are critical for the endoscopic exposure: bilateral nasal access (binarial) to allow for a two-surgeon, three/four-hand technique, and the optimized removal of the posterior septum to create a single cavity for work. These allow a bimanual dissection technique with dynamic movement of the scope to
provide best visualization of the surgical field at all times during the surgical procedure with freedom of movements. This becomes more critical if there is a bleeding complication, so that the surgeons can maintain visualization while controlling the hemorrhage and avoiding injury to adjacent structures.

**ANATOMICAL MODULES**

The modules are divided in midline (sagittal plane) and paramedian (coronal planes) approaches. The coronal planes are considered in three levels: anterior, mid-coronal and posterior.

**SAGITTAL PLANE**

**Transsellar approach**

The most common indication for this approach is a pituitary adenoma. Purely intrasellar craniopharyngiomas and Rathke cleft cysts are also commonly encountered. It is defined by the opening of the sella turcica. The anterior wall of the sella is drilled exposing both cavernous sinus and both superior and inferior intercavernous sinus. Frequently the bone anterior to the internal carotid arteries needs to be completely removed to allow further retraction on the lateral wall of the cavernous sinus to permit exposure of the postero-lateral contents of the sella turcica. Wide exposure provides adequate space for intrasellar dissections (FIG 5). The transsellar approach is frequently used in association with transplanum and transclival (upper third) approaches particularly to access intradural extrasellar disease. The most important critical structures related to this module are the cavernous sinuses containing both ICAs limiting the area laterally. The chiasm is located in the suprasellar compartment and can be affected in large sellar lesions with suprasellar extension as occurs in large macroadenomas.

**Transplanum/transstuberculum approach**

The transplanum approach is indicated for lesions involving the posterior aspect of the anterior skull base (intra or extradural) and the suprasellar region. Tuberculum sellae meningiomas, craniopharyngiomas, epidermoid tumors are examples of lesions that can be resected through a transplanum approach (FIG 6).

**Transcribriform approach**

Commonly a transcribriform approach is associated with a transplanum approach for resection of anterior fossa meningiomas. Other pathologies that often require a transcribriform approach are esthesioneuroblastomas and invasive sinonasal malignancies (FIG 1). While the cribriform exposure damages olfaction, it is likely the disease in question has already com-

![Figure 5 - Intraoperative endoscopic image using a zero degree endoscope](image1)

![Figure 6 - Intraoperative endoscopic image using a zero degree endoscope during resection a craniopharyngioma through an expanded endonasal transplanum approach. Note the pituitary gland just below the tumor, which was involving the pituitary stalk in this case.](image2)
promised that olfaction. A unilateral approach can be performed for small paramedian lesions with the intention of olfaction preservation.

It is defined by the removal of the cribriform plate. This module extends anteriorly from the posterior ethmoidal arteries up to the level of the crista galli and frontal sinus. The limits of this module are both laminae papyraceae laterally, the frontal sinus anteriorly and the transition with the planum sphenoidale posteriorly at the level of the posterior ethmoidal arteries. The most important structures related to this module are the orbits and the anterior cerebral arteries (A2) and their branches (fronto-orbital, fronto-polar). The ethmoidal arteries also represent a risk for retrobulbar hematoma if not well coagulated or clipped before incised during the approach.

**Transclival approach**

A transclival approach is frequently utilized for resection of extradural and intradural diseases such as chordomas and chondrosarcomas. It is also used to access purely intradural pathologies anterior to the brain stem such as meningiomas and craniopharyngiomas.

It is defined by partial (upper, middle or lower thirds) or complete removal of the clivus (panclivectomy) (FIG 7). The upper third is related to the dorsum sellae in the midline and the posterior clinoids in the paramedian region. They can be removed either intradurally via a transsellar approach or extradurally via a subocular corridor by first performing a superior pituitary transposition. Removal of these structures can provide access to the basilar artery and interpeduncular cistern (FIG 8).

**Transodontoid approach**

This approach can be used for resection of the odontoid process in degenerative / inflammatory diseases or to allow for exposure of the ventral medulla and upper cervical spinal cord. Foramen magnum meningiomas are examples of lesions that can be treated using this approach.

It is defined by the removal of the odontoid process of the axis (second vertebra). This approach is an extension of the transclival approach. The lower third of the clivus is exposed as well as the anterior arch of C1 after dissection of the nasopharyngeal mucosa and the rectus capitis anterior muscle. The arch of C1 is drilled and the odontoid process is exposed and drilled out. The most vital neurovascular structures for this module are the vertebral arteries, posterior inferior cerebellar arteries (PICAs), brain stem and lower cranial nerves. The ICAs have to be considered as a risk factor as well because occasionally they can be positioned close to the midline in their parapharyngeal

*FIGURE 7* - Intraoperative endoscopic image using a zero degree endoscope during the initial portion of a clivectomy. Note the pituitary gland superiorly and both carotid protuberances laterally.

*FIGURE 8* - Intraoperative endoscopic image using a zero degree endoscope during an expanded endonasal transdorsal approach after pituitary transposition. Note the Basilar artery, the superior cerebelar arteries, posterior cerebral arteries and the left III cranial nerve under the Liliquist membrane.
segment under the mucosa.

**CORONAL PLANES**

The coronal plane approaches are considered in three different depths. Anterior coronal plane has an intimate relation with the anterior fossa and orbits, the middle coronal plane with the middle fossa and temporal lobe and the posterior coronal plane with the posterior fossa.

The middle and posterior paramedian modules are divided based on the morphology of the ICAs. In order to allow dissections on middle and posterior planes, a transpterygoid approach is performed. The vidian nerve and artery are key landmarks for all lateral expanded approaches since the vidian canal leads to the lacerum segment of the internal carotid artery (ICA).

**ANTERIOR CORONAL PLANE (ANTERIOR FOSSA)**

**Transorbital approach**

It is indicated for resection of sinonasal lesions that are invading the medial wall of the orbit as sinonasal malignances, to decompress the optic nerves in the presence of unresectable intracranial pathologies or to access intracranial diseases with the goal of resection as for schwannomas, cavernomas and meningiomas.

It is defined by the removal of the lamina papyracea or the medial optic canals. This module requires a wide resection of the anterior and posterior ethmoid cells in order to expose the lateral wall of the sinonasal cavity. It can be performed unilaterally or bilaterally as dictated by the pathology. At the point the ethmoid cells are removed, the surgical field is limited laterally by the lamina papyracea and orbital apex deeply (FIG 9). The most important vital structures related to this module are the optic nerves, the anterior and posterior ethmoidal arteries and the ophthalmic artery with its central retina artery branch. The ocular muscles must be well identified during surgery and dissection can be performed in between them. The space between the medial rectus and the inferior rectus form a great window to access intracranial disease. Subconjunctival localization and mobilization of eye muscles are extremely helpful during endonasal endoscopic procedures.

**MID-CORONAL AND POSTERIOR CORONAL PLANES**

**Transpterygoid approach**

All the modules in the mid-coronal and posterior coronal plane start with a transpterygoid approach. Initially a maxillary antrostomy is performed exposing the posterior wall of the maxillary sinus. The sphenopalatine artery (SPA) is identified and its branches are coagulated and ligated. The posterior wall of the maxillary sinus is removed and the soft contents of the sphenopalatine fossa are retracted laterally. The vidian foramen and foramen rotundum are identified posteriorly in the sphenoid bone (FIG 10). Superiorly in this exposure the superior orbital fissure and the orbital apex is situated. The lateral sphenoid recess can be exposed once the sphenoid wedge and the base of the sphenoid plates are drilled. This exposure allows direct access to the medial temporal fossa were commonly spontaneous CSF leaks are encountered and can be treated.

![Figure 9](image1.jpg)

*Figure 9 - Intraoperative endoscopic image using a zero degree endoscope during the exposure for an expanded endonasal transorbital approach. Note that the right posterior ethmoidal artery was coagulated and will be cut after hemoclip ligation. The right lamina papyracea was removed and the anterior fossa skull base bone is still intact.*

![Figure 10](image2.jpg)

*Figure 10 - Intraoperative endoscopic image using a zero degree endoscope during an expanded endonasal transpterygoid approach. Note the left vidian nerve being followed posteriorly to allow for localization of the left internal carotid artery.*
MID-CORONAL PLANE (MIDDLE FOSSA)

Petrous apex (Zone 1)\(^{18}\)

Chondrosarcomas and cholesterol granulomas are typical pathologies at this location (FIG 11). It is fundamentally a lateral extension of a transclival approach in its middle third (FIG 2). The most pertinent structures are the ICAs and the VI cranial nerve at the Dorello’s canal.

Suprapetrous approach (Zone 3)\(^{18}\)

Pathologies commonly encountered in this region are invasive adenoid cystic carcinomas, meningiomas, schwannomas and invasive pituitary adenomas. This module is indicated to access lesions located in the Meckel’s cave through the quadrangular space. This space is outlined by the petrous ICA inferiorly, the ascending vertical cavernous/paraclival ICA medially, the VI cranial nerve superiorly in the cavernous sinus and the maxillary division of the trigeminal nerve (V2) laterally. The key structures related to this module are exactly the boundaries: ICA, VI cranial nerve and trigeminal nerve.

Cavernous sinus approach (Zone 4)\(^{18}\)

It is rarely indicated and most commonly applied in cases where the patient has already cranial nerve deficits (III, IV, VI) such as in apoplectic pituitary adenomas that invade the cavernous sinus causing a cavernous sinus syndrome. It is anatomically defined by the area lateral to the sella turcica where the cavernous ICA is located. The cavernous sinus is approached laterally to the cavernous ICA. The structures at risk for this approach are the III, IV, V, VI cranial nerves and the ICA with its sympathetic fibers.

Infratemoral approach (Zone 5)\(^{18}\)

Pathologies encountered in this region are invasive carcinomas, CSF leaks, encephaloceles, and skull base meningiomas. The dissection can be pursued laterally until the lateral pterygoid plate (LPP) is recognized. The LPP can be drilled rostrally until it is flush with the middle cranial fossa and foramen ovale. The relevant structures in this module are the internal maxillary artery with its branches, the vidian nerve, the trigeminal nerve (V2 and V3) with branches and the superior orbital fissure superiorly.

POSTERIOR CORONAL PLANE (POSTERIOR FOSSA)

Infraclival approach (Zone 2)\(^{18}\)

Chondrosarcomas are the commonest pathology in this region. It is defined by resections at the petroclival junction. The petrous bone under the ICA in its petrous segment can be removed until underlying dura of the posterior fossa and venous plexus is identified. The middle fossa represents the superolateral boundary. If required, the dura mater posterior to the drilled petrous bone can be opened to provide access to the paramedian section of the pre-pontine cistern as to expand the corridor to approach petroclival meningiomas for instance. The vital structures related to this module are the inner ear with VII and VIII nerves laterally, the petrous ICA superiorly and the XII cranial nerve infero-laterally. Medially will be the VI nerve crossing Dorello’s canal.

Jugular foramen/hypoglossal canal approach\(^{18}\)

Pathologies encountered in this region are invasive carcinomas, paragangliomas, schwannomas and skull base meningiomas. The relevant structures in this region are the internal maxillary artery, the ICA (pharyngeal and petrous segments), the trigeminal nerve, the jugular foramen with jugular vein and lower cranial nerves (IX, X, XI), and the XII cranial nerve exiting the hypoglossal canal inferiorly. The Eustachian tube is an important landmark to safely determine the position of the internal carotid artery in its ascending parapharyngeal segment at the point it penetrates the carotid canal in the petrous bone. The Rosenmüller fossa is followed laterally. The medial aspect of the occipital condyle is encountered lateral to the foramen magnum and followed laterally. The hypoglossal canal is localized rostro-lateral to the condyle and should be navigated carefully. Once the ICA is localized, the jugular foramen is located immediately lateral. The cranial nerves IX, X and XI are located in between the jugular vein and the ICA.
CURRENT RECONSTRUCTION TECHNIQUE

A following the principles of reconstruction in open skull base surgery, we started to use vascularized tissue to rebuild the skull defect. Hadad and Bassagasteguy from Argentina developed a nasoseptal flap supplied by the posterior nasoseptal arteries, which are branches of the posterior nasal artery. This nasoseptal mucosal flap (HBF) has been our preferable reconstruction technique. The flap is harvested initially in the surgery. In general it is harvested in the side that needs less exposure, contralateral to the lesion.

During the reconstruction, the flap needs to be in contact with the denuded bone wall for appropriate defect closure.

We favor a multilayer reconstruction of the defect. Besides the HBF, we use an inlay subdural graft of collagen matrix. Occasionally, an additional onlay fascial graft and/or abdominal free fat may be used. It is imperative to avoid any foreign body or non vascularized tissue between the flap and the surrounding edges of the defect. Biologic glue helps to fix the flap in place and nasal sponge packing or the balloon of a 12 French Foley catheter is inserted to press the HBF against the defect. Inflation of the Foley balloon should be under endoscopic observation, as over inflation may result in compression of intracranial structures or compromise of the neurovascular pedicle. Silicone splints, left in place for 10-14 days, protect the denuded septum.

COMPLEXITY OF THE CASES

We categorized the cases in 5 levels of difficulty in which the probability of problems are supposedly higher as the level raises in endoscopic endonasal surgery following the same natural progression lived in our own experience (Table 1). We suggest new skull base endoscopists to use these stepwise-organized levels of complexity as a safe form to acquire skills in order to perform complex and advance procedures without jumping into difficult surgeries early in the experience.

Level I procedures represent endoscopic sinonasal surgery. They are considered as having the lowest risk of major complication since the neurovascular structures are well protected under the skull base bone. Level I procedures do not represent endoscopic skull base surgery in our opinion. These procedures do not intentionally violate the confines of the bone along the skull base.

Table 1

<table>
<thead>
<tr>
<th>Level</th>
<th>Procedures</th>
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<tbody>
<tr>
<td>Level 1</td>
<td>Sinonasal surgery</td>
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<tr>
<td>Level 2</td>
<td>Pituitary surgery, CSF leaks</td>
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<tr>
<td>Level 3</td>
<td>Extrudal, Transcribriform, Transplanum, Transorbital (extraconal), Transclival, Transodontoid</td>
</tr>
<tr>
<td>Level 4</td>
<td>Intradural, With cortical cuff, Transplanum, Transcribriform, Type I craniopharyngiomas, Lack of cortical cuff, Transorbital (intraconal), Transplanum, Transcribriform, Type II/III craniopharyngiomas, Transclival intradural</td>
</tr>
<tr>
<td>Level 5</td>
<td>Cerebrovascular surgery, A. Middle and posterior coronal planes, B. AVM/Aneurysms</td>
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Level II procedures represent the initial step for endoscopic endonasal skull base surgery. They encompass the treatment of CSF leaks and pituitary adenomas. The sellar dura is opened for intrasellar resections. The expected rate of complication increases from level I procedures since dissections occur beyond the confines of the skull base and into intradural structures.

Level III procedures are the extrasellar extradural dissections of the skull base. They are defined as any endoscopic endonasal procedure that required drilling of the skull base exposing dura (periosteal layer) without transgressing it. This level of complexity requires a critical understanding of the endoscopic ventral skull base anatomy since a vast number of fine neurovascular structures are directly beneath the dura.

Level IV procedures are intradural surgery and the likelihood of complications theoretically increases significantly. This level represents cases in which the surgeon performs the dural opening intentionally in order to access an intracranial lesion. These situations occur in purely intradural pathologies or by invasive lesions of the skull base that destroyed and invaded the subdural space.

Level V procedures are cerebrovascular surgery. Endonasal endoscopic surgery for the treatment of aneurysms and vascular malformations are included here. Any endoscopic procedure that extends beyond the carotid in the mid-coronal and posterior coronal plane is also incorporated into this ultimate level. These approaches require dissecting lateral to the ICAs. Dissecting and transposing the internal carotid arteries with the use of angled scopes are daunting maneuvers that harbor ele-
vated risk of serious complications.

COMPLICATIONS ON HIGHER LEVELS

There were 2 cases of carotid rupture in our series (0.3%). Both were surgeries of level V in terms of complexity (2/74 cases at level V). The bleeding was controlled intraoperatively applying endoscopic endonasal techniques. In both cases the ICAs were sacrificed and both patients tolerated this well. Consistent with our categorization of the EEA cases into levels of complexity, the most feared complication (ICA compromise) occurred in two cases that fell into the most complex category: “Level V” (p<0.0001).

Discussion

Endonasal access to the ventral skull base was first proposed almost a century ago. Over this time period, significant advancements in biotechnology and improved understanding of ventral skull base anatomy have resulted in the development of the expanded endonasal approaches. It is ideal for centrally located pathology where the lesion is surrounded by critical neurovascular structures located around the perimeter.

The modular approaches are based on anatomical knowledge of the ventral skull as viewed endonasally. The sphenoid sinus is the epicenter and the starting point for most of these modules due to the concentration of critical structures around the periphery. It should be emphasized that the principles of endoscopic tumor dissection are no different than those for open surgical approaches with microscopic support. Extracapsular dissection is performed with full visualization of important neurovascular structures. There is no pulling of tumor and the dissection is controlled and accurate.

THE FOUNDATION OF ENDOSCOPIC SKULL BASE SURGERY

During the last decade there has been a considerable movement to determine the viability of accessing extra- and intradural complex lesions via fully endoscopic endonasal routes through the ventral skull base. The anatomic corridors and instrumentation, at least the first generation, have been established and feasibility of access been proven. We are observing an increasing body of literature demonstrating and addressing safety and efficacy data. There is, we believe, a strong probability that expanded endonasal approaches will prove to be a viable part of the skull base surgeon’s armamentarium. If centers evolve conscientiously, we feel that endoscopic skull base surgery will be validated.

THE TRAINING

Although much learning occurs in the operating theater, time must be spent in the dissection. Cadaveric work continues to be valuable even after earlier level procedures have been mastered as it provides an enhanced understanding of anatomical relationships that cannot be adequately explored in the operative setting. It is also useful to receive extra training after level II procedures (pituitary surgery) have been mastered since the educational needs and focus of the surgeon change with experience.

It should be noted that cadaveric work, although helpful, cannot be a replacement for the operative experience. It is unlikely that the more complex levels can be mastered based on cadaveric work or weekend courses. It is our recommendation that the evolving endoscopic surgeon initiate his/her career with appropriate assessment of anatomic literature. Following this, a cadaveric dissection course with an experienced group may be useful to provide fundamental principles. The first is to understand clearly the barriers and obstacles in performing levels I, II and III procedures and to try to address these in a problem-solving manner. The second is to begin gaining insight into levels IV and V and to seek more sustained periods of training to be able to advance to more complex cases of skull base surgery.

DECISION POINT

Levels I, II and III represent a very demanding practice. Most of the extradural midline tumors are included in these levels. Advancing represents a vital commitment, one that cannot be pursued simply by attending courses but rather requires a complete immersion within the field, as is the case with any subspecialization.

The next steps necessitate that the surgeons deliberately open the dura mater to operate within the subarachnoid space. Devastating complications can be related to vascular compromise, bleeding or strokes, cranial nerve injuries, uncontrolled CSF leaks and meningitis. The choice of stepping forward should be accompanied by a total dedication to the field. Our analysis showed that probability of major complications as such as neural deficits are related to level 4 procedures and internal carotid artery rupture increases significantly as level 5 procedures are reached. The team must be prepared to deal with these potentially devastating complications if they decide to embrace the entire field of endoscopic endonasal skull base surgery.

The endoscopic surgical team should feel comfortable with each level before proceeding to the next. Performing at least
30-50 pituitary procedures together before undertaking advanced stage operations is suggested. Many surgeons may plateau at mid-level procedures (level II and III) and may not want or need to progress to more difficult and complex procedures. If surgeons choose to perform level IV procedures, there needs to be a commitment to endoscopic skull base surgery with the development of a stable surgical team that operates together regularly with an adequate volume of cases. Sufficient institutional resources need to be available to enable the surgery. Whatever level of competence is achieved, it is important for surgeons to recognize their own limitations and not attempt procedures that are beyond their training and institutional capabilities.

Adherence to a training program may prevent negative experiences that will stall the growth and advancement of endoscopic skull base surgery globally. Hospitals and professional organizations are encouraged to adopt guiding principles to foster safe and responsible surgical practices for the benefit of our patients.

CONCLUSIONS

Given the significant interest throughout multiple surgical fields in minimally invasive surgery, it is important to define this concept. In our opinion, it is considered minimally invasive only if it is “minimally disturbing” to the patient’s quality of life. In the end the procedure must have maximum functional preservation. We believe that endoscopic skull base surgery has the potential of offering this as long as the principles are upheld.

REFERENCES

19. Kassam AB, Mintz AH, Gardner PA, Horowitz MB, Carrau RL, Snyderman CH: The expanded endonasal approach for an en-


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