Nearly every surgical specialty has witnessed an evolution toward minimal access techniques. In otolaryngology, neurologic surgery, skull base surgery, and in other fields, progress has been driven by the introduction of the endoscope. This, coupled with commensurate advancements in anatomic knowledge, instrumentation, and imaging technology (intraoperative computed tomography [CT], image-guidance surgery), facilitates approaches that “provide access and visualization through the narrowest practical corridor by providing the maximum effective action at the target with minimal disruption of normal tissues.”1,2

Skull base surgery, as a subspecialty, has been slow to assimilate endoscopic techniques. However, endoscopic endonasal surgery has become commonplace for the treatment of expansive mucoceles and sinonasal tumors that involve the skull base and intracranial pathology, such as pituitary tumors, cerebrospinal fluid (CSF) fistulas, and encephaloceles.3–6 Through experience and innovation, the expanded endonasal approach (EEA) currently provides a nasal corridor for the surgical treatment of various benign and malignant pathologies in any area of the ventral skull base.

A paradigm shift is happening with effective skull base surgery, including large resections, carotid artery mobilization, and complex intracranial dissection, being performed through a minimally intrusive transnasal corridor.

**PRINCIPLES OF ENDONASAL SKULL BASE SURGERY**

The origins of the EEAs to the skull base can be traced back to endoscopic approaches to the sella turcica. This seminal work arose from the combined efforts of otolaryngologists and neurosurgeons who used their experience and knowledge to take advantage of endoscopic technology for the treatment of pituitary tumors.3 Even today, this collaboration is a central tenet of our paradigm.

The technique involves 2 cosurgeons, usually an otolaryngologist and a neurosurgeon, working simultaneously and side-by-side throughout the procedure. The operating surgeon uses a bimanual technique, an essential asset for hemostasis, vascular control, and intracranial dissection. The co-surgeon maximizes the visualization benefits of the
endoscope by providing a dynamic, "real-time" view with continual adjustments to provide the best view, appropriate magnification, and to guide instruments and assist with dissection. A skilled and experienced surgical duo working together is a major advantage for intraoperative decision-making, delineation of complex or distorted anatomy, and for the management of potentially catastrophic vascular injuries.

A rod-lens endoscope (Karl Storz, Tuttlingen, Germany), in itself, confers multiple advantages that allow a minimal-access approach. It has a narrow profile that is 4 mm in diameter, which allows its introduction through small apertures. This obviates extensive transfacial or transcranial approaches (typically required for microscopic visualization), with their resultant tissue disruption. Furthermore, the lens of a rod-lens endoscope is divergent and provides a panoramic view that greatly exceeds its 4-mm diameter. By changing the proximity of the scope to the operative field, magnification is simple and precise, and with the advent of high-definition camera systems, clarity of the image is unparalleled. Rod-lens endoscopes provide enhanced visualization, and the use of angled lenses avoids the "line-of-sight" limitations of the microscope. Although binocular 3-dimensional vision is lost, the surgeon’s brain quickly adapts to working in 2-dimensional views by using proprioceptive cues and surgical landmarks.

The sinonasal cavity provides an ideal corridor for the surgical treatment of ventral cranial base lesions (Fig. 1). Conventional ("open") approaches consist of facial or scalp incisions combined with a craniotomy and/or maxillofacial osteotomies. Postoperative pain after conventional approaches is significant and convalescence may take weeks. Surgical scars and complications, such as wound infection, bone malunion, and loss of cranio-orbital bone grafts, can result in substantial facial disfigurement. In addition, transcranial approaches often mandate brain retraction and manipulation, which may result in cognitive or memory dysfunction.

Alternatively, the use of an EEA provides a direct caudal approach to the ventral skull base obviating brain manipulation. Furthermore, facial incisions, osteotomies, and bone grafts are unnecessary, greatly decreasing postoperative pain and eliminating facial scarring and disfigurement. Of greatest benefit, however, is that the EEA provides unhindered access to the midline corridor that is flanked by cranial nerves and internal carotid arteries.7,8 Endonasal access thus obviates cranial nerve manipulation that beleaguer conventional lateral approaches.

Paramount to efficient and successful skull base surgery is choosing the best corridor or combination of corridors to address a specific pathology, which is not about whether to use direct visualization, a microscope, or an endoscope. However, the golden rule of endonasal surgery is to address the pathology without displacement of critical neural and vascular structures. If a tumor extends lateral or deep to the cranial nerves or a major blood vessel, a lateral conventional approach may be preferable. Extensive tumors often require the combination of an endonasal corridor and a traditional approach to access various components of the lesion (Fig. 2).

Principles of tumor dissection for endoscopic approaches are identical to those of traditional approaches. Critical neural and vascular structures are identified early, and when possible, the blood supply to the tumor is controlled. Tumors are first debulked so that precise dissection around the periphery can be performed. This allows for preservation of crucial submillimeter vessels and a precise dissection of the lesion from parenchymal pia mater (Fig. 3).

Critical to the success of surgery is the clearance of margins, especially when addressing malignancies. Intraoperative frozen-section analysis should confirm that microscopic negative margins have been achieved. A minimal access approach does not license the surgeon to be a minimalist. EEA may be less destructive to normal tissue and provide a more anatomically sound corridor, but the invasiveness of the procedure is commensurate with the pathology, the
needs of the patient, and the intended goals, whether it be cure or palliation. When treating malignancies, the resultant skull base defect after complete tumor extirpation is identical to that of a traditional approach (Fig. 4). However, facial tissues disruption, craniotomy, and brain manipulation are obviated with EEAs.

**PREOPERATIVE EVALUATION**

Patients with skull base lesions may present with otolaryngological, neurologic, ocular, or endocrine symptoms. Despite the patient’s specific symptoms, all 4 of these axes should be investigated. For example, a patient with epistaxis secondary to an extensive sinonasal tumor may have an undiagnosed optic neuropathy. Alternatively, a patient with headache and visual disturbance from a tuberculum sella meningioma may have a concomitant sinonasal inflammatory disease that must be addressed before the EEA. Therefore, a multidisciplinary skull base team is critical to optimizing the diagnosis and outcomes.

Besides a thorough history and physical examination, which includes a nasal endoscopy, skull base imaging is an essential aspect of the preoperative evaluation. This often includes a CT and a magnetic resonance imaging (MRI) scan. An imaging algorithm must be applied to obtain fine cuts (1–2 mm) through the entire skull base. CT angiography (CTA) provides excellent anatomic detail of proximity and distortion of vascular structures (Fig. 5). MRI sequences with different

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**Fig. 2.** (A) T1-weighted, contrast-enhanced, coronal magnetic resonance image (MRI) of a patient with a right anterior clinoid meningioma (T). The white arrows indicate the location of both optic nerves as they course lateral to the sphenoid (Sp) sinus. Because the optic nerve lies medial and inferior to the tumor, would obstruct endonasal (transsphenoidal) access. Because the nerve cannot be mobilized, this case is best done through an "open," pterional craniotomy. (B) T1-weighted, contrast-enhanced, coronal MRI of a patient with an olfactory groove meningioma tumor (T). White arrows locate the optic nerves lateral to the tumor. Because the optic nerves are not interposed between the skull base and the lesion, this tumor is amenable to EEA.

**Fig. 3.** Intraoperative photograph of a suprasellar tumor (T) being dissected off the optic apparatus. The right optic nerve (II), anterior cerebral arteries (ACA), and left posterior cerebral artery (PCA) are shown. The arrowheads demonstrate the crucial submillimeter vessels that can be preserved with microdissection, maintaining vascularity to important structures, such as the optic nerve and chiasm.
relaxation times (T1-weighted versus T2-weighted) help in characterizing the lesions, formulating a differential diagnosis, determining the brain-tumor interface, and delineating adjacent neural and vascular structures. In addition, malignant tumors with potential for regional or distant metastasis may mandate a positron emission tomography (PET)/CT or CT of neck, lungs, and abdomen. Malignant sinonasal tumors with parameningeal involvement require a lumbar spinal tap for cytology and a spine MRI to rule out “drop metastasis” or carcinomatosis.

INTRAOPERATIVE STRATEGIES

Several intraoperative factors are instrumental in successful endoscopic endonasal skull base surgery. First, the administration of appropriate general neuroanesthesia with intra-arterial blood pressure monitoring and venous access is a basic requirement. Contrary to hypotensive anesthesia, which is a common practice during inflammatory sinonasal surgery, the patient is maintained normotensive or mildly hypertensive to ensure perfusion of neural tissues (mean arterial pressure >85 mmHg). This is critical when compression or edema manifests as a preoperative neurologic defect. Compressed neural tissues are inherently ischemic; therefore, even transient perfusion fluctuations may cause prolonged or sustained deficits. To further assess neurologic function and perfusion, all patients undergo intraoperative monitoring of somatosensory evoked potentials and, when indicated, electromyography of muscles innervated by cranial nerves that are considered at risk.

The progressive expansion of endonasal skull base surgery beyond the sella would not be safely possible without the concomitant technological advancement of intraoperative image guidance. Real-time correlation of the operative field to

Fig. 4. Endonasal view after endoscopic anterior craniofacial resection of an esthesioneuroblastoma. The resection extends from the right lamina papyracea (RLP) to the left lamina papyracea (LLP) and from the frontal sinus to the planum sphenoidale. The olfactory tract has been transected to obtain negative tumor margins. The white arrowhead indicates the ligated left anterior ethmoidal artery.

Fig. 5. (A) Sagittal CTA of a patient with a large olfactory groove meningioma tumor (T). The A2 segments of both anterior cerebral arteries (arrowheads) have been displaced superiorly and directly juxtapose the superior aspect of the tumor, making the tumor-brain interface dissection technically difficult. The parasellar internal carotid artery (C), sphenoid sinus (Sp) and vertebral artery (arrow) are also seen. (B) A sagittal CTA of another patient with a meningioma (T). A cuff of brain parenchyma (arrowhead) intercedes between the tumor and the A2 arteries (arrow). Dissection of the brain tumor interface is technically easier in such cases.
preoperative CT, CTA, MRI and magnetic resonance angiography precisely reflects and corroborates the surgeon’s impression of the surrounding anatomy (Fig. 6). It is possible to identify and preserve critical structures and anticipate the position of others while focusing on the endonasal exposure and tumor dissection, especially in the presence of anatomic variants or distortion of normal anatomy and surgical landmarks by the tumor.

The lack of specialized surgical instruments initially presented a technical challenge for endonasal skull base surgery. Many of the instruments were designed for endoscopic sinus surgery and did not have the length, angles, touch, and precision necessary for endoscopic skull base surgery. Now commercially available, these endoscopic instruments emulate conventional neurosurgical instruments and allow for efficient and precise manipulation of tissues. Similarly, instruments, such as bipolar electrocautery, high-speed drills, and ultrasonic aspirators, have been lengthened and made slimmer to accommodate the endonasal corridor.

Hemostasis, in particular, provides a special technical challenge for the endoscopic skull base surgeon. Prevention, the optimal solution, is best accomplished by visualization, cauterization, and sharp dissection, and by simultaneously limiting blunt dissection and traction. Realistically, bleeding from either the tumor or the surrounding vasculature is often unavoidable.

Low-flow bleeding from either the mucosa, bone, or from a venous source is best controlled using warm-water irrigation. It is a common misconception that cold-water irrigation provides effective hemostasis; the modest resultant vasoconstriction is often insufficient to significantly reduce bleeding. Warm-water irrigation, in contrast, is nearly as effective as surgery for epistaxis. Proposed mechanisms of action include platelet activation, interstitial edema, and enhanced enzymatic activity of coagulation. The ideal temperature for this is 48°C, but 40°C is used to avoid hyperthermia of the neural structures. For example, brisk venous bleeding from a dural sinus requires application of a hemostatic agent, such as FloSeal (Baxter International, Inc, Deerfield, IL, USA), Avitene (Ethicon

![Fig. 6. Intraoperative snapshot of the image-guidance system for a patient with a right petroclival meningioma (white arrowhead and asterisk). The tumor emanates from the jugular tubercle (JT) just above the hypoglossal canals (black arrows). After the vidian canal (black arrowhead) was drilled away, the internal carotid artery (ICA) was mobilized to obtain access to the tumor.](image-url)
In the case of high-flow arterial bleeding, direct application of bipolar cauteration or hemostatic or aneurysms clips is paramount. Although packing may provide temporary hemostasis, the potential for delayed intracranial bleeding mandates definitive control. Collaborative experience with the 2-surgeon approach is requisite for maintaining adequate visualization in a bloody field. Similarly, a bimanual approach facilitates suctioning with concomitant cautery (Fig. 7). On occasion, in the face of significant operative blood loss, tumor resections may be staged to allow hemodynamic recovery.

**SURGICAL APPROACHES**

The concept of surgical corridors typical of open skull base surgery can also be adopted for endoscopic skull base surgery; therefore, the endoscopic approaches to the ventral skull base have been defined by a series of surgical modules. These modules define the sinonasal exposure, the location and extent of skull base osteotomies, and the anticipated extracranial and intracranial anatomy. Furthermore, these modules can be combined to control multiple areas of the skull base and, segmentally, address a large, complex tumor as necessary. These modules have been categorized based on their relationship to the internal carotid artery (ICA); the sagittal plane modules define corridors medial to the ICA, whereas paramedian corridors lateral to the ICA are addressed by coronal plane modules.

**Sagittal Plane Modules**

The sagittal plane modules are divided into transsellar, transplanum, transcribriform, transclival, and transodontoid approaches (see Fig. 1). The transsellar module provides exposure to the pituitary gland, the dorsum sella, and the medial aspects of the cavernous sinus. Sinonasal exposure with bilateral sphenoidotomies and posterior ethmoidectomies allows an adequate working corridor. This approach is most commonly used to address pituitary adenomas and Rathke cleft cysts.

The transplanum module exposes the dura overlying the planum sphenoidale, with the lateral limits defined by the optic nerves. Removal of the tuberculum and control of the superior intercavernous sinus augments this approach by providing access to the suprasellar cistern and the optic apparatus, distal ICA, and anterior cerebral and anterior communicating arteries. Meningiomas, craniopharyngiomas, and gliomas, involving the suprasellar cistern and planum sphenoidale, are approached via this module.

The transcribriform module provides access to the anterior cranial fossa. A complete ethmoidectomy, sphenoidotomy, and wide endoscopic frontal sinusotomy (Draf III or endoscopic Lothrop) exposes the bone of the posterior table of the frontal sinus, ethmoid roof, and sphenoid roof. The cribriform plate can then be removed after the anterior and posterior ethmoidal arteries are ligated. Dura, frontal lobes, and olfactory bulbs and tracts may be exposed thereafter. This module is commonly used for meningiomas, schwannomas, and sinonasal malignancies (eg, esthesioneuroblastoma,
squamous cell carcinoma) (Fig. 8). The bony and dural resection is identical to an open anterior craniofacial resection. The clivus separates the sphenoid sinus and nasopharynx from the posterior fossa. Tumors, such as chordomas, chondrosarcomas, and meningiomas, can be successfully approached by the transclival module (Fig. 9). Cranial nerves VI and XII and the vertebral and basilar arteries are encountered during the dural dissection of the posterior fossa. By further exposing the nasopharynx, removing the body of C1, and resecting the odontoid process, one can approach the ventral aspect of the craniocervical junction. This transodontoid module allows for decompression of the spinal cord for rheumatoid diseases and also serves as a transnasal approach for limited intra-axial tumors.

**Coronal Plane Modules**

Approaches to tumors that are lateral to a virtual plane created by the paraclival ICA require an understanding of the coronal plane modules. These approaches are considered in 3 different depths from anterior (superficial) to posterior (deep). The anterior coronal plane has an intimate relationship with the orbits and anterior cranial fossae. The mid-coronal plane addresses the pterygopalatine, infratemporal, and middle cranial fossa (temporal lobe). The posterior coronal plane gives access to the lateral nasopharynx, jugular foramen, and posterior fossa. Because the ICA demarcates the boundary, mastering its anatomic relationships, variations, and landmarks is essential for successfully and safely addressing these tumors.

Several critical landmarks help the surgeon around the ICA. The plane of the anterior genu of the carotid artery is marked by the plane of the medial pterygoid plate. Clival bone removal lateral to this plane should be avoided until the ICA is definitively identified. A critical landmark for the more proximal petrous portion of the carotid artery is the vidian (pterygoid) canal (see Fig. 9). Dissection along the lower half of this canal provides safe exploration until the ICA is identified; then, the superior portion and, if required, the bone of the carotid canal may be removed (Fig. 10). The cartilaginous eustachian tube provides a reliable landmark for the parapharyngeal ICA and the carotid canal.

The working corridor to the most anterior coronal module, the transorbital approach, is via a total ethmoidectomy and medial orbital decompression. Once the periorbita is incised, the medial compartment of the orbit is accessed. Vessel loops may be slung around the medial rectus and inferior oblique muscles via a transconjunctival incision, if necessary, allowing them to be stretched to further open the endonasal window to the intracranial compartment. Extension of the orbital decompression posteriorly provides for optic nerve decompression.

![Fig. 8. (A) T1-weighted coronal MRI scan postcontrast demonstrates a large olfactory groove meningioma (T) with the A2 segments of the anterior cerebral arteries (arrows) flanking the tumor. (B) Postresection MRI, 3 months postoperative, shows complete tumor excision. The sphenoid is obliterated with fat and the skull base was reconstructed with a nasoseptal flap (asterisk).](image-url)
lesions, and cavernomas, may also be addressed (Fig. 11).

The midcoronal plane modules specifically allow access to the pterygopalatine, infratemporal, and middle cranial fossa. The petrous portion of the ICA and its anterior genu must be successfully negotiated.\(^{21}\) However, the width of the native nasal passage is insufficient to provide the required lateral access; an endoscopic medial maxillectomy (sometimes combined with an endoscopic Denker extension) and transpterygoid dissection is often necessary. The spheno- palatine artery is ligated and the posterior antral wall and pterygoid plates are removed flush to the middle cranial fossa and foramen rotundum, to fully access the pterygopalatine and medial aspect of the infratemporal fossa.\(^{22,23}\) Such exposure is essential to access large juvenile nasopharyngeal angiofibromas (JNA) that extend into the infratemporal fossa.\(^{24}\) Tumors of Meckel cave and sinonasal malignancies with lateral extension are also addressed via this approach (Fig. 13).\(^{23}\)

The posterior component of the coronal plane provides access from the occipital condyle medially to the jugular foramen laterally. This working corridor is medial to the parapharyngeal ICA and the hypoglossal nerve, and nerves IX, X, and XI may be in the field of dissection. Commonly treated pathologies include nasopharyngeal carcinomas, jugular foramen tumors, and chordomas.

**RECONSTRUCTION**

As endoscopic skull base resections have continued to increase in complexity, new challenges have been presented for the reconstruction of these defects. Indeed, the continued evolution of the EEA to successfully and safely address larger and more intricate lesions has been commensurate with the development and growing experience with vascularized reconstructions.

All skull base reconstructions strive to recreate a separation of the cranial cavity from the sinonasal cavity to prevent CSF fluid leakage, pneumocephalus, and intracranial infection. Small skull base defects and CSF fistulas can be reconstructed with various free-grafting techniques, resulting in a success rate greater than 95%.\(^{25,26}\) However, for large dural defects, free grafts are associated with unacceptably high rates of postoperative CSF leakage typical after an EEA. The lack of supporting structures and high flow of CSF in cisterns and ventricles pose further challenges to the reliability of reconstruction.

Initial reconstructions strategies consisted of suturing of allografts, buttressing the dural repair with free fat grafts, and supporting the reconstruction

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**Fig. 9.** Enclosed within the dotted lines is a right petroclival chondrosarcoma seen in the CTA. A transclival (C) module was used to approach and resect this tumor. The internal carotid artery (asterisk), vidian canal (white arrow), and basilar artery (arrowhead) are shown in relation to the tumor. Note the vidian canal’s relationship to the anterior portion of the petrous ICA (asterisk).

**Fig. 10.** Intraoperative photograph showing the clival recess (CR) and the right pterygoid fossa. Drilling along the inferior aspect (from 3 o’clock to 9 o’clock) along the vidian nerve (asterisk) is the safest technique for identifying the petrous ICA and the anterior genu (arrowhead), which is often medial to the vidian nerve. The protrusion of the paraclival ICA (C) is seen within the right lateral wall of the sphenoid sinus.
with balloon stents. These techniques provided only modest improvements in outcomes. The greatest advance has been the development of vascularized, pedicled flaps that provide several advantages over traditional reconstructions. Compared with rotation or advancement flaps that recruit a random blood supply from a wide-based pedicle, an axial blood supply allows the flap to be mobilized over a larger arc of rotation and to conform better to irregular surfaces. A robust, reliable blood supply supports a large tissue surface area and expedites healing. In the authors’ experience, the incidence
of postoperative CSF leaks has reduced significantly to less than 5% from 20% to 30% with vascularized tissue reconstruction.\textsuperscript{28}

The Hadad-Bassagasteguy nasoseptal flap (NSF) is the workhorse for endonasal skull base reconstruction.\textsuperscript{29} Its large surface area and wide arc of rotation, coupled with a robust blood supply and technical ease, make for a reliable, versatile, and hardy reconstruction. The pedicle of this flap is the posterior septal artery (PSA), a terminal branch of the sphenopalatine artery (SPA), which traverses the sphenoid rostrum inferior to the sphenoid natural ostium. The reconstructive paddle incorporates the mucoperichondrium and mucoperiosteum of the nasal septum, which contains a highly vascular submucosal arcade of vessels derived from the PSA.

The large surface area of the nasal septum provides a flap that is capable of reconstructing virtually any skull base defect. In a radioanatomic study of the cranial base and flap dimensions, the authors’ group demonstrated that the NSF could adequately reconstruct any single segment of the ventral skull base including the sella/plenum, clivus, or cribiform.\textsuperscript{30} In its largest dimensions, the NSF can reconstruct an entire anterior craniofacial defect from the frontal sinus to the planum sphenoidale and from orbit to orbit (Fig. 14). However, the flap length may not adequately cover defects resulting from combined approaches (eg, from frontal sinus to sella turcica or clivus). In such cases, adjuvant flaps, free fat grafts, or a shorter contralateral NSF may be necessary to provide adequate reconstruction. The reach of the flap is maximized when it is on a planar surface instead of following the curves of the sinuses and skull base. Obliteration of a sphenoid or clival defect with a fat graft will allow the NSF to reliably reach the posterior table of the frontal sinus, if necessary.

If the NSF is not available because of tumor invasion, septal perforation, or prior sacrifice of the pedicle, adjuvant vascularized flaps may be used to provide a reliable reconstruction. Local endonasal pedicled flaps include inferior turbinate and middle turbinate mucoperiosteal flaps.\textsuperscript{31,32} Both flaps are pedicled posteriorly on respective branches of the SPA. Although both flaps provide a more limited surface area than the NSF, they may be sufficient for small defects of the planum sphenoidale and sella (middle turbinate flap) or the clivus (inferior turbinate flap).

For large skull base defects where the NSF is unavailable, regional axial flaps may be used for reconstruction: the endoscopic pericranial flap and the transpterygoid temporoparietal fascia flap.\textsuperscript{33,34} Although both flaps require scalp incisions, they can be transposed endonasally and placed onto the skull base defect without the use of a craniotomy. For the endoscopic pericranial flap, the loose areolar tissue and pericranium of the scalp are harvested, much the same as for open cranial base surgery. The flap is pedicled on the supratrochlear and supraorbital vessels and transposed endonasally via a narrow glabellar osteotomy, obviating craniotomy.\textsuperscript{33} A Draf III endoscopic frontal sinusotomy, requisite for this procedure, accommodates the pedicle as it is transposed. Tissue from this flap is ideal for large defects secondary to transcribriform, transplano-
The temporoparietal flap incorporates the pericranium, loose areolar tissue, and aponeurosis (which is continuous with the temporoparietal fascia). This flap is based on the superficial temporal artery and is harvested via a hemicoronal incision. Mobilization of the pterygopalatine fossa contents and removal of the pterygoid plates provides an endoscopic transpterygoid corridor that accommodates the pedicle of the flap. Once the flap is transposed via the infratemporal/pterygopalatine fossae, it provides a large surface area of tissue capable of reconstructing clival and sellar defects.

Although vascularized flaps provide the cornerstone, skull base reconstruction is best performed using a multilayered technique. A collagen matrix synthetic graft is placed intradurally (inlay graft), which is then covered with the vascularized flap. Oxidized methylcellulose and DuraSeal (Confluent Surgical, Inc, Waltham, MA, USA) are applied as a tissue glue and sealant. The reconstruction is then bolstered with a balloon or expandable sponge nasal packing. Lumbar spinal drains are not routinely used; rather, they are reserved for cases where a cistern or ventricle has been exposed and a high-flow CSF leak is present.

CONTROVERSIES

One of the major controversies surrounding endoscopic skull base surgery is the oncological validity of endoscopic techniques. Critics of the EEA cite that en bloc resection is essential for surgical tumor control. However, numerous examples in current medical practice refute this claim. Endoscopic removal of inverting papilloma of the sino-nasal cavity has shown to have equivalent or even superior results to conventional en bloc resection. Tumor debulking, in this case, provides for better exposure and delineation of normal and abnormal anatomy. The stalk or base of the tumor can be easily identified and resected totally, providing an equally complete extirpation. Mohs micrographic surgery for dermatologic neoplasms and transoral supraglottic laryngectomy for laryngeal neoplasms have similarly shown that en bloc resection is not needed to achieve adequate and appropriate tumor control. In reality, given the proximity to neural and vascular structures and friability of tumors, en bloc resection of skull base malignancies is often not possible even with a traditional open approach.

However, EEA techniques must conform to oncological principles. It is of utmost importance to achieve clear surgical margins, as confirmed by intraoperative analysis. To address a sinonasal tumor with skull base invasion, the portion of the tumor not attached to the skull base is first debulked to provide visualization of areas of tumor invasion. Bony margins of the skull base are identified and osteotomies are created to surround the tumor. Once the bone is removed, the underlying involved dura is resected en bloc (sometimes with the olfactory bulbs, such as in esthesioneuroblastoma). In this way, a sequential, layered resection of the tumor is performed to provide complete tumor excision.

SUMMARY

The continued progression of the EEA to cranial base lesions has been spurred by advances in instrument and imaging technology, growth in anatomic knowledge and surgical experience, and innovations in reconstructive techniques. Currently, a wide variety of malignant and benign lesions may be treated via the endonasal corridor without using facial incisions, craniotomy, or brain retraction. Understanding the complex, 3-dimensional anatomy is essential for success and safety. Although the endonasal route provides a less invasive corridor, the surgical principles of resection, especially for malignancies, are not violated; tumor resections and resultant skull base defects mirror those of traditional “open” approaches.

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