Indications and Limitations of Endoscopic Skull Base Surgery

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Abstract and Background

A wealth of critical neurovascular structures within a relatively small area adds to the already intricate nature of skull base surgery. Surgical approaches to the area are difficult and often associated with significant morbidity and mortality. During the past two decades, endoscopic endonasal approaches (EEAs) have evolved to access the ventral skull base for the resection of tumors (benign and malignant), the decompression of neural structures including the cervicomедullary junction (pannus from rheumatoid arthritis or congenital anomalies, such as platybasia) and the reconstruction of skull base defects (cerebrospinal leaks, meningoencephalocele). These minimal access approaches obviate the need for incisions, translocation of maxillofacial bones and retraction of the brain. Furthermore, EEAs yield improved visualization, which may reduce complications, and improve quality of life outcomes. Anatomical difficulties (e.g., vascular encasement or extension beyond the plane of a major vessel or cranial nerve), various special conditions (e.g., pediatric patients and vascular tumor) and limitation of institutional resources and technical difficulties may limit the use of EEAs. Thus, one should understand the indications and limitations of EEAs to optimize patient selection, which, in turn, may lead to superior surgical outcomes and reduced morbidity.

Background

Surgical approaches to the skull base are challenging owing to its intricate and deep-seated anatomy. The skull base presents a wealth of critical neurovascular structures within a relatively small area. Surgical approaches are technically difficult and associated with significant morbidity and mortality. Henceforth, the medical literature contains multiple
external, microscopic and endoscopic endonasal approaches (EEAs) that have been designed in an attempt to control lesions and critical anatomical structures within this area.

Over the past two decades, EEAs have evolved to enable skull base surgery through minimal access ports using pre-existent air spaces that provide direct routes to various areas of the skull base. EEAs eliminate the need for external incisions or scars, translocation of the maxillofacial skeleton and retraction of brain or other neurovascular structures. EEAs use bilateral nasal access and customized removal of bone to provide a relatively wide surgical corridor that allows dynamic visualization, a two-surgeon–four-hand dissection technique, and some additional space for supplementary instrumentation. In addition, endoscopy provides excellent magnification, high-definition images and a panoramic view with extended cephalo-caudal and laterolateral visualization. These advantages eliminate the need for grasping or curettage of tumors without a clear visualization, contributing to decrease the incidence of neurovascular injury, incomplete tumor resection and ineffective repair of the defect.

A wide variety of pathologies can be encountered at various sites along the ventral cranial base, including benign neoplasms (pituitary adenoma, meningioma, schwannoma and craniopharyngioma); malignant neoplasms (esthesioneuroblastoma, chordoma and chondrosarcoma); defects of the skull base (cerebrospinal fluid [CSF] leaks and meningocele/meningoencephalocele) and inflammatory conditions (pannus from rheumatoid arthritis and petrous apicitis). EEAs allow surgical access to the ventral skull base to manage these pathologies with complete extirpation or debulking of tumor, decompression of cranial nerves or craniovertebral junction, and/or reconstruction of skull base defects. Furthermore, EEAs are based on modular anatomical approaches in the sagittal (median) and coronal (paramedian) planes that often provide the most direct access to pathologies arising or extending to these areas with the least degree of manipulation of critical neurovascular structures (less morbidity).

As previously mentioned, EEAs provide improved visualization, decreased trauma to the maxillofacial soft and bone tissues, and therefore, are associated with faster recovery time, reduced risk of neurological damage, the potential for improved oncologic and endocrinologic outcomes, fewer complications, improved quality of life and decreased hospitalization and cost. EEAs, however, have limitations according to the location, diagnosis and vascularity of the lesion; the ability to reconstruct the resulting defect; medical comorbidities of the patients; training, expertise and experience of the surgeon; and the availability of institutional resources, such as an intensive care unit, operating room equipment and interventional and advanced imaging services. These multifactorial circumstances may require the use of alternative approaches.

2. Indications & Limitations of EEAs

Technique

Advantages. The technique of EEA comprises the concomitant work of two surgeons, using a two-nostril–four-hands technique. One surgeon primarily dissects while the other provides visualization and adjunctive manipulation of the tissues. One focuses in the operative field while the other surveys a more global perspective. In addition, the two surgeons provide each other with continuous feedback and supportive situational analysis. This ‘additional’ information improves intraoperative decision-making and problem solving. The roles of
the co-surgeons are usually reversed several times during the surgery according to expertise and experience; thus, enhancing productivity and helping to combat fatigue, expediting surgery and increasing its efficiency and safety.

**Limitations.** A two-surgeon technique provides many advantages; however, the need to find a co-surgeon constitutes a significant challenge. Finding someone with a compatible personality, philosophy of treatment, skills, ethics and professional vision is not a straightforward task. In addition, many surgeons are dismissive toward a ‘team’ approach, as they erroneously think of it as contrary to the image of independence and self-reliance often promoted during surgical training. There is also a prevalent misconception that one of the members of the team will be subservient to the other. Moreover, even under the best circumstances, it takes considerable effort and time investment to become an effective team.

Iatrogenic complications, including sinonasal tract and neurovascular events, do occur. Nasal crusting is the most common sinonasal morbidity (95% of patients at 1 month postoperatively). Other significant sinonasal complications are rare but include nasal synechiae (9%), alar sill burns (5%), maxillary nerve hypoesthesia (2%), palatal hypoesthesia (7%), incisor hypoesthesia (11%), serous otitis media (2%), taste disturbance (7%) and malodor (19%). Severe crusting requires aggressive and frequent outpatient debridement and nasal irrigations. Approximately 50% of patients achieved a crust-free nasal cavity 3 months after surgery over 3 months and most patients recover full nasal function 6 months after surgery.

Important neurovascular complications include postoperative CSF leaks and injury to a major vessel with consequent hemorrhage (i.e., massive blood loss and potential for stroke). A recent study reported intraoperative vascular injuries (0.9%) that included avulsion of P1 (segment of the posterior cerebral artery) perforator, pontine bleeding, internal maxillary laceration, frontopolar avulsion, ophthalmic laceration and internal carotid artery (ICA) laceration. Injury to the ICA is a potentially catastrophic complication; however, an experienced surgeon can control the vessel using bipolar electrocautery, application of hemostatic materials, focal packing or aneurysm clamps. Techniques that are most effective for vascular control have been elucidated in an animal model and include the use of large bore suctions, use of lens-cleansing devices and a muscle patch for hemostasis. Once intraoperative control is achieved, angiography with possible sacrifice or stenting of the vessel is performed. In addition, the team performing endoscopic skull base surgery should also be familiar with cerebrovascular surgery and perform a vascular bypass when necessary. Repair of CSF leaks will be discussed in a subsequent section.

Other postoperative neurovascular complications include intracranial infection, such as abscess or meningitis (1.9%), delayed visual deterioration (0.9%), hydrocephalus (0.1%), intrasellar hematoma (0.5%), retrobulbar hematoma (0.1%) and seizures (0.6%).

Avoidance of complications and optimum surgical and oncological outcomes mandate proper training in endonasal surgical techniques. Training should follow a systematic progression in anatomical complexity, technical difficulty, potential risk of neural and vascular injury, extent of intradural dissection and type of pathology. Ideally, all skull base surgeons should be well versed with both open and endoscopic techniques so that they can offer the best surgical option to the patient. This includes having the ability to convert an endoscopic approach to an open approach or combination approach without hesitation, should it be necessary to achieve an optimal oncologic outcome and avoid complications. A five level training scheme based on these parameters has been proposed. Levels I–III are
extradural procedures. Levels IV and V are intradural and/or cerebrovascular procedures and require a greater level of anatomic knowledge, surgical expertise and teamwork.\[21\]

**Technology**

**Advantages.** EEA uses rod-lens rigid endoscopes providing superior magnification, distal illumination and visualization (of the surgical target). Furthermore, angled lenses (0, 30, 45 and 70 degrees) offer the possibility to look ‘around corners’.\[1–3,14\] Recent development of customized instrumentation has greatly facilitated the popularization and, to some degree, standardization of EEAs.

The endoscopic operative field is wider than the microscope’s, as the view of the microscope is hindered by all structures in its line-of-sight. Endoscopic visualization is not hindered in this fashion, as the rod lens endoscope can be advanced distally to the structures or angled lenses can be used to look around obstacles. Rod-lens rigid endoscopy provides superior panoramic visualization to that of the tunnel vision provided by a microscope (Figures 1 & 2). In practical terms, endoscopy optimizes visualization and surgical fields, such as the planum sphenoidale, sella and suprasellar space. These fields are not in a direct line of sight with the nostrils; thus, they are better visualized and controlled via endoscopic endonasal surgery than with microscopic approaches.\[2,3\]. EEA provides free access to the median skull base (bound by cranial nerves and internal carotid arteries); thus it is ideal to manage pathologies that are medial and/or anterior to these critical structures (it avoids manipulation of the cranial nerves and dissection of critical vessels).

![Figure 1. Comparison of the Endoscopic and Microscopic Field of Visualization.](https://example.com/figure1.png)

(A) The endoscopic field of visualization is more panoramic than (B) the microscope’s.
**Limitations.** Any minimal access surgery depends heavily on technology to achieve its goals. EEA’s are no exception to this concept, as they require specific instrumentation, such as longer endonasal microinstruments with secure grips and minimal width. Cutting and grasping forceps, rongeurs, dissecting instruments, bipolar forceps and a high-speed drill should be in any ‘basic’ tray. Other types of powered instrumentation such as a micro-debrider or the NICO Myriad (NICO Corp., IN, USA) are not critical but highly desirable. A computer-assisted navigation device and Doppler probe are very useful and they become critical to manage complex lesions. Fundamental institutional resources include the formation of a dedicated operating room team and the availability of an intensive care unit. Unfortunately, these resources, as well as technological advances and special instruments, are costly and not readily available in all institutions.

Rod-lens endoscopy provides a monocular view; thus, neurosurgeons accustomed to the binocular visualization provided by the microscope have to train in order to compensate for the lack of depth perception. Bimanual dissection (constant maintaining one hand in the field), and the dynamic visualization provided by the co-surgeon (constantly moving the endoscope/camera) provide visual cues that compensate for the lack of 3D. The incorporation of endoscopic training into neurosurgery residencies, significant improvements in endoscope optics, high-definition cameras and video monitors, and the emergence of 3D endoscopes are likely to eliminate this limitation. 3D endoscopy seems useful, especially for novice surgeons, as it significantly improves depth perception. A recent report demonstrated that 75% of skull base surgeons preferred 3D endoscopy and 87.5% determined that 3D visualization helps with the completion of specific tasks. Surgeons’ speed and efficiency improved significantly when moving from 2D to 3D. Moreover, surgeons using 3D demonstrated a significantly higher efficiency than those using 2D (p = 0.04). It should be noted, however, that the resolution, illumination and field of view are superior with rod-lens endoscopes. 3D technology is rapidly evolving and will soon be equivalent in these parameters. These advancements will propel its adoption by a large number of centers.

### 3. Clinical Applications

**Resection of Tumors**
As previously mentioned, endonasal endoscopic approaches often provide the most direct access to the ventral skull base, while obviating the need for the manipulation of neurovascular structures.\[^{4,8–10,25–28}\] EEA\[^{s}\] are classified according to the anatomical orientation of their target areas into sagittal (median) and coronal (paramedian). Sagittal plane EEA\[^{s}\] extend from the frontal sinus to the second cervical vertebra;\[^{11}\] whereas the coronal plane EEA\[^{s}\] extend to the midline of the roof of the orbit (anterior), the floor of the middle cranial fossa (middle) and the jugular foramen (posterior).\[^{12}\] EEA\[^{s}\] offer a surgical corridor that encompasses the entire ventral skull base; thus, providing adequate access, the ability to resect benign and malignant tumors and to reconstruct the consequent defects.

**Benign Tumors.** Aims of a benign tumor resection are similar regardless of the approach or method of visualization: gross tumor resection and/or decompression of critical structures, while minimizing surgical morbidity. Herein, we provide a brief review of surgical outcomes for the most common pathologies. We need to acknowledge, however, that these studies contain several intrinsic biases and that must be considered when comparing outcomes. Nonetheless, the available literature suggests that EEA is a feasible alternative approach for dealing with benign tumors of the skull base.

Pituitary adenomas are most commonly approached using craniotomy, microscopic-transsphenoidal, microscopic-transnasal and EEA\[^{s}\] (and combinations of these). Outcomes associated with EEA\[^{s}\] seem superior to those obtained with microscopic approaches regarding rate of gross total resection (89 vs 83%)\[^{29}\] and remission of hyper-secretion rate (63 vs 50%).\[^{30}\] Transcranial approaches were associated with a higher rate of perioperative mortality compared with the transsphenoidal group (p = 0.004).\[^{31}\]

Outcomes following resection of meningiomas suggest that EEA\[^{s}\] are associated with a lower morbidity rate than open approaches; however, they are also associated with a higher rate of postoperative CSF leaks. Nonetheless, recent studies suggest that the use of a vascularized tissue flap for reconstruction after EEA decreases the rate of CSF leak to <5%, which is similar to that reported with traditional approaches.\[^{12}\] Although the previous study reported that the gross-total resection rate of transcranial approaches (92.8%) was better than EEA (63.2%)\[^{14}\] in experienced hands and in carefully selected patients, the EEA may be a preferred alternative. A recent study reported that EEA yields a gross-total resection of tuberculum sellae meningioma in 83.3% of the patients.\[^{33}\] Furthermore, EEA was superior regarding vision improvement (71.4% in EEA and 61.4% in transcranial approach).\[^{26}\]

Another recent study regarding the resection of craniopharyngiomas, suggests that EEA had a greater rate of gross total resection (88.5 vs 79.5%) and improved visual outcomes (40.0 vs 34.3%) than transcranial approaches.\[^{14}\] Moreover the transcranial group had a greater rate of postoperative seizure disorders (8.5%), which did not occur in other groups (p < 0.003).\[^{35}\] Microscopic-transsphenoidal approaches, however, yielded similar outcomes to EEA.

**Malignant Tumors.** The goal of surgery for the great majority of malignant tumors is that of complete tumor extirpation. Oncologic outcomes after EEA are similar, if not superior, to those reported after external approaches. However, these outcomes are not necessarily comparable as the indications and/or patient selection for these approaches vary significantly. In our practice, external approaches are indicated in patients with extensive tumors that are not amenable to EEA\[^{s}\]; therefore, external approaches carry the burden of being indicated for the most advanced stages, which imply a worse prognosis. Eloy et al.\[^{1}\] reported that overall survival of patients who underwent transnasal endoscopic resection of
malignant tumors at the anterior skull base was not significantly different from that of patients who underwent open craniofacial resection (94.4% for EEA vs 83.3% in open craniofacial resection). However, local recurrence approximated statistical significance (5.6% after EEA vs 29.2% after open craniofacial resection). Nicolai et al. compared the oncologic outcomes between EEA and a ‘cranioendoscopic approach’ (CEA). These authors reported that the 5-year disease specific survival was statistically different (91.4 ± 3.9% for the EEA group vs 58.8 ± 8.6% for the CEA group [p < 0.0004]). Recurrence rates were 18.8% for EEA and 36.7% for CEA. However, as previously mentioned, these outcomes are influenced by a patient selection bias; therefore, histology and staging of the tumor should be considered when interpreting these data. Recent reports support the concept that EEA has an important place in the surgical armamentarium for the management of sinonasal malignancies. Nonetheless, its role is still controversial and needs further clarification through larger cohorts of cases, extended follow-up and better stratification of staging, histological and outcomes data.

Other Outcomes. A recent report demonstrated that 12 months after EEA the vast majority of patients had an overall quality of life (QOL) that ranged from good (mean score of 3.0) to very good (mean score of 4.0). In comparison, others have reported a mean score of 2.8 ± 0.5 for overall QOL 3 months after a subcranial approach to the anterior skull base. Another recent report demonstrated that patients who underwent EEAs reported significantly better scores in the ‘physical function’ and ‘impact on emotion’ domains than patients who underwent an open craniofacial approach (p < 0.04). In addition, long-term QOL studies suggest that postoperative pain and discomfort are less severe in patients who underwent EEA. Nasal morbidity is a concern when applying EEAs; however, following appropriate postoperative care, EEAs resulted in little or no long-term QOL sinonasal deficits.

Multiple reports allude to a significant decrease in operative time and length of hospital stay (LOS) associated with EEAs. However, reports comparing operative time are controversial, as operative time varies according to surgical experience, technique, institutional practices and policies, and pathology. Regardless, surgical time is a factor of much lesser importance than functional and oncologic outcomes. LOS after anterior skull base tumor removal via external craniofacial resection (8.1 days) is significantly longer than that of EEA (3.8 days). Similarly, LOS after microscopic transseptal pituitary surgery via a sublabial transeptal approach (5.3 days) seems longer than that after EEA (3 days). However, one should note that LOS after pituitary surgery is most often dictated by endocrine abnormalities. In addition, some surgeons use a direct transnasal microscopic approach that obviates many of the wound and sinonasal problems arising from a microscopic transseptal approach. A recent report has suggested that the cost of pituitary surgery via EEA is significantly less than that of a microscopic approach. As previously mentioned, we should recognize that these results are influenced by selection biases regarding the criteria for each procedure.

Limitations. The surgical extent of EEAs is limited by surrounding critical neurovascular structures (Table 1 & Table 2); thus the spread of a tumor beyond the lateral boundaries constitutes a contraindication for EEA. However, if the goal is debulking rather than complete resection, or if the lesion is cystic or very soft the indications may be ‘stretched’.

Absolute contraindications to a pure EEA include tumors with invasion of the orbit requiring exenteration, or involving skin or anterior wall of the frontal sinus; or those that require microvascular reconstruction. When a cranial nerve needs to be mobilized or a major vessel dissected when coming from an endonasal route, alternative approaches should be
considered (disease lateral to the optic nerve or mid-point of the orbital roof or below the nasopalatine line). In these situations we favor a combination of two or even more approaches allowing 360° of dissection around the cranial nerve or vessel with minimal manipulation.

A technical consideration is that when dealing with malignant tumors, EEAs offer resection of the tumor in a piece-meal manner rather than the principle of en bloc resection. The need for an en bloc resection is a paradigm that has been challenging in multiple other areas. It seems that complete tumor extirpation with negative margins is more important than the concept of en bloc resection. [51,52] Recent studies comparing open and endoscopic techniques failed to show that endoscopic techniques carry a greater risk for a positive margin. [36,53]

**Craniocervical Decompression**

**Indications.** Pathologies at the craniovertebral region can compress the nervous system and compromise the blood supply to the cervicomedullary junction. Craniovertebral pathologies include congenital anomalies (atlas and axis malformations, clivus segmentation and odontoid dysplasia); developmental and acquired anomalies (foramen stenosis achondroplasia and secondary invagination); infection (Grisel’s syndrome and tuberculosis); trauma (odontoid fracture); inflammation (rheumatoid arthritis); and tumors (chordoma and chondrosarcoma). [54]

The primary aim of therapy is to relieve compression of the cervicomedullary junction. Decompression can be achieved via anterior or posterior routes according to the location of the pathology. Several techniques have been developed to access the anterior compartment, including transoral, transcervical and transnasal approaches. A transoral surgical corridor may require splitting of the soft palate, resection of the hard palate and occasionally, transmandibular or transmaxillary extension. [55–57] Common sequelae of these approaches include tongue and tracheal edema, and velopharyngeal insufficiency. Some have advocated the use of an endoscopic transcervical approach using a tubular retractor system to avoid these sequelae. [58] However, this model is limited by a restricted surgical field provided by a tubular retractor system and by the fact that the technique is not appropriate for patients who are obese, barrel-chested or have a kyphotic cervical spine. [59] Conversely, EEA obviates the sequelae of a transoral approach and provides panoramic visualization and a wide surgical field to resect the odontoid process and relieve the compression. [60]

**Limitations.** EEAs provide access to the anterior upper cervical spine (C1 and C2) and foramen magnum. However, the parapharyngeal ICAs and the vertebral arteries limit EEA laterally. An imaginary line connecting the inferior edge of the nasal bones and cervical spine, intersecting the most posterior aspect of the hard palate (nasopalatine line), defines its inferior limit; therefore, an alternative approach (or combined approaches) is needed if disease extends inferiorly to this line. [59]

**Reconstruction of Skull Base Defects**

**Indications.** CSF leaks are relatively rare but their sequelae, such as ascending meningitis or brain abscess, are life threatening. Location and size of the defect are related to its etiology. After a craniofacial trauma, the most common sites of CSF leaks are the sphenoid sinus (30%) and frontal sinus (30%). Following endoscopic sinus surgery, the most common site of CSF leaks is the ethmoid roof/cribiform plate area (80%); conversely, following neurosurgical procedure, the most common site of CSF leaks is the sphenoid sinus (67%).
For those with CSF presenting spontaneously, the sphenoid sinus is the most common location (40.3%); and for those that are secondary to congenital anomalies, the most common location is the ethmoid sinus (28.6%).

Management of a CSF leak may involve a conservative or nonsurgical treatment or surgical repairs. Traditionally, most CSF leaks resulting from craniomaxillofacial trauma have been treated conservatively with bed rest, head elevation and strict sinus precautions prior to considering their surgical repair. However, long-term follow-up has demonstrated that up to 29% of patients eventually develop meningitis. Therefore, early surgical closure of leaks or defects at the skull base should be considered to prevent ascending meningitis.

EEA has become a standard approach for the repair of CSF leaks regardless of the etiology. EEA provides a magnified and wide panoramic view that exposes the ethmoid roof, cribiform plate and sphenoid sinuses. Furthermore, the lateral recess of the sphenoid sinus, which is difficult to access via microscopic transseptal or transethmoidal approaches, can be directly accessed via the endoscopic transpterygoid approach.

Endoscopic repair yields overall success rates of 97–99%, while being associated with a very low incidence of morbidity and mortality. Recurrent CSF leaks may occur within 2 years, but these failures are often encountered in patients with spontaneous CSF leaks associated with pseudotumor cerebri or are the result of poor technique.

Limitations. EEs allow the reconstruction of a wide spectrum of skull base defects. Small defects may be repaired using a monolayer of free tissue grafts that can be placed onlay or inlay. Conversely, free tissue grafting is inadequate for the closure of large defects, which are more reliably reconstructed using vascularized pedicled mucosal flaps, such as the Hadad-Bassaigaisteguy nasoseptal flap. This flap can cover an area from the posterior wall of the frontal sinus to the sellae and from orbit to orbit. Nonetheless, if the nasoseptal flap is unavailable owing to invasion of the nasal septum by tumor or removal by previous surgery, a variety of alternative flaps are available. These include the inferior and middle turbinate flaps, lateral nasal wall or pedicled regional flaps, such as the temporoparietal fascia flap, pericranial flap and island palatal flap. Technical errors still constitute the most common cause for postoperative CSF leaks when using vascularized tissue for the reconstruction.

Vascular Tumors

Indications. EEs have been modified to extirpate vascular tumors. Fundamental steps of the operative technique include defining the circumferential extent of the tumor before any resection and early control of its vascular supply to reduce blood loss and expedite the surgical resection. A recent study compared EEA and open approaches for the resection of juvenile nasopharyngeal angiofibroma. EEs seemed to reduce operative time (mean 240 min in EEA; mean 525 min in open approach) blood loss (mean 550 ml in EEA; mean 4000 ml in open approach) and hospital stay (2 days for EEA; 5 days for open approach).

Limitations. Limitations of endoscopic endonasal resection include an extensive vascular supply arising from the ICA, its encasement, intracranial extension lateral to the paraclival segment and residual lesions involving critical areas (ICA, optic nerve, cavernous sinus and dura). Large vascular tumors with skull base involvement may require staging of the surgery (i.e., multiple procedures) owing to significant blood loss. Large tumors may be divided into two or more segments corresponding to their blood supply; then, each segment can be removed in different surgical stages separated by a period of time that allows the
resuscitation of the patient. Intracranial extensions are excised last.\(^{[13]}\) Resection of vascular tumors is challenging regardless of the approach. EEA for vascular tumors is very complex and should only be entertained by experienced teams.

**Pediatric Patients**

**Indications.** Craniofacial growth may be affected by any surgery; therefore; the extensive approaches requiring osteotomies or maxillofacial translocation should be avoided owing to the possible disruption of mid-face growth centers.\(^{[13]}\) EEA offers the advantage of using pre-existent air spaces obviating facial incisions/scars and less disruption of growth centers. Nonetheless, its long-term effects are yet to be elucidated.

**Limitations.** EEA is challenging owing to the smaller dimensions of the sinonasal anatomy and lack of sinus pneumatization.\(^{[13]}\) Piriform aperture dimensions, however, are a limitation only in patients under 2 years of age. Sphenoid pneumatization to the planum and sella starts at 3 years and is complete by 10 years of age. However, clival intercarotid distances do not change significantly; therefore, do not seem to be a prohibitive obstacle at any age, since careful drilling can be performed in these areas recreating the desired ‘pneumatization’.\(^{[91]}\)

4. **Conclusion & Future Perspective**

EEAs include minimally invasive techniques capable of accessing the ventral cranial base to facilitate the resection or debulking of tumors and/or the repair of the target pathologies. The advantages of EEA include the lack of facial scars, decreased trauma to normal tissue, improved QOL and diminished morbidity. EEA, however, are just one of the tools available to the modern skull base surgeon. EEA are limited by the nature of the pathology (location, diagnosis and vascularity), patient characteristics (age and medical comorbidities), surgeon attributes (training, experience and expertise) and available institutional resources (adjunctive services, intensive care unit and operating room equipment).

Endoscopic endonasal skull base surgery is currently a reality in few places around the world. The authors believe the great advantages offered by this ventral midline approach are going to progressively become a constant technique in most, if not all, of the neurosurgical centers worldwide. The authors do not foresee EEA replacing the standard skull base approaches, but rather complementing them to better serve our patients. It will be very important for the skull base team to be versatile in both open and endoscopic approaches in order to tailor the best approach for the patient. There are situations in which EEA will be the best option, others in which a craniotomy will offer the best angle and there will be further occasions when a combination of both techniques will be the ideal way to access the pathology.

5. **Executive Summary**

- Endoscopic endonasal approaches (EEAs) are based on a wide surgical corridor that includes bilateral nasal access and customized removal of bone to allow dynamic
visualization, a two-surgeon–four-hand dissection technique and adequate space for instrumentation.

- **EEAs** can access the entire ventral skull base extending from the frontal sinus to the second cervical vertebra and stretching laterally across the ethmoidal roof, floor of the middle cranial fossa and jugular foramen.
- Surgical indications of EEAs include the resection or debulking of neoplasms (benign and malignant), decompression of neural structures and reconstruction of skull base defects.
- EEA eliminates the need for external incisions or scars, the translocation of the maxillofacial skeleton and retraction of the brain. Other advantages include an improvement of quality of life, a reduction of postoperative pain/discomfort and a significant decrease in operative time and length of hospital stay.
- Endoscopy provides superior magnification, distal illumination and visualization (of the surgical target) and offers the possibility of using angled lenses (0, 30, 45 and 70°) to look ‘around corners’. This benefit eliminates ‘blind’ grasping or curettage of the tumor; thus diminishing the risk of neurovascular injury, incomplete removal of the tumor or inadequate reconstruction of a dural defect.
- Factors that may limit or even contraindicate the use of an EEA include the location and vascularity of the lesion; the ability to reconstruct the resulting defect (i.e., the need for a free flap); medical comorbidities of the patient; proper training, expertise and experience of the surgeon; and the availability of institutional resources.

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•• Compares the outcomes between EEA and an open approach to dealing with malignant tumors.


   • Systematic review demonstrating the outcome of reconstruction of large skull base defects.


Papers of special note have been highlighted as:
• of interest
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