Orbitocranial Approaches to the Skull Base

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Abstract

Keywords

- ▶ anterior skull base
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There are a myriad of approaches and surgical options for removal and treatment of skull base diseases. While, historically, large open approaches have been preferred, several endoscopic and minimally invasive techniques are now available that preserve intraoperative visualization and surgical success while minimizing morbidity and recovery times. Herein, the authors review common open, minimally invasive, and endoscopic approaches to the anterior skull base.

Tumors and other anomalies of the skull base present a challenge to surgeons; their resection and reconstruction are complicated by the presence of many surrounding, important neurovascular structures that can make surgical access difficult. Many approaches to the skull base have been developed and refined over the past several decades in an effort to improve complete surgical resections and minimize complications. Herein, we review common open and minimally invasive techniques employed today.

Open Approaches

The treatment of sinonasal, cranioorbital, and anterior cranial fossa pathologies such as tumors, traumatic cerebrospinal fluid (CSF) leak, and arteriovenous malformations requires a variety of approaches to address the underlying problem. Traditionally, open approaches were pioneered to provide maximum exposure to removal and reconstruction of virtually any defect of the skull base. Many of these approaches are still in use today.

Transfacial Approach

A *transfacial approach* is any approach that involves violation of facial structures to develop exposure of the skull base. As a

single approach, it is ideal for low-lying tumors involving the anterior nasal cavity, inferior maxilla, and hard palate,¹ but it can be combined with transmaxillary, transbasal, zygomatic, or orbitozygomatic approaches to reach the skull base.² The transfacial approach begins with a classic lateral rhinotomy incision extended into a Weber–Ferguson when access to the palate or orbital floor is necessary.¹ The skin soft-tissue envelope is elevated off the nasal bones, medial and inferior orbital walls, and the anterior face of the maxilla. Care is taken to preserve the maxillary nerve and to carefully ligate the angular and ethmoid arteries.

Alternatively, a midface-degloving transfacial approach can also be employed. In this approach, there are no external incisions. Rather, it begins with an intranasal full transfixion incision and intercartilaginous incisions extended laterally, beyond the pyriform aperture, then inferiorly for circumferential vestibular release. The nasal dissection is then connected to intraoral bilateral sublabial incisions such that the entire skin soft-tissue envelope of the bilateral cheeks and nose can be lifted off the maxilla and nasal bones.¹

Following exposure of the maxilla, nasal bones, and orbit, either via midface degloving or a lateral rhinotomy with Weber–Ferguson, an osteotome can be directly applied to the nasal bones to allow their medial retraction with subsequent

direct access to the nasal cavities and ethmoid sinuses.¹ Alternatively, LeFort I and midline split osteotomies can be performed for a “transmaxillary” approach to the clivus.² Similarly, orbitofrontal osteotomies could be performed for a transbasal approach to the suprasellar hypothalamus and tuberculum sellae tumors.² Finally, either transfacial approach could also be combined with a bicoronal approach to facilitate even greater bony exposure and allow a more extensive craniofacial resection.¹

The major drawbacks of transfacial approaches revolve around poor aesthetic outcomes from extensive facial incisions and distortion of the appearance of the nose (from osteotomies and disruption of the major tip support mechanisms. Further if the midface soft tissues are not appropriately resuspended, then patients can experience midface droop. Despite these drawbacks, transfacial approaches are nonetheless invaluable in facilitating exposure for many other approaches to the anterior skull base.

Transbasal Approach

The transbasal approach to the anterior skull base was first described by Derome and Tessier in the 1960s and 1970s. This approach consists of a low bifrontal craniotomy with extradural exposure, and it allows for wide exposure of the dura and, subsequently, access to the entire ventral skull base. Since its development, numerous modifications have been published.³

Frontal, Subfrontal, and Extended Frontal Approaches

Frontal, subfrontal, and extended frontal approaches are related to transbasal approaches and often classified together (►Fig. 1). A frontal approach is any approach that includes craniotomy of the frontal bone for direct access to the anterior fossa (►Fig. 2). A subfrontal approach is any approach that

includes craniotomy of the inferior aspect of the frontal bone, often in continuity with the superior orbital rim and superior aspects of the nasal bones.⁴ A modification of a true frontal approach is a lateral frontal approach in which a unilateral coronal incision is made, the lateral frontal bone is exposed, and craniotomy is made taking care to leave the supraorbital ridge intact.⁵ The subfrontal approach necessarily violates the frontal sinus, which the frontal approach can too, and thus frontal sinus cranialization is often performed after tumor resection.⁴

Lateral Approaches

Lateral approaches to the skull base include supraorbital, zygomatic, infratemporal, and similar approaches that remove lateral cranial bones to access intracranial contents.⁶ The classic supraorbital approach includes craniotomy of the unilateral frontal bone and superior orbital rim.⁷ The zygomatic approach is similar, but it involves removal of the lateral orbital rim and zygomatic arch to access the anterior temporal base.⁸ Next, an extended orbitozygomatic approach has also been described.⁶ In this approach, the lateral orbital rim and zygomatic arch are removed, the temporalis muscle is reflected anteriorly, and a frontotemporal craniotomy is performed to access the cavernous sinus, superior clivus, and parasellar regions (►Figs. 3, 4).⁶

Lateral approaches can also be combined with frontal and subfrontal approaches to improve visualization of the orbital apex, paraclinoid and parasellar regions, basilar apex, cavernous sinus, and the anterior and middle fossa floor.⁴ Some have classified these as fronto-orbito-zygomatic (FOZ) approaches, as they involve entry to the cranium via osteotomies of the superolateral orbital rim, lateral frontal bone, and zygoma.⁴ Compared to the classic pterional approach, the extended subfrontal-FOZ approach has been posited to require less brain retraction but improved visualization of neurovascular structures, thus minimizing patient risks and complications.⁴ Further, it allows better exposure to the nasal cavity, ethmoid and sphenoid sinuses, and the orbit.⁴

Minimally Invasive Open Approaches

Open approaches have the distinct disadvantage of high morbidity, given that they often involve large head and face incisions, osteotomies, translocation of neurovascular structures, and generally lead to a prolonged recovery time. Today, the main indications for use of open approaches to the ventral skull base include very large lesions or those requiring larger resections, lesions with greater intracranial extension, firmer tumor consistencies more amenable to open resections, and/or proximity of disease to vital structures with encasement.⁹

Minimally invasive techniques have been developed to yield similar outcomes as open approaches with less extensive, more direct dissection. Further, they have had the goal of improved cosmetic results and shorter recovery times.

Minimally Invasive Subfrontal Approach

This approach describes a minimally invasive version of the subfrontal approach developed by Raveh¹⁰ to allow adequate access to the cavernous sinus, orbital apex, internal carotid

Fig. 1 Transbasal and lateral approaches to the skull base. F: frontal craniotomy and approach. SF: subfrontal craniotomy and approach. FOZ: fronto-orbito-zygomatic approach.

Fig. 2 68-year-old male status postresection of a right forehead basal cell carcinoma 10 years previously, now with deep recurrence. (A) Preoperative appearance of patient. (B) Appearance of frontal craniectomy with dural exposure after disease removal. (C) Superior view of frontal sinuses. (D) Frontal sinus obliteration with adipose. (E) Temporary mesh covering of craniectomy defect. (F) Patient-specific implant for the frontal craniectomy defect. (G) Inset of patient-specific implant. (H) Two-week postoperative appearance of patient.

Fig. 3 Extended orbitozygomatic approach with frontotemporal craniotomy. (Image originally published by Pontius and Ducic.⁶ Reproduced with permission from Sage Publications, License #4418900831666.)

arteries, and tumors of the median or paramedian anterior fossa extending extracranially, or intraorbital or paranasal sinus tumors extending intracranially, while minimizing morbidity from extensive dissection.¹¹ It avoids disruption of the lacrimal system and nasofrontal beak.

To start, patient scans are reviewed to evaluate pneumatization of the frontal sinus; a minimally pneumatized frontal sinus precludes this approach, and it is not ideal when tumor extends superiorly beyond the roof of the frontal sinus. Next, a bicoronal incision is made. A pericranial flap is elevated, and then the flap is elevated in a subperiosteal plane to expose the frontal bone inferiorly to the supraorbital ridges. Next, the edges of the pneumatized frontal sinus are outlined; transnasal illumination and intraoperative computer navigation can be helpful.¹¹ Osteotomies are then performed to remove the anterior wall of the frontal sinus followed by the posterior wall. Following this, with adjustments in patient position, the surgeon can directly access subfrontal tumors with minimal brain retraction. After tumor removal, mucosa is drilled from the inner aspect of the anterior wall of the frontal sinus, and the frontal outflow tracts are plugged with native mucosa or temporalis muscle. Dura is repaired, the pericranial flap is placed along the base of the anterior cranial fossa, and the anterior table bone of the frontal sinus is replaced and plated in position.

Fig. 4 Exposure achieved via an extended orbitozygomatic approach. (Image originally published by Pontius and Ducic.⁶ Reproduced with permission from Sage Publications, License #4418900831666.)

Minimally Invasive Supraciliary and Transfacial Approach

The open frontolateral approach has been modified to include only a supraciliary incision through which a keyhole craniotomy could be performed. Similarly, a combined minimally invasive craniotomy through a supraciliary incision with a transfacial approach for tumors involving both the sinonasal region and anterior skull base has been performed.¹²

The transfacial approach is via a Weber–Ferguson incision with planned maxillotomy based on the extent of tumor invasion. A supraciliary incision is then made 5 to 10 mm lateral to the brow edge and extended medially to connect with the transfacial incision. The fascia and muscle are cut and a 3 to 4 mm burr hole is made below the anterior portion of the superior temporal line. A bone flap of 2.5 cm height × 3.5 cm width is created and removed. A portion of the orbital roof is then drilled to avoid frontal lobe retraction.¹²

The advantage of this technique is that it spares the patient a standard coronal incision while still allowing adequate intracranial visualization. Further, it avoids bilateral frontal lobe retraction and superior sagittal sinus transection.

Endoscopic Approaches

In addition to minimally invasive open approaches, the past few decades have seen the development and refinement of endoscopic approaches to the skull base. The goal of endo-

scopic approaches is to provide adequate skull base exposure while avoiding head and face incisions.

Endonasal

The endoscopic endonasal approach is begun in a similar fashion to standard endoscopic sinus surgery. Ethmoidectomy, sphenoidotomy, or frontal sinusotomy including a Lothrop procedure can be performed as needed depending on the ultimate location goal. Following, the medial orbit can be accessed through the lamina papyracea. The pituitary gland, optic chiasm, and cavernous sinuses can be accessed through the posterior, superior, and lateral walls of the sphenoid sinus. Also, the olfactory groove can be accessed through the cribriform.

Endoscopic approaches can also employ use of the microscope so that the operating surgeon can use both hands to operate. The endoscope can then be used intermittently for angled visualization of structures not quite captured by the microscope. Alternatively, the endoscope can be used solely for visualization in a two-surgeon approach in which one navigates the endoscope and the other manipulates tissue. Finally, a rigid endoscope holder can also be used to secure the endoscope in one position and allow the surgeon to operate with both hands.¹³ When working posteriorly, a posterior septectomy is often required to improve the working angle and to allow visualization through one nasal passageway with working instruments inserted through the opposite nasal passageway.¹³

The endoscopic endonasal approach has been proposed to be useful for treating skull base CSF leaks, encephaloceles, pituitary gland abnormalities, craniopharyngiomas, skull base meningiomas, sinonasal malignancies, chordomas, petrous apex lesions, medial orbital pathology, and some vascular lesions.¹³ It has many advantages to open approaches; it does not require facial incisions, allows magnification and enhanced visualization of important structures, and allows excellent access to the nasal sinuses, medial orbit, and central skull base, leading to the anterior, middle, and posterior cranial fossae.¹⁴ It is less useful and potentially contraindicated when there is disease involvement of skin and subcutaneous tissues, the nasolacrimal sac, the anterior table of the frontal sinus, the carotid artery, or extensive dural or brain parenchymal involvement. In these cases, a transfacial transcranial open approach would be more appropriate.

Transorbital

The endoscopic transorbital approach allows access to lateral structures that cannot be reached by the endonasal approach, specifically the lateral regions of the anterior and middle skull base.^{14,15} It can be used for removal of skull base lesions, treatment of CSF leaks, repairs of cranial base fractures, and optic nerve decompressions.¹⁶

Transorbital endoscopic surgery is carried out with two surgeons and four hands. One surgeon holds the endoscope; it is recommended not to fix the endoscope in a rigid holder, as this can apply persistent unabating pressure to orbital structures and cause ischemia with long-term compromise. The orbit can be entered in one of four ways: precaruncular,

through an upper eyelid crease, lateral retrocanthal, and lower eyelid preseptal.¹⁴ In the upper eyelid crease approach, incision is made in the natural eyelid crease through the skin and orbicularis oculi muscle. The orbital septum is identified and followed superiorly and posteriorly; care should be taken not to violate the septum to prevent orbital fat from herniating into the operative field. The orbital septum leads to the orbital rim, from which a subperiosteal elevation is undertaken to expose the superior and inferior orbital fissures. From here, the greater wing of the sphenoid at the posterior aspect of the orbit can be removed with a drill to expose the middle cranial fossae.¹⁴ Specifically, this approach allows access to the floor of the middle cranial fossa with excellent exposure of the gasserian ganglion with the trigeminal nerve branches and cavernous sinus contents.¹⁴ The orbital part of the frontal bone and lesser wing of the sphenoid can also be drilled to allow access to the anterior cranial fossa and frontal lobe.¹⁷

In the lower eyelid approach, a subciliary or subtarsal incision can be used to gain access to the orbital septum. A preseptal plane is followed to the orbital rim, after which a subperiosteal elevation reveals the orbital floor, medial, and lateral walls. This approach allows access to the floor of the middle cranial fossa, the infratemporal fossa, and as well as transdural approaches to the temporal lobe.¹⁴ The lateral retrocanthal approach, alone or in combination with other transorbital approaches, allows improved lateral wall access with subsequent exposure to the lateral cavernous sinus, and the precaruncular approach allows improved access to the medial orbital wall.^{14,18}

Compared to open approaches to the lateral cranial fossae, the endoscopic transorbital approach does not include external facial incisions, includes less dissection of normal structures, and has shorter recovery times. Further, it can be performed without compromise of the orbit or eyelids.^{14,16}

Combined Endoscopic Approaches

The transnasal and transorbital approaches can be combined for multiportal endoscopic surgery. An anatomical study by Dallan et al demonstrated that combined transorbital transnasal endoscopic approaches to the middle and anterior cranial fossae achieved near 360-degree visualization of the optic nerve, orbital apex, cavernous sinuses, and supraclinoid internal carotid arteries.¹⁹ Clinically, a multiportal approach has been used to successfully treat sphenoorbital meningiomas and malignant schwannomas of trigeminal nerve, and the authors propose that it is a safe and valid approach for management of large skull base lesions.¹⁹

Outcomes

Many approaches to the skull base share a common set of surgical risks. When operating around the brain itself, there is a risk of brain contusion, brain edema, syndrome of inappropriate antidiuretic hormone (SIADH) secretion, CSF leak, pneumocephalus, meningitis, encephalitis, and intracranial abscess.¹ When operating around the orbit, there is a risk of blindness or visual loss. Meticulous dissection is

important to prevent uncontrolled intracranial and intraorbital bleeding, and minimization of brain manipulation or retraction can significantly decrease many brain-related complications.¹

A review of 1,193 patients who underwent craniofacial resections from 1970 to 2000 found an overall mortality rate of 4.7% and a complication rate of 36%.²⁰ Wound complications were most common, occurring in nearly 20% of patients, while central nervous system complications occurred in 16% of patients. Orbital and systemic complications were less common.²⁰ Not unsurprisingly, larger resections predispose patients to more complications. Many studies have found that the extent of intracranial extension of dissection is the greatest predictor of postoperative complications, and surgical involvement of more than one skull base site is significantly associated with postoperative complications.^{1,21,22}

A recent study reviewed 465 cases of anterior skull base tumor resections via open or endoscopic approaches and found that open approaches were associated with significantly higher postoperative infections and systemic complications.²³ However, the authors noted that larger tumors presenting at a more advanced stage were not amenable to endoscopic resection, and their results should, therefore, be interpreted with the possibility of selection bias.²³ In general, endoscopic approaches to the skull base involve longer operative times than open approaches.

Recently, two separate meta-analyses have compared endoscopic approaches to open approaches for esthesioneuroblastoma resection, and both concluded that endoscopic approaches were associated with higher survival, lower rates of local recurrence, and lower rates of regional metastases developing.^{1,24,25} Of note, these studies did not control for tumor stage or grade which is known to significantly affect patient outcomes.¹

A literature review of transorbital endoscopic approaches to the skull base revealed that no patients suffered significant neurological or vascular complications, death, intraorbital or extraorbital bleeding, or infections.¹⁴ Rarely, transient diplopia has been described, presumably from damage to the ocular muscles or orbital nerves, but no cases of permanent diplopia have been reported. While no functional disturbances have been noted, cosmetic enophthalmos can occur from disruption of the bony housing of the orbit.¹⁶ No problems with external scarring of the eyelids has been reported after transorbital endoscopic approaches to the skull base.¹⁴

A literature review by Komotar et al found that early gross total resection rates of olfactory groove meningiomas via an endoscopic endonasal approach were around 63%, whereas gross total resection was achieved via a transcranial open approach in more than 92% of cases.²⁶ A recent systematic review found that gross total resection rates of lower grade (I or II) olfactory groove meningiomas were 70% from an endoscopic endonasal approach but 91% from an open transcranial approach.²⁷ Interestingly, the same review also found that 80% of patients with preoperative visual disturbances who underwent endonasal endoscopic resection reported improved vision after surgery. Comparatively, only 12% of patients with preoperative visual disturbances who underwent a transcranial

approach reported visual improvement, a rate which was significantly lower than the endonasal group.²⁷ Additionally, 6% of patients who underwent an open transcranial approach experienced visual worsening, while none who underwent an endoscopic endonasal approach did, but this comparison did not reach statistical significance.²⁷ Rates of CSF leak and meningitis were significantly higher after an endonasal approach, 25 and 4% respectively, compared to rates from an open approach, 6 and 1%, respectively.

Conclusion

There are a myriad of approaches and surgical options for the removal and treatment of skull base diseases. While, historically, large open approaches have been preferred, several endoscopic and minimally invasive techniques are now available that preserve intraoperative visualization and surgical success while minimizing morbidity and recovery times.

Conflict of Interest

None declared.

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