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HOW I DO IT - NEUROSURGICAL TECHNIQUES

Endoscopic endonasal resection of sinonasal/anterior skull base malignancy (Kadish C esthesioneuroblastoma)

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Abstract

Background The surgical management of anterior skull base malignancies requires the full complement of open and endoscopic skull base approaches. Due to the evolution of endoscopic techniques, endoscopic approaches are now being employed for complex skull base tumors.

Methods We present our technique for endoscopic management for an advanced (T4) anterior skull base malignancy that provides a systematic approach to resection, margin assessment, and reconstruction.

Conclusion Our surgical strategy provides a systematic approach by which an oncologic resection can be performed within the context of a spectrum of surgical strategies necessary to manage skull base malignancies.

Keywords Endoscopic endonasal · Skull base · Cancer · Malignancy · Esthesioneuroblastoma

Introduction

A combined cranio-endoscopic approach has been traditionally used for anterior skull base malignancies, particularly with extensive dural involvement or disease extension laterally over the orbits. However, pure endoscopic management of sinonasal malignancies is now well defined with supporting oncologic outcomes [3]. Given these data, we present our technique for endonasal endoscopic resection of a T4 sinonasal malignancy with extensive skull base involvement. A representative surgical video demonstrates resection of a Kadish C (extends beyond the nasal cavity and paranasal sinuses) esthesioneuroblastoma.

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Relevant surgical anatomy

Landmarks delineating the limits of an endoscopic anterior skull base resection and vascular structures must be identified (Table 1).

Description of technique

This approach provides access to all subcranial compartments and the central anterior cranial fossa. As with all skull base malignancy resections (Fig. 1a, b), we employ a "next compartment principle"—at least one compartment away from the tumor is opened to obtain negative margins beyond the tumor [4]. The key steps of the resection are outlined in Table 2. Rotatable micro-instruments are typically used along with 15° angled drills. The procedure can generally be performed with 0° endoscopes.

Soft tissue dissection/tumor resection

Topical vasoconstrictors (i.e., Afrin) are applied. A nasoseptal flap is raised on its posterior vascular pedicle unless involved by cancer. In such cases, a pericranial flap is used. The tumor is debulked to facilitate identification of its origin, the surrounding sinuses, and subcranial vascular pedicles to the tumor. A septectomy is performed to clear margins and facilitate

Table 1 Relevant anatomic landmarks

Anatomic landmarks	Relevance	Relevant dissection step
Bony landmarks		
Posterior frontal sinus wall	Anterior boundary of resection	Draf III frontal sinusotomy
Lamina papyracea	Lateral boundary of anterior skull base resection	Ethmoidectomy
Optic canals	Posterior extent of anterior skull base resection	Sphenoidotomy
Vascular structures		
Sphenopalatine arteries	Vascular supply to posterior aspect of the tumor and nasoseptal flap	Maxillary antrostomy identification of sphenopalatine foramen
Anterior ethmoid arteries	Vascular supply to skull base component of tumor	Ethmoidectomy and lamina papyracea dissection identification of anterior ethmoid foramen
Posterior ethmoid arteries	Vascular supply to skull base component of tumor	Ethmoidectomy and lamina papyracea dissection identification of posterior ethmoid foramen
Frontopolar segment of anterior cerebral arteries	Vascular supply to frontal lobes overlying tumor	Intradural dissection

binasal access; the septum is resected inferior to the tumor extending down to the maxillary crest and posteriorly to the sphenoid rostrum.

The maxillary antrostomy provides access to disease within the maxillary sinus and allows identification of the lamina papyracea. A wide antrostomy is created extending from the nasolacrimal duct to the posterior maxillary wall and superiorly to the orbital floor. The sphenopalatine arteries are ligated to minimize subsequent blood loss. Any disease spread into the maxillary sinus is

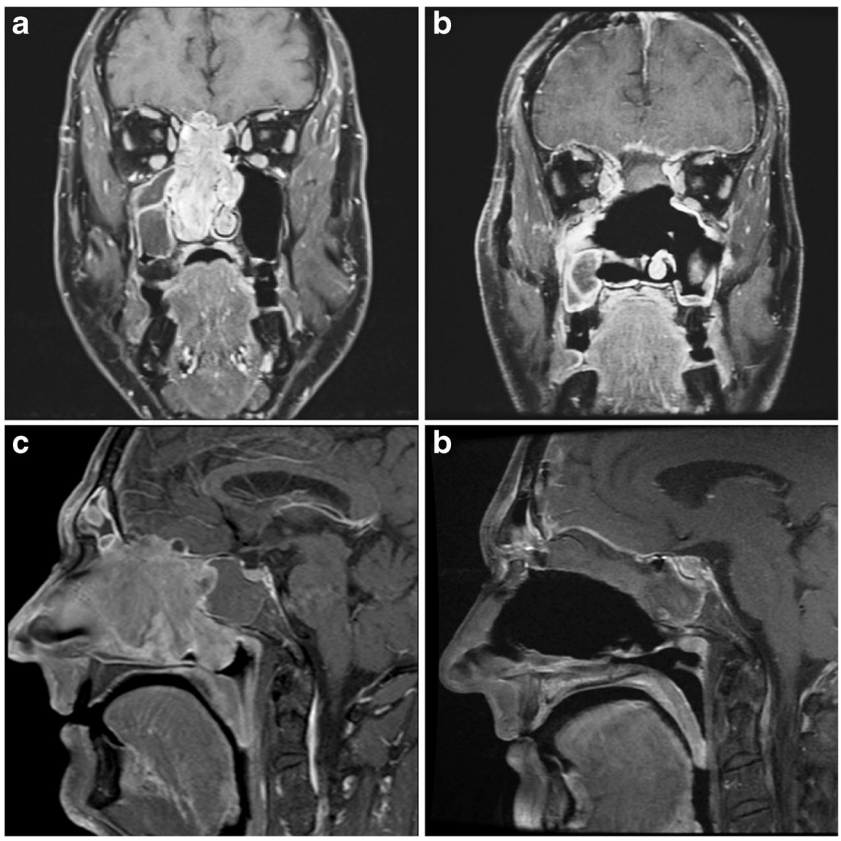

Fig. 1 Preoperative (**a** coronal and **b** sagittal) and post-operative (**c** coronal and **d** sagittal) MRI T1 weighted with gadolinium contrast scans demonstrating extent of disease and resection

Table 2 Key procedural steps of endoscopic endonasal skull base malignancy resection

Procedural steps
1) Debulking the intranasal component of the tumor
2) Developing a vascularized nasoseptal flap if not involved with tumor
3) Opening of the maxillary and sphenoid sinuses, anterior/posterior ethmoidectomies, exposure of the lamina papyracea, and control of vascular pedicles
4) Draf III frontal sinusotomy
5) Cribriform plate/skull base resection
6) Dural incisions, dural and/or brain resection
7) Multilayered reconstruction

removed. Bony involvement overlying the nasolacrimal duct can be resected—facilitated by removal of the inferior turbinate. If the duct is resected because of tumor involvement, the superior cut edge is marsupialized to avoid post-operative epiphora.

The sphenoid sinus is opened from the planum to the floor and between the optic canals bilaterally. If the mucosal margins are positive, bone is resected to the level of the dura. The optic canals are identified; they serve as the posterior limit of the anterior skull base resection to be performed later.

The orbital floor is then followed from the maxillary sinus superomedially towards the lamina papyracea. Bilateral ethmoidectomies facilitate tumor dissection along the lamina from the anterior margin back to the orbital apex. This exposes the anterior skull base. With overlying mucosal involvement, the lamina papyracea is removed. In this process, the anterior/posterior ethmoid arteries are identified intraorbitally lateral to the tumor and interrupted; this devascularizes the skull base component of the tumor and facilitates lateral mobilization of the orbital contents to expose the orbital roof.

A Draf III sinusotomy exposes the anterior margin of the cribriform plate (Table 1) [2]. By removing the frontal sinus floor, the superior portion of the nasal septum, and the intrafrontal sinus septum, this unifies both frontal sinuses and exposes the posterior frontal sinus wall. At this point, the entire ethmoidal component of the tumor and its skull base attachment has been isolated facilitating safe intracranial resection (Table 3).

The anterior skull base is resected by creating osteotomies along the anatomic structures listed in Table 1. The dura is incised beyond the limits of the tumor and the falx is detached. The subdural component of the tumor along with the olfactory bulbs is dissected from the gyrus rectus bilaterally with careful attention to overlying vascular structures. The olfactory bulbs are transected posteriorly after which the skull base attachment of the tumor is removed. Margins are obtained along both olfactory bulbs, the falx, and dura (laterally, anteriorly, and posteriorly).

Reconstruction

Reconstruction for malignancy resections often requires repairing larger defects and the use of salvage tissue flaps. Beyond preventing a CSF leak, vascularized reconstruction promotes skull base healing prior to adjuvant radiation therapy. A multilayered closure commences with an in-/onlay of fascia lata. Both grafts should be approximately 30% larger than the dural defect. Vascularized coverage can be provided by a pericranial flap harvested via a bicoronal incision. Based on a supraorbital vascular pedicle, the flap is transposed on the nasal side of the dural defect with endoscopic assistance via a bony window

Table 3 Description of the Draf I–III frontal sinusotomy procedures

Procedure	Structures removed	Drainage achieved
Draf I (simple drainage)	- Anterior and middle ethmoidal cells	Drainage through frontal sinus infundibulum.
Draf II (extended drainage)	- Anterior and middle ethmoidal cells - Frontal sinus floor from lamina papyracea to nasal septum	Drainage through frontal sinus floor unilaterally
Draf III (median drainage)	- Bilateral anterior and middle ethmoidal cells - Frontal sinus floor from lamina papyracea to lamina papyracea - Superior nasal septum beneath frontal sinus - Interfrontal sinus	Drainage through frontal sinus floor bilaterally

Adapted from Draf W (1991) endonasal micro-endoscopic frontal sinus surgery: the Fulda concept. Operative techniques in Otolaryngology—Head and Neck Surgery 2:234–240

Table 4 Diagnostic assessment of anterior skull base malignancy

Diagnostic modality	Features to assess
CT face/orbits	Lamina papyracea
	cribriform plate
	cranial nerve foramina
	nasal bone involvement
MRI face/orbits with fat saturation	Extent of dural invasion
	orbital tissue involvement
	perineural invasion
	brain invasion
	cavernous sinus/carotid artery involvement
	pterygopalatine fossa involvement
	paranasal sinus involvement
PET/CT	Regional/systemic disease staging
	response to neoadjuvant therapy
Nasal endoscopy/biopsy	Histologic diagnosis
	anatomic assessment
	intranasal reconstruction options

Note that CT and MRI imaging are complimentary with regard to assessing extent of tumor involvement

created at the nasofrontal suture. Graft migration is prevented by securing its periphery with surgicel and a biologic glue. Final post-operative scan is shown in Fig. 1c, d.

Indications

The initial evaluation of skull base cancers includes as follows: (1) local and systemic staging, (2) establishment of a diagnosis via biopsy, and (3) development of a multidisciplinary treatment plan based on histology. The diagnostic pathway is delineated in Table 4. Surgery should be curative; several large studies have identified a positive resection margin as an independent risk factor for recurrence and reduced survival [1, 3, 5].

Limitations

Clear contraindications to a purely endonasal approach are shown in Table 5.

How to avoid complications

To limit risk of infection, a thorough preoperative nasal wash with clindamycin-impregnated saline is used after the patient is positioned. Pre- and post-operative intravenous vancomycin, cefepime, and flagyl are also used. Complications after an endoscopic resection are often reconstruction-related or failure to clear margins. Larger defects should be repaired with vascularized flaps, while free grafts can sometimes be used for

Table 5 Anatomic limits of endoscopic endonasal approach for anterior skull base malignancy

Anatomic compartment	Anatomic limit	Surgical approach required
Maxillary sinus	Floor	Infrastructure maxillectomy
	Roof lateral to infraorbital nerve	Maxillectomy
Orbit	Orbital contents (beyond periorbita)	Orbitectomy
Frontal sinus	Anterior wall	Open frontal sinustomy/bifrontal craniotomy
Nasal cavity	Nasal bone involvement	Lateral rhinotomy or transbasal
Soft tissue	Skin	Transfacial
Intracranial	Lateral dural involvement over orbit (beyond endoscopic field of view)	Bifrontal craniotomy
	Brain parenchyma	Bifrontal craniotomy

small defects. When a CSF leak is encountered (less than 3%) [3], low-flow leaks respond to short-term lumbar drainage. With a high-flow leak, the patient should be taken to the operating room for a definitive repair.

Specific perioperative considerations

With careful preoperative imaging review, the need for intraoperative conversion to an open skull base resection due to an inability to clear negative margins is now exceedingly rare. Our data indicates equivalent rates of negative margins (85%) between endoscopic and cranio-endoscopic approaches in well-selected cases [3]. For patients who have previously undergone surgery, the challenges primarily relate to the achieving an oncologic resection despite disrupted anatomic structures and providing a robust skull base reconstruction. In order to ensure that accurate margins are assessed intraoperatively, all imaging prior to any previous surgical intervention should be carefully studied. This provides a thorough understanding of the original anatomic extent of the tumor and which anatomic compartments should be resected in an oncologic fashion. Of note, in situations where induction chemotherapy has been delivered (i.e., for neuroendocrine carcinomas), the surgical approach is tailored to the post-chemotherapy tumor volume based on a high-resolution MRI scan. Otherwise, in post-radiated cases, careful preoperative planning should include an assessment of adequate vascularized coverage. Though, it is important to note that the indications of surgery and availability of adjuvant therapies (i.e., re-irradiation) must be carefully considered if a salvage resection is being performed for progressive disease post-radiation. Adjuvant (chemo)radiation, if necessary, is typically deferred until 3–4 weeks after surgery to allow for appropriate skull base healing prior to initiation of therapy.

Specific information for patient and potential risks

Detailed discussion regarding the goals of surgery in the context of an overall treatment plan is mandatory. There should be counseling regarding the indications for a purely endoscopic versus a cranio-endoscopic resection and the indications for intraoperative conversion to an open approach, including as follows: intraoperative identification of anatomic structures prohibitive of solely an endoscopic resection (Table 4) or positive dural margins at the limits of the exposure. The primary risks of surgery include CSF leak, failure to clear margins, and risk of infection. The rhinologic risks associated with this procedure are related to evacuation of the intranasal contents. In situations where the superior/middle/inferior turbinates must be resected due to cancer involvement, patients are at risk for "empty nose syndrome" [6]. Hence, effort is taken to preserve uninvolved structures during the course of the resection without sacrificing the oncologic goal of negative margins. Additionally, intranasal crusting can be encountered in the initial post-operative period and during the course of adjuvant radiotherapy. This can be addressed endoscopically in clinic 2 weeks after surgery and as needed during radiation.

Relevant points

1. Surgical resection is considered within the context of a multimodality treatment protocol tailored to histology.
2. The goals of surgery are to achieve negative margins, minimize brain retraction, preserve neurovascular function, reconstruct to exclude the intracranial space from subcranial compartments, and optimize esthetic and functional outcome.
3. Preoperative imaging must be carefully assessed for extent of disease spread and the anatomic limits of an endoscopic endonasal resection.
4. The endoscopic endonasal resection begins within the subcranial space and should result in isolation of the nasoethmoidal component of the tumor and its skull base attachment before proceeding intracranially.
5. The anatomic limits defining an endoscopic anterior skull base resection include as follows: the frontal sinus anteriorly, lamina papyracea laterally, and optic canals posteriorly.
6. Carefully planned dural incisions and meticulous subdural dissection facilitate resection of the skull base component of the tumor.
7. Tumor-free surgical margins should be achieved both intra- and extracranially under frozen section control with the expertise of a dedicated head and neck/neuropathologist.
8. Positive margins obtained at the anatomic limits of the endoscopic exposure require consideration of the need for further surgical adjuncts.
9. A multilayer closure incorporating a vascularized reconstruction is necessary to prevent a post-operative CSF fistula and to facilitate skull base healing prior to adjuvant therapy.
10. In the setting of a re-operation, consideration must be given to the use of salvage reconstructive options (i.e., tunneled pericranial flap).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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