Head and Neck Surgery

SKULL BASE SURGERY
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Series Editor
Eugene N. Myers, MD, FACS, FRCS Edin (Hon)
Distinguished Professor Emeritus
Department of Otolaryngology
University of Pittsburgh School of Medicine
Professor
Department of Oral Maxillofacial Surgery
University of Pittsburgh School of Dental Medicine
Pittsburgh, Pennsylvania

Editors
Carl H. Snyderman, MD, MBA
Professor
Departments of Otolaryngology and Neurological Surgery
University of Pittsburgh School of Medicine
Co-Director
Center for Cranial Base Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Paul A. Gardner, MD
Associate Professor
Department of Neurological Surgery
University of Pittsburgh School of Medicine
Co-Director
Center for Cranial Base Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

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This volume on skull base surgery is dedicated to the visionary pioneers who had the courage, creativity, and dedication to patients to tackle the problems of the skull base, and to the next generation of skull base surgeons who will continue the cycle of innovation. We are especially indebted to Dr. Eugene N. Myers (series editor) for his unflagging support and mentorship and to Mary Jo Tutchko for her tireless efforts on our behalf. None of this would have been possible without their selfless dedication.
Vijay K. Anand, MD
Clinical Professor
Department of Otolaryngology and Head and Neck Surgery
Weill Cornell Medical College
Attending Surgeon
Department of Otolaryngology and Head and Neck Surgery
New York Presbyterian Hospital—Weill Cornell Medical Center
New York, New York

Pete S. Batra, MD, FACS
Stanton A. Friedberg, MD, Professor and Chairman
Co-Director, Rush Center for Skull Base and Pituitary Surgery
Department of Otorhinolaryngology—Head and Neck Surgery
Rush University Medical Center
Chicago, Illinois

Roy R. Casiano, MD
Professor and Vice Chairman
Rhinology and Endoscopic Skull Base Program
Department of Otolaryngology, Head and Neck Surgery
University of Miami, Miller School of Medicine
Miami, Florida

Paolo Castelnuovo, MD
Professor
Department of Biotechnology and Life Sciences
University of Insubria, Varese
Chief
Department of Otorhinolaryngology
Ospedale di Circolo Fondazione Macchi Varese, Italy

William T. Couldwell, MD, PhD
Jospeh J. Yager Professor and Chairman
Department of Neurosurgery
University of Utah School of Medicine
Salt Lake City, Utah

Johnny B. Delashaw, MD
The Ben and Catherine Ivy Center for Advanced Brain Tumor Treatment
Department of Neurosurgery
Swedish Medical Center
Seattle, Washington

Franco DeMonte, MD
Professor
Departments of Neurosurgery and Head and Neck Surgery
The University of Texas M.D. Anderson Cancer Center
Houston, Texas

Richard G. Ellenbogen, MD, FACS
Professor and Chairman
Theodore S. Roberts Endowed Chair
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Giorgio Frank, MD
Department of Neurosurgery
Center for Pituitary Surgery and Endoscopic Surgery of the Anterior Skull Base
Hospital Bellaria
Bologna, Italy

Paul A. Gardner, MD
Associate Professor
Department of Neurological Surgery
University of Pittsburgh School of Medicine
Co-Director
Center for Cranial Base Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Ziv Gil, MD, PhD
Associate Professor
The Clinical Research Institute at Rambam Rappaport School of Medicine
The Technion Israel Institute of Technology
Chairman
Department of Otolaryngology, Head and Neck Surgery
Rambam Healthcare Campus
Haifa, Israel

Atul Goel, MCh
Professor and Head
Department of Neurosurgery
King Edward Memorial Hospital and Seth G.S. Medical College
Mumbai, India

Chester F. Griffiths, MD
Pacific Eye and Ear Specialists
Los Angeles, California

Richard J. Harvey, MD
Associate Professor and Program Head
Department of Rhinology and Skull Base Surgery
UNSW and Macquarie University
Associate Professor
Departments of Otolaryngology/Skull Base Surgery
St. Vincent’s Hospital
Darlinghurst, New South Wales, Australia

Peter H. Hwang, MD
Professor
Department of Otolaryngology-Head and Neck Surgery
Stanford University School of Medicine
Chief
Division of Rhinology and Endoscopic Skull Base Surgery
Stanford University Medical Center
Stanford, California

Daniel F. Kelly, MD
Professor of Neurosurgery
Director
Brain Tumor Center and Pituitary Disorders Program
John Wayne Cancer Institute Providence Saint John’s Health Center
Santa Monica, California

Dennis Kraus, MD
Director
New York Head and Neck Institute
NSLIJ—Lenox Hill Hospital
New York, New York

Ali F. Krisht, MD
Director
Arkansas Neuroscience Institute
St. Vincent Infirmary
Little Rock, Arkansas

Kurt Laedrach, MD, DMD
Medical Director
Department for Craniomaxillofacial Surgery
University Hospital of Bern
Bern, Switzerland

Edward R. Laws, Jr., MD, FACS
Professor
Department of Neurosurgery
Harvard Medical School
Attending Surgeon
Department of Neurosurgery
Brigham and Women’s Hospital
Boston, Massachusetts
John P. Leonetti, MD
Professor and Vice Chairman
Department of Otolaryngology
Loyola University School of Medicine
Director, Cranial Base Tumor Surgery
Department of Otolaryngology
Loyola University School of Medicine
Maywood, Illinois

Theodore H. Schwartz, MD, FACS
Professor
Departments of Neurosurgery,
Otolaryngology, Neurology, and Neuroscience
Weill Cornell Medical College
Attending Neurosurgeon
New York Presbyterian Hospital
New York, New York

Chandranath Sen, MD
Professor
Department of Neurosurgery
New York University
Attending Surgeon
Department of Neurosurgery
New York University-Langone Medical Center
New York, New York

Dharambir S. Sethi, FRCSEd
Associate Professor, Yong Loo Lin School of Medicine
National University of Singapore
Visiting Consultant, Department of Otolaryngology
Singapore General Hospital
Singapore

Carl H. Snyderman, MD, MBA
Professor
Departments of Otolaryngology and Neurological Surgery
University of Pittsburgh School of Medicine
Co-Director
Center for Cranial Base Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

C. Arturo Solares, MD, FACS
Associate Professor
Departments of Head and Neck Surgery and Neurosurgery
Co-Director, Center for Skull Base Surgery
Georgia Regents University
Augusta, Georgia

Aldo C. Stamm, MD
Associate Professor
Department of ENT—Head and Neck Surgery
Federal University of São Paulo
Head
Department of Otolaryngology
Hospital Professor Edmundo Vasconcelos
São Paulo, Brazil

Charles Teo, MBBS, FRACS
Associate Professor
Department of Neurosurgery
University of New South Wales
Director
Center for Minimally Invasive Neurosurgery
Prince of Wales Private Hospital
Randwick, New South Wales, Australia

Mark A. Varvares, MD
Professor and Donald and Marlene Endowed Chair
Department of Otolaryngology, Head and Neck Surgery
Director
Saint Louis University Cancer Center
Saint Louis University
Chief
Department of Otolaryngology, Head and Neck Surgery
St Louis University Hospital
St Louis, Missouri

Allan Vescan, MD
Assistant Professor
Department of Otolaryngology—Head and Neck Surgery
University of Toronto
Toronto, Ontario, Canada

Ian J. Witterick, MD, MSc
Professor and Chair
Department of Otolaryngology—Head and Neck Surgery
University of Toronto School of Medicine
Chief
Department of Otolaryngology—Head and Neck Surgery
Mount Sinai Hospital
Toronto, Ontario, Canada

Peter-John Wormald, MD, FRAC, FCS(SA), FRCS I(Ed), MbChB
Professor and Chair
Department of Otolaryngology—Head and Neck Surgery
The University of Adelaide
Chairman
Department of Otolaryngology—Head and Neck Surgery
Queen Elizabeth Hospital
Adelaide, South Australia, Australia

Adam M. Zanation, MD
Associate Professor
Department of Otolaryngology—Head and Neck Surgery
University of North Carolina
Chapel Hill, North Carolina

Lee A. Zimmer, MD, PhD
Associate Professor
Department of Otolaryngology—Head and Neck Surgery
University of Cincinnati
Director, Rhinology and Anterior Cranial Base Surgery
University of Cincinnati Medical Center
Cincinnati, Ohio
Skull base surgery has witnessed several eras of major disruption and innovation. Each transition has been characterized by a conflict between early adopters and skeptics. Eventually, the excessive enthusiasm of the early adopters is tempered by increased experience and evidence-based analysis of outcomes. The most recent example is the dichotomy between external (open) and endonasal (endoscopic) approaches to the skull base. The adoption of endoscopic techniques over the last decade has been primarily driven by endoscopic surgeons (rhinologists and pituitary surgeons) as opposed to oncologic head and neck surgeons (traditional skull base surgeons). This results in a knowledge and skills gap that can only be addressed through greater collaboration and integrated educational programs.

Skull base surgery is perhaps unique among the surgical specialties as a true model of interdisciplinary collaboration. The synergy in learning that occurs through collaboration benefits our patients and drives innovation across specialties. This volume on skull base surgery is unique in that it achieves equipoise between the competitive and complementary fields of open and endoscopic skull base surgery. We have succeeded in capturing the secrets of expert skull base surgeons from around the world. Overlap in surgical procedures is intentional and provides an opportunity to compare the benefits and limitations of different approaches and techniques. The format of the chapters is designed to provide the essential information in an accessible format. Some of the chapters describe time-tested techniques that every skull base surgeon should master whereas others are devoted to the latest endoscopic techniques, still in a period of evolution. We are indebted to the authors for investing the time to share their invaluable experience in their own words.

We hope that this volume will be the definitive source for skull base surgeons of all types for many years to come. We would be guilty of hubris not to realize, however, that all knowledge is fleeting, especially in a field as dynamic as skull base surgery.

Carl H. Snyderman, MD, MBA
Paul A. Gardner, MD
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INTRODUCTION

Optic neuropathy (ON) most frequently results from blunt and penetrating trauma. Estimates suggest that traumatic ON occurs in 0.5% to 5% of all closed head injuries and up to 10% of patients with craniofacial fractures. The mechanisms of traumatic ON are likely multifactorial, with both direct and indirect mechanisms contributing to the visual loss. Direct injury, resulting from penetrating trauma from midfacial and orbital fractures, can lead to avulsion of the nerve, partial transection, orbital or hemorrhage into the optic nerve sheath, and orbital emphysema. Indirect injury results from ischemia caused by damage from the mechanical shearing of the optic nerve axons and contusion necrosis. The vascular ischemia and/or trauma induce swelling of the optic nerve within the confines of the optic canal further contributing to the death of retinal ganglion cells. Nontraumatic compressive ON can also lead to loss of vision due to a variety of pathologic processes, such as benign and malignant neoplasms of the sphenoid and sellar region, mucoceles, and Graves orbitopathy.

A variety of surgical approaches have been described for decompression of the optic nerve. Traditionally, open techniques have been employed including craniotomy, extra nasal transethmoidal, transorbital, transantral, and intranasal microscopic approaches. The introduction of rigid endoscopes, refinement of surgical instrumentation, and advent of image-guided surgery have facilitated the consideration of management of orbital and skull base pathology with minimally invasive endoscopic techniques. Indeed, endoscopic optic nerve decompression (EOND) now represents the procedure of choice to address traumatic and nontraumatic ON, given its reduction of morbidity, preservation of olfaction, superior cosmetic result, rapid recovery time, and less operative stress, especially in the patient with multisystem trauma.

HISTORY

Given that traumatic ON often occurs in patients having suffered significant blunt force trauma, the diagnosis may be often delayed as the patients are unable to provide a history due to an altered level of consciousness. This underscores the importance of maintaining a high incidence of suspicion for traumatic ON in this setting. Evaluation by an ophthalmologist is imperative in order to assess visual acuity at the earliest possible juncture. Patients with nontraumatic compressive ON may report vague ocular symptoms with complaints of blurry or “fuzzy” vision. Patients with paranasal sinus and skull base neoplasms may have associated nasal obstruction, epistaxis, headaches, proptosis, or trigeminal hypo- or anesthesia. Patients with a sphenoid mucocele may have a history of previous trauma or sinus surgery.

PHYSICAL EXAMINATION

Patients with traumatic ON require comprehensive evaluation by the trauma team. Concomitant intracranial, spinal, thoracic, and abdominal injuries must be ruled in or out. Significant blunt concussive injury or penetrating
trauma may result in cerebrospinal fluid (CSF) rhinorrhea or otorrhea. Any fractures of the carotid canal at the skull base require angiography to rule out an internal carotid artery (ICA) aneurysm or cavernous–carotid fistula. Timely ophthalmologic evaluation is imperative to determine and document baseline vision. Commonly, visual acuity will be 20/400 or less in the affected eye. Detailed examination may reveal a multitude of ocular abnormalities, including visual field deficit, decrease in color vision, and an afferent papillary defect on the affected side. Funduscopic examination is essential to rule out optic nerve atrophy; further, this may rule out other etiologies of decreased vision, such as choroidal rupture, retinal detachment, or vitreous hemorrhage. Patients with nontraumatic compressive ON often have similar ocular defects and require complete neuroophthalmologic evaluation including visual field testing. Patients suspected of skull base neoplasms require comprehensive head and neck and neurologic examination. Nasal endoscopy is important to rule out exophytic masses in the middle meatus or sphenoethmoid recess (SER).

## INDICATIONS

EOND should be considered in the setting of traumatic ON in patients with persistent visual loss who have failed a trial of high-dose steroids and who have evidence of a fracture of the optic canal, a hematoma of the optic nerve sheath, or a compressive hematoma at the orbital apex demonstrated on computed tomography (CT). Patients without an obvious fracture or hematoma but with suspected edema of the nerve in the bony optic canal confines may also benefit from EOND. Theoretically, this may relieve constrictive pressure from edema of the nerve in a rigid bony canal or allow for removal of an impinging bone fragment or hematoma, thus facilitating reestablishment of nerve function. Patients with a multitude of etiologies resulting in nontraumatic compressive ON may also benefit from EOND, including primary tumors of the optic nerve, such as meningiomas or gliomas, benign and malignant neoplasms of the sphenoid sinus, sellar and suprasellar tumors, fibrous dysplasia of the central skull base, mucocles of the sphenoid sinus or sphenoethmoid (Onodi) cell, Graves orbitopathy, and benign intracranial hypertension.

## CONTRAINDICATIONS

Long-standing complete optic nerve atrophy is an absolute contraindication to EOND as vision restoration is not possible in this setting. Traumatic ON presenting with injury to the nerve in the orbital portion and complete nerve transection are also contraindications to the procedure. Comatose patients should not be considered candidates for surgery until adequate visual assessment can be performed.

## PREOPERATIVE PLANNING

### Anatomic Considerations

Intimate knowledge of the anatomy of the sphenoid sinus and optic nerve–ICA relationship is imperative prior to embarking on surgery. Embryologically, the sphenoid sinus originates from the cartilaginous nasal capsule. Through the process of ossification and resorption between the 9th and 12th years of life, it comes to occupy a central location at the cranial base. The sphenoid pneumatization may be conchal, presellar, sellar, or postsellar, with optic nerve and ICA protuberances being more prominent with increasing pneumatization. Pneumatization of the posterior ethmoid cells more posterior and superior to the sphenoid sinus results in a sphenethmoid or Onodi cell. This is evident in 25% to 30% of cases and results in the optic nerve being closely associated with the Onodi cell, instead of the sphenoid sinus.

Multiple important structures are present on the surface of the sphenoid sinus. The opticocarotid recess (OCR) represents the pneumatization of the optic strut of the anterior clinoid process. The optic nerve courses in the optic canal just above the OCR, while the anterior bend of the ICA (C3 segment) is present just inferiorly. Dehiscence of the bone and direct septal insertions of the medial optic canal can be seen in 15% and 30% of cases, respectively. Dehiscence of the bone and direct septal insertions of the ICA canal can be seen in 20% and 40% of cases, respectively. The median distance between the ICA protuberances is 12 mm, and the median length of the OCR is 5 mm.

The optic canal is formed by the two struts of the lesser wing of the sphenoid transmitting the optic nerve and the ophthalmic artery. The nerve is a direct continuation of the brain carrying all three meningeal layers, including the pia, arachnoid, and dura. The optic nerve is divided into three segments—i.e., ophthalmic, intracranial, and intracranial. The intracranial segment is most prone to injury with blunt head trauma and is most likely to benefit from EOND. The optic nerve sheath is attached to the bone in the canalicular segment of the optic canal; consequently, fractures in this area may result in a higher incidence of injury to the optic nerve. The ophthalmic artery originates from the subdural cavity and accompanies the optic nerve in the dural sheath...
CHAPTER 1 Optic Nerve Decompression

in the optic canal. The ophthalmic artery typically enters the nerve sheath from an inferolateral direction and is typically not in the surgical field during EOND. However, 15% of patients may have the artery entering the medial aspect of the optic canal, thus making it susceptible to injury during the medial approach.

Preoperative Imaging

High-resolution CT imaging (1 mm or less) is an absolute requisite prior to considering EOND. It will help to delineate key anatomic relationships in the sphenoid sinus region, to identify dehiscence of the bone or presence of septations of the optic nerve and ICA, and to provide a roadmap for computer-aided surgery. Indeed, a preoperative checklist must be created prior to the surgical endeavor (Table 1.1). CT imaging will also identify fractures of the optic canal, ICA canal, or the skull base in cases of traumatic ON. Magnetic resonance (MR) imaging may be problematic in critically injured patients. However, when possible, it may demonstrate optic nerve swelling and intraorbital or optic canal hematomata. CT and MR imaging are imperative in cases of non-traumatic compressive ON. It will assist in defining the full extent of the skull base neoplasm and its relationship to the optic canal. CT imaging will help to demonstrate the site of a compressive lesion in cases of Graves orbitopathy.

SURGICAL TECHNIQUE

General endotracheal anesthesia is induced with the patient in the supine position. The endotracheal tube is secured to the left side out of the surgical field. The head is secured in a doughnut, and eyes are carefully taped shut with Steri-Strips or thin pieces of tape after placement of lubricating ointment. The eyes should be palpated at the beginning of the case to assess firmness at baseline. They should remain accessible and clearly visible throughout the surgery should any orbital complication be suspected during the surgery. The nose is maximally decongested using cotton pledgets soaked in oxymetazoline. Image guidance is registered and verified at this juncture. The face is prepped and draped in the standard sterile fashion.

The procedure is started with a 0-degree endoscope. One percent lidocaine with 1:100,000 epinephrine is injected along the lateral nasal wall and the sphenopalatine foramen. In general, a transethmoid approach to the sphenoid sinus will provide the best exposure of the orbital apex and optic nerve region. A standard uncinctomy with maxillary antrostomy is performed to improve access to the middle meatus and to provide a place for blood to collect out of the surgical field. The floor of the orbit also provides a general landmark to the level of the sphenoid ostium in the SER. Total ethmoidectomy is now performed to skeletonize the orbit from the lacrimal system to the orbital apex. Great care is taken to avoid violating the lamina papyracea or periorbita as resulting herniation of orbital adipose tissue will obscure the surgeon’s vision. The superior turbinate is identified in the SER; the lower third is sharply resected to identify the sphenoid ostium. The sphenoid sinus is now opened widely to expose the optic nerve and ICA bulges. If the optic nerve courses through an Onodi cell, this should be fully dissected and the relationship between this cell and the sphenoid sinus established.

The bone at the orbital apex is now removed approximately 1 cm from the optic nerve tubercle. The bone at the orbital apex can be thick; a diamond burr drill may be required to expose the periorbita and annulus of Zinn. The bone over the medial optic canal is next addressed with a long 2- or 3-mm diamond burr drill. Concurrent suction irrigation is critical to clear bone dust and blood from the surgical field and to minimize transmission of heat to the optic nerve sheath (Fig. 1.1). The drill should be circumferentially visible when being used; this will decrease the risk of inadvertent injury to the ICA canal or the planum sphenoidale. The bone is initially blue lined with the drill and then can be subsequently removed with curettes or otologic picks. The entire optic nerve sheath, typically ranging from 10 to 15 mm, is exposed from the lateral wall of the sphenoid to the optic chiasm. The optic nerve sheath is decompressed 180 degrees along the medial and inferior aspects (Fig. 1.2).
Incision of the optic nerve sheath has been advocated by some authors to further decompress the optic nerve. This maneuver is controversial and can be potentially associated with risk of damage to the underlying optic nerve and accompanying ophthalmic artery and possible intraoperative CSF leak. It may be considered in cases with known intrasheath hematoma or severe edema of the nerve. However, routine incision of the sheath of the optic nerve is to be discouraged as proper studies demonstrating clear benefit outweighing the potential risks are not available at the present time.

**POSTOPERATIVE MANAGEMENT**

Patients are typically observed overnight to monitor for any associated complications, such as epistaxis, CSF rhinorrhea, or orbital issues. High-dose steroids should be continued overnight to decrease the risk of edema.
of the optic nerve. Serial visual acuity checks should be performed as clinically warranted. Careful ophthalmologic evaluation is obtained on postoperative day 1 to establish a baseline for future testing. Oral antibiotics and steroid taper is continued for 7 to 10 days. Gentle saline rinses are started on postoperative day 1 and continued until all mucosal healing is complete. Initial postoperative debridement is performed 5 to 7 days after surgery; this facilitates removal of any nasal crusting or early granulation tissue to ensure patency of the paranasal sinuses. The periorbita or optic nerve region is not debrided at this juncture; mucosalization of these areas will occur within 4 to 6 weeks.

**COMPLICATIONS**

Potential complications include adhesions in the nasal cavity and paranasal sinus, bleeding, postoperative infectious sinusitis, epiphora, and alteration in smell and/or taste. More serious complications include complete, irreversible loss of vision, CSF leak, and ICA injury. Though these serious risks are low, the expected incidence would be higher than standard endoscopic sinus surgery given the proximity of drilling close to these critical structures.

**RESULTS**

The optimal management of traumatic ON has been a source of considerable debate over the years, given the unclear natural history and multiple confounders in studies published to date. Multiple retrospective case series have demonstrated benefit for EOND over steroids or observation. The largest series thus far, the International Optic Nerve Trauma Study, comprised of 133 patients with traumatic ON injury was unable to demonstrate clear benefit from either steroid therapy or decompression of the optic canal when compared to observation alone. However, a treatment bias likely existed as patients in the surgery group were statistically more likely to have no light perception, relative to the steroid and observation groups. A systematic review of the literature by Cook et al. evaluated outcomes of steroids, surgery, combination, and no treatment for traumatic ON. They noted that treatment with steroids, surgery, or both was better than no treatment; furthermore, patients with moderately severe injuries had a greater recovery of vision than patients with less severe injuries. The accrued literature for traumatic ON suggests that surgery should not be considered the standard of care for patients with traumatic ON. However, careful patient selection on an individualized basis is imperative in patients with severe visual loss who have failed high-dose steroid therapy and have objective CT evidence of optic nerve lesions, that is, optic canal fracture with bony fragment impingement or hematoma.

Patients with nontraumatic ON may also benefit from EOND. Pletcher and Metson performed 10 EONDs in 7 patients with a variety of pathologic entities, including skull base neoplasms, mucoceles, and Graves disease. Mean visual acuity improved from 20/300 to 20/30 at mean follow-up of 6 months. Outcomes for nontraumatic ON will continue to evolve with growing adaptation of skull base approaches.

**PEARLS**

- Careful ophthalmologic evaluation is crucial in patients with traumatic and nontraumatic ON.
- High-resolution CT imaging is a requisite to define key anatomic relationships in the sphenoid region and to provide a roadmap for image-guided surgery.
- Multidisciplinary coordination is important in cases of skull base neoplasms with optic nerve encroachment.
- Comprehensive paranasal sinus dissection is essential to identify salient anatomic structures including the medial orbital wall, ethmoid roof, sella, and ICA in relation to the optic nerve.
- The bone of the orbital apex and optic nerve should be drilled with a diamond burr, preferably with concurrent suction and irrigation, to optimize view of the surgical field and to minimize risk of heat trauma to the optic nerve.
- The entire optic nerve sheath is exposed from the lateral sphenoid wall to the optic chiasm and is decompressed 180 degrees along the medial and inferior aspects.
- Postoperative care should include antibiotics and steroids for 7 to 10 days, gentle saline rinses starting the day after surgery, and meticulous nasal debridement 1 week postoperatively.

**PITFALLS**

- The course of the ophthalmic artery should be considered prior to embarking on EOND.
- The entire drill tip should be circumferentially visible to minimize risk of injury to the skull base or ICA.
- Incision of the optic sheath is controversial and may be associated with CSF leak or trauma to the optic nerve.
INSTRUMENTS TO HAVE AVAILABLE

- Endoscopic skull base set should be present for any tumor resection in this region.
- High-speed diamond burr drill, preferably with concurrent irrigation and suction.
- Bipolar cautery.
- Unipolar cautery should be avoided under all circumstances given potential for deeper heat penetration and risk of damage to critical orbital and intracranial structures.
- Image guidance should be strongly considered, especially in cases with significant anatomic alteration from extensive trauma or skull base neoplasms.

SUGGESTED READING

INTRODUCTION

Surgical treatment for pituitary tumors has undergone a major paradigm shift to minimally invasive techniques. In the past 15 years, the endonasal endoscopic approach for pituitary tumors has gained acceptance and is now established as a safe and effective approach. Following tumor removal with a 0-degree endoscope, intrasellar endoscopic examination with angled endoscopes allows for better visualization of residual tumor enabling a more complete tumor extirpation. For a successful outcome in the surgical treatment of pituitary tumors, complete tumor resection is important for maximal decompression of the optic chiasm and to minimize recurrence. Complete removal is particularly important for secretory tumors for long-term reversal of endocrinopathy.

In the past 16 years, the combined rhinology–neurosurgical team in our institution has operated on more than 700 pituitary tumors. We had previously reported on our endoscopic endonasal approach to the sella and the “four-handed surgical technique.” Our technique involves a sphenoidotomy that is limited by the superior turbinates on either side. The middle turbinates are not resected. About 1 cm of the posterior nasal septum is resected to facilitate instrumentation through both nostrils. A vascularized nasal septal flap pedicled on the sphenopalatine artery is not routinely elevated though we preserve the sphenopalatine artery at least on one side (usually the left) so that if a vascularized nasoseptal flap is required, it may be elevated after the removal of the tumor. Our approach is aimed at maximally preserving the nasal anatomy using minimally invasive techniques.

HISTORY

A detailed history and physical examination is essential. As most patients present with visual or endocrinologic symptoms, these should be thoroughly investigated. Some patients may be asymptomatic when the pituitary lesion is discovered on a routine magnetic resonance (MR) scan for headaches. Acute headache occurs in pituitary apoplexy, and a chronic headache may result from hydrocephalus. Periorbital headache may signify compression or invasion of the cavernous sinus. Ophthalmologic disturbances include visual deficit, homonymous hemianopia, or complete bitemporal hemianopia to blindness. Diplopia may result due to involvement of the abducent and oculomotor nerves when the tumor invades the cavernous sinus. Endocrinologic symptoms may result from pituitary insufficiency or pituitary hyperfunction. Pituitary insufficiency may be associated with both large and small tumors. Pituitary hyperfunction may lead to several hypersecretory states. Acromegaly patients present with characteristic symptoms. They have characteristic coarse facial features that include enlargement of hands, feet, facial bones, and jaw. Patients with Cushing’s disease also have characteristic features that include facial plethora, supraclavicular adipose tissue deposition, posterior cervical adipose tissue, acne, hirsutism, thin skin, ecchymosis, and violaceous striae. These patients usually experience weight gain, fatigue, irritability, depression, and loss of memory.
PHYSICAL EXAMINATION

Physical examination includes a complete evaluation of the head and neck region including neurologic assessment. The stigmata of pituitary hyperfunction (acromegaly, Cushing’s disease) may be present. If ophthalmologic symptoms are present, a complete ophthalmologic examination should be performed by an ophthalmologist. Nasal endoscopy is important to assess the nasal airway for surgical planning and to rule out coexistent pathology such as sinusitis or nasal polyposis.

INDICATIONS

Surgery for pituitary tumors has proven to be an effective treatment for both endocrine active and nonfunctioning pituitary adenomas. Indications for surgery include all nonsecreting and most secreting pituitary tumors except for prolactinomas, which are usually well controlled by medical therapy with dopamine antagonist. Indications for surgery also include failure of or resistance to medical management or intolerable side effects of medical therapy.

Nonsecretory tumors may vary in size, expanding the sella and extending along the paths of least resistance, laterally into the cavernous sinuses and superiorly into the suprasellar cistern and anteriorly into the sphenoid sinus. Some nonsecretory tumors may have very large suprasellar extension. These tumors are best managed surgically with a combined endonasal and transcranial approach either in the same sitting or as staged operations. Most secretory tumors, presenting with features of acromegaly and Cushing disease, are an indication for surgery. For prolactin-secreting tumors, surgery is considered for those who do not respond to medical therapy, for patients who are unable to tolerate medical treatment, or for tumors that are predominantly cystic. Pituitary apoplexy may require emergency surgery as these patients usually present with sudden and rapid deterioration of vision.

CONTRAINDICATIONS

A recent review of the literature has compared the different modalities of treatment for pituitary tumors. The review confirms that the endoscopic technique compares favorably with other modalities of treatment in terms of tumor debulking, optic nerve decompression, and hormonal control. However, some patients are not suited to the endoscopic technique. Patients who are not suitable for a general anesthetic procedure may be treated with radiation or medical therapy in the case of functional tumors. The main (relative) contraindication for the endoscopic approach to pituitary surgery is the presence of extensive intracranial growth. This is highlighted by a tumor with a small sellar component, as resection of it is less likely to lead to significant descent of the tumor into the surgical field. In such patients, the surgeons must be willing to undertake wide resection of the skull base with reconstruction in order to achieve adequate access. Another relative contraindication is in the treatment of prolactinomas. In most cases, these tumors can be managed medically in the absence of immediate threat to vision, providing that the dopaminergic side effects of treatment are tolerated by the patient.

PREOPERATIVE PLANNING

All patients scheduled for pituitary surgery are required to undergo radiologic evaluation, endocrine assessment, and visual field tests pre- and postoperatively. A preoperative nasal endoscopic examination by the otolaryngologist is part of routine preoperative assessment. We in our institution, have developed a “Pituitary Surgery Pathway” for patients undergoing this operation. After initial investigations and referrals, patients are reviewed in a multidisciplinary Pituitary Clinic composed of otolaryngologists, neurosurgeons, and ophthalmologists. This is to ensure strict perioperative participation by different specialists involved in the patient’s management.

Imaging Studies

Magnetic resonance imaging (MRI) of the pituitary gland is the preferred imaging modality. Fine-cut MRI scanning of the pituitary region with sagittal and coronal reconstruction is the gold standard for pituitary tumors. Computed tomographic (CT) scans of the nose, paranasal sinuses, and sella turcica should be routinely done as not only are these useful in studying the bony anatomy but calcified lesions such as craniopharyngiomas may be more easily identified on CT. MRI scan of the pituitary fossa provides useful information about the location, size, and boundaries of the tumor, as well as its relationship to adjoining structures. The extent to which neurovascular structures in the cavernous sinus are encased by the tumor must be carefully assessed. Although encasement is not a contraindication to this approach, the surgeon must judge his or her ability to safely dissect the tumor off of the carotid artery and should keep in mind the possibility of radiosurgery and fractionated radiation to control the growth of residual unresectable tumor. In some cases, what appears to be tumor encasement
of a vessel on preoperative MRI scan turns out to represent a vessel coursing along the capsule of the tumor that can be separated by an excellent arachnoid plane.

Visual Field Testing

All patients undergo preoperative visual field testing. Progressive deterioration of visual fields is often the principle neurologic criterion upon which surgical management decisions are based. Humphrey and Goldmann visual field evaluations are useful even if there appears to be no contact between the optic pathway and the pituitary mass. This is because field defects may reflect previous impingement, potential vascular shunting, or displacement of the chiasm following decompression. Detection and quantification of visual pathology in the preoperative setting is important for prognostic information as well as medicolegal documentation.

Endocrine Evaluation

A preoperative endocrine evaluation is routine. The perioperative endocrine management of a patient undergoing pituitary surgery may vary depending on the size of the pituitary lesion, the type of the lesion, the surgical approach (transsphenoidal, craniotomy), and the preoperative endocrine function.

Otolaryngology Assessment

Preoperative nasal endoscopic examination to exclude active rhinosinusitis is undertaken by the otolaryngologist. It is essential to treat infections of the nasal cavity and paranasal sinuses and ensure the surgical field is without infection prior to commencing the pituitary surgery. Perioperative prophylactic antibiotics are routinely used. In addition, preoperative nasal endoscopy provides useful information of the nasal anatomy such as hypertrophy of the turbinates, concha bullosa, or a gross septal deviation that may necessitate a septoplasty for access to the sphenoid sinus.

Endoscopic Camera Setup

The Digital Endoscopic Video Camera System (Karl Storz) is placed at the cephalic end of the table to enable both surgeons to view surgery on the LCD video monitor. The otolaryngologist stands on the right side of the operating table and neurosurgeon on the left side. Video documentation of the surgical procedure is routinely done on a digital recording device.

SURGICAL TECHNIQUE (VIDEO 2.1)

More than 700 patients have undergone endoscopic pituitary surgery at our institution since 1994. In most cases, an exclusively endoscopic approach to the sella was used. Our surgical technique is demonstrated in the accompanying minimally edited operative video.

Patient 1: This 50-year-old female from a neighboring country presented with headaches and bitemporal hemianopia. MRI scans revealed a large sellar lesion extending to the suprasellar cistern (Figs. 2.1 and 2.2).
Following preoperative evaluation, an endoscopic removal of the pituitary tumor was carried out using the surgical technique described as follows.

1. The nasal cavity is decongested by placing two Neuro Patties soaked in 4% cocaine on each side about 20 minutes prior to induction of anesthesia. The patient is placed under general anesthesia in the supine position. Antibiotics, glucocorticoids, and antihistamines are administered. We routinely use cefazolin (2 g, intravenous), dexamethasone (10 mg, intravenous) and diphenylhydramine (50 mg, intravenous). Oral endotracheal intubation is used, and a pack is placed in the pharynx. The endotracheal tube is anchored on the left angle of the mouth to keep the chest free as manipulation of the endoscope over the chest may occasionally dislodge the endotracheal tube. A Foley catheter is routinely inserted into the bladder to monitor urinary output intra- and postoperatively. The patient’s head is supine and turned slightly to the right. The head is elevated by about 30 degrees above the heart to facilitate venous drainage. Antiseptic solution (such as a 5% povidine–iodine solution) is applied to the nose and mouth, and the area is draped with sterile towels and Steri-Drape. The lower abdomen is prepared and draped to obtain adipose tissue for grafting if necessary.

2. The Neuro Patties that had been placed in the nasal cavity earlier are removed and discarded. The nasal cavity is once again decongested with topical application of cocaine. Sterile Neuro Patties soaked in 4% cocaine are placed endoscopically in the sphenoethmoid recess bilaterally. Allowing about 10 minutes for decongestion, the Neuro Patties are removed and the sphenoethmoid recess is infiltrated bilaterally with 1% lidocaine with 1:80,000 epinephrine. A gauge 21 spinal needle is used for infiltration of the anterior wall of the sphenoid, sphenopalatine foramen, and the posterior aspect of the nasal septum.

3. After the nose has been adequately decongested, an endoscopic examination is performed using a 0-degree endoscope. The ostia of the sphenoid sinus are identified bilaterally.

4. Surgery is started on the side where the sphenoid ostium is better visualized. In most cases, we start on the right side. The microdebrider with a 4-mm bit and a serrated outer shaft is used to debride the mucosa in the sphenoethmoid recess around the ostium of the sphenoid sinus taking care not to traumatize the mucosa on the superior turbinates. The serrated blade of the microdebrider is directed medially and the outer sheath laterally protecting the mucosa of the superior turbinate. The sphenoid ostium is widened inferiorly and medially down to the floor of the sphenoid sinus. Care is taken to avoid the septal branch of the sphenopalatine artery (SPA) by not going too far inferolaterally. A 2-mm up or down biting Kerrison rongeur is used to extend the sphenoidotomy. Mucosa is debrided from the posterior aspect of the vomer and the sphenoid rostrum. The sphenoidotomy is extended to the contralateral side by dislocating the attachment of the vomer from the sphenoid rostrum. The ostium of the sphenoid sinus on the contralateral side is identified, and the sphenoidotomy is extended as far as the contralateral superior turbinate (Fig. 2.3). The sphenoid rostrum is removed with strong septal forceps. A wide sphenoidotomy that extends superiorly to the roof of the sphenoid, inferi ory to the floor of the sphenoid sinus, and laterally to the superior turbinate on either side is fashioned.

5. About 1 cm of the posterior aspect of the vomer is removed with a reverse cutting forceps to facilitate the introduction of instruments from both nostrils. A panoramic view of the sphenoid sinus is obtained. The removal of part of the posterior nasal septum provides the ability to use both hands by two surgeons enabling introduction of up to four separate instruments, two through each nostril. The access to the sphenoid sinus is complete (Fig. 2.4). From this point onwards, the neurosurgeon and otolaryngologist...
work as a team. The otolaryngologist manually manipulates the endoscope and assists the neurosurgeon in removal of the tumor.

6. The sphenoid sinus is next examined with 0-degree, 30-degree, and 70-degree, 4-mm endoscopes, and important anatomical landmarks within are noted. Of particular importance are the structures on the lateral wall. The carotid prominence, optic prominence, and opticocarotid recess can be well identified when the sphenoid sinus is well pneumatized (Fig. 2.5). On the lateral recess of a well-pneumatized sphenoid sinus, the second branch of the trigeminal nerve (V2) and the vidian canal may be identified superolaterally and inferomedially, respectively.

On the posterior wall, the tuberculum sella, the anterior wall of the sella, and the clival recess are identified. The location of the intersinus septa, if any, is noted. Caution is exercised in not stripping the sphenoid mucosa as this may result in considerable bleeding. Once a panoramic view of the entire sphenoid sinus and the surgical landmarks is obtained, the access to the sella turcica is complete. The major landmarks for proper identification of the sellar floor are the planum sphenoidale above, clivus below, and carotid prominences bilaterally. Neuronavigation, if available, is used to confirm the landmarks (Fig. 2.6).

7. Once the sellar floor has been identified, the mucosa over the floor of the sella is cauterized with bipolar diathermy to expose underlying bone. The thickness of the floor of the sella is assessed by gentle palpation with an instrument such as a ball probe. By direct visualization and tactile feedback, the thinnest part
of the sellar floor is identified and gently fractured at the point of least resistance. A plane is developed between the dura and floor of the sella with a right-angle hook. A 1-mm Kerrison punch or a curette is used to delicately remove the floor of the sella exposing dura. Boundaries of removal of the sellar floor are the planum sphenoidale superiorly, clivus inferiorly, and the carotid prominence laterally (Fig. 2.7).

8. Bipolar diathermy is used for hemostasis over the dura before incising it. The incision is made using a sickle knife or a scalpel with a retractable blade or a pair of 45-degree-angle alligator scissors.

9. A biopsy of the tumor tissue is taken. Once we have sufficient tumor tissue for a histologic examination, the tumor is removed using a combination of blunt ring curettes and pituitary forceps. The otolaryngologist and neurosurgeon work in tandem at this point. While one surgeon removes the tumor, the other provides continuous suction enabling rapid removal. A systematic approach in removing the tumor is useful.

**FIGURE 2.5**
View of the structures within the sphenoid sinus with 30-degree endoscope. Structures of note are the left optic nerve (on), left opticocarotid recess (asterisk), and the insertion of the accessory intrasphenoid septum onto the left paracaval carotid artery (arrow).

**FIGURE 2.6**
Endoscopic image showing the interior of the sphenoid sinus with perspective of the bony sellar floor (s) bulging into the sphenoid sinus. Adjunctive neuronavigation is also demonstrated where the position of the tip of the probe is displayed in sagittal, coronal, and axial T1-weighted magnetic resonance images.
We start to remove tumor from the floor, work on the lateral extent next, and finally remove the suprasellar component if any. Often the tumor decompresses rapidly in areas where it is cystic or gelatinous. The diaphragma may descend rapidly in this region, giving the impression that the tumor has been completely removed, whereas pockets of tumor where the tumor was more semisolid or adherent to the diaphragma may be left behind. Therefore, it is useful to attempt to control the descent of the diaphragma by systematic removal of the tumor. When the diaphragma descends unequally, there may be a pocket of tumor left behind. A careful inspection of such pockets is done by gentle retraction of the arachnoid by one surgeon to enable visualization while the other removes any residual tumor.

10. Once the tumor has been removed, a 4-mm-angled endoscope (30-degree, 45-degree, or 70-degree) is used to view the cavity of the sella and suprasellar cistern to ensure absence of residual tumor (Fig. 2.8). Lateral visualization with angled endoscopes enables exploration of the medial wall of the cavernous sinus.

11. Once the tumor has been completely removed, minor oozing from the sella is controlled by packing it with Neuro Patties providing a tamponade for about 5 minutes. Upon removal of the Neuro Patties, the sella is once again examined endoscopically and any localized oozing is controlled with placement of Surgicel (Johnson & Johnson, New Brunswick, NJ) over the area. In the situation where oozing from the sella persists despite the above measures, it may controlled by application of thrombin-infused gelatin matrix (FloSeal; Baxter International Inc., Deerfield, IL).

**FIGURE 2.7**
The anterior wall and the floor of the sella have been removed to expose the underlying dura (asterisk); tuberculum sella (ts).

**FIGURE 2.8**
The arachnoid (asterisk) is identified after the tumor has been removed. Arrow points to the suprasellar extension.
12. Once the surgery is concluded, nasal hemostasis is ensured. Any minor mucosal oozing or bleeding from the septal branch of the sphenopalatine artery is controlled with bipolar diathermy.

13. The cavity of the sella is lined by a thin film of Surgicel. Repair of the defect in the sella is not routine. A thin film of Surgicel is placed over the defect.

14. To facilitate postoperative healing of the mucosa, we ensure that the bone of the sphenoid rostrum is not exposed and is adequately covered with mucosa. Eight-centimeter nasal Merocels (Medtronic Xomed Surgical Products, Jacksonville, FL) are placed in the nasal cavity on either side and hydrated with saline to expand. These are removed after 24 hours.

There was no leakage of cerebrospinal fluid (CSF) in the above patient. The total operative time was 57 minutes and blood loss about 150 mL. Three-month-interval postoperative MRI scans showed the tumor had been completely removed (Figs. 2.9 and 2.10)

Another case demonstrating a different sellar pathology is presented to demonstrate the surgical technique and results.

**Patient 2:** A 49-year-old Caucasian male presented with headaches and diplopia of 2 weeks’ duration. MRI scan revealed a uniformly enhancing mass within the sella extending into the suprasellar cistern, compressing and elevating the optic chiasm (Fig. 2.11A and B). Figure 2.12 showed bilateral sphenoidotomies created in the midline. Figure 2.13 provides a view of the floor of the sella. Note that the midline intersinus septum inserting on the floor of the sella has been removed. Figure 2.14 shows the anterior wall of the sella being removed. Figure 2.15 demonstrates the tumor being removed from the arachnoid using the two-hand
technique. Figure 2.16 depicts the intrasellar view of the membranous arachnoid (black asterisk). There was a minor CSF leak in this patient that was repaired using a plug of adipose tissue and a pedicled nasoseptal flap. Figure 2.17 is the intraoperative view with neuronavigation probe within the sella. The MRI scans (Fig. 2.18A and B) 2 years postoperative show postsurgical changes.

POSTOPERATIVE MANAGEMENT

Once the surgery is complete, the patient is extubated and brought to the recovery room where the patient’s vital signs are monitored. For the next 24 hours, the patient is monitored in the neurosurgical intensive care unit, particularly for diabetes insipidus and for deterioration of vision. A fasting morning cortisol level is obtained on the morning of the 2nd postoperative day, and cortisol replacement is initiated only if the level is abnormally low. Nasal packing is removed on the first postoperative day. If no lumbar drain has been placed, patients ambulate on the 2nd postoperative day and may be discharged on the 3rd postoperative day or as soon as they are ambulating and eating well. During the postoperative period, the patient is monitored for any CSF leak, or symptoms and signs of meningitis or any hemorrhage. Antibiotics and analgesics are routinely prescribed. The patient is examined following the removal of the packs. Any blood clots in the nasal cavity are aspirated under endoscopic guidance.

The first office visit is scheduled 1 week following the surgery. After application of topical 4% cocaine, blood clots are endoscopically removed from the nasal cavity and sphenoid sinus. The sella is carefully examined for any bleeding or CSF leakage. The patient is seen on a weekly basis by the otolaryngologist for the first 3 weeks and then every 3 weeks for the next two appointments. Healing usually takes about 3 to 6 weeks and is hastened by endoscopic removal of crusts. Further appointments are scheduled as necessary. Postoperative follow-up is also provided by the endocrinologist, ophthalmologist, and neurosurgeon.
It is imperative that the operating surgeon is familiar with the complications that can take place and is prepared to handle these complications. Table 2.1 lists complications that the surgeon must anticipate.

The most common intraoperative complication is CSF leak. The usual cause of CSF rhinorrhea is trauma to the diaphragma resulting from instruments such as curettes, forceps, or suctions. The diaphragma is often very thin and susceptible to trauma so that extreme caution must be exercised when removing tumor from this delicate structure. It is also important to remember that anterior to the infundibulum, the superior aspect of the gland is related directly to the arachnoid and pia, and the subarachnoid space here extends below the diaphragm and may be inadvertently breached while removing tumor. When a CSF leak is identified intraoperatively, the intrasellar defect should be identified. Precautions should be taken not to make it worse or larger, and surgery should be completed by working around it. At the conclusion of the surgery the defect should be repaired with intrasellar placement of abdominal adipose tissue and fibrin matrix (Tisseel; Baxter, Deerfield, IL). In some cases, the CSF leak may be due to minor “weeping” from the arachnoid when the vertical component of the cruciate incision is extended superiorly. In these patients, the “weeping” defect is repaired with a small amount of adipose tissue placed on the defect and fixing it with fibrin matrix (Tisseel; Baxter, Deerfield, IL).

Intraoperative bleeding may result from inadequate nasal decongestion prior to surgery, trauma to the sphenopalantine artery (SPA), inadvertent stripping of sphenoid mucosa, cavernous sinus trauma, intercavernous sinus injury, or trauma to the cavernous part of the internal carotid artery. Decongesting the nasal mucosa preoperatively and intraoperatively, the use of bipolar diathermy on the tumor capsule and the dura prior to incising it, and taking the precaution of not stripping the sphenoid mucosa are the key points in reducing intraoperative bleeding. Tumor tissue tends to bleed. Quick removal of tumor ensures early hemostasis. If bleeding continues from the sellar cavity, endoscopic examination with a 30-degree telescope is particularly useful in identifying the bleeding point or residual tumor. The bleeding point can then be controlled with tamponade,
bipolar diathermy, or a thin layer of Surgicel. Bleeding of the cavernous sinus should be suspected when venous blood fills the surgical field. It can be repaired with Surgicel, fibrin matrix, or application of FloSeal (Baxter, Deerfield, IL).

Perhaps the most feared complication is trauma to the cavernous carotid artery. Bleeding from the carotid artery should be suspected if the surgeon is working laterally. Tamponade by promptly packing the nose and the sinus cavity is the initial measure to be taken. Meanwhile, the patient’s condition is assessed. Replacement of blood loss should be expedient. At the same time, arrangements are made for angiography and test occlusion. If the packing is sufficient to stop the bleeding and the patient passes the occlusion test, the internal carotid artery may be occluded with a balloon. However, if the patient fails the occlusion test, a bypass procedure is necessary prior to occluding the internal carotid artery. If the packing is unable to stop the bleeding, emergent measures such as occlusion of the internal carotid artery in the neck or a craniotomy may need to be undertaken.

Significant postoperative hemorrhage may be due to oozing from the nasal mucosa at the site of the sphenoidotomy or active bleeding from one of the branches of the sphenopalatine artery. Profuse bleeding that is difficult to control should alert the surgeon to the possibility of intracranial vascular trauma that warrants an angiogram.

Transient or permanent worsening of vision may occur as a result of intrasellar hematoma or direct damage to the optic nerve. Intrasellar hematoma should be suspected when the patient complains of deteriorating vision after surgery. Emergent CT scan of the brain and immediate surgical evacuation of the hematoma must be carried out if intrasellar hematoma is suspected.

In our series, the incidence of postoperative CSF leak was low and in most cases the CSF leak was identified and managed intraoperatively. If CSF leak presents in the postoperative period and endoscopic examination suggests that there may be a breach in the arachnoid, formal identification and closure of the defect and repair of the sella may be necessary. An alternative is to undergo a trial of bed rest with a lumbar drain, but it should be noted that a prolonged duration of CSF leak is associated with meningitis.
RESULTS

Endoscopic surgery for the treatment of pituitary adenomas has become the new standard of care. Comparison of endoscopic and microscopic techniques have demonstrated the benefits of endoscopic surgery, especially for macroadenomas. The enhanced visualization of the endoscope enables more complete dissection with a higher gross total resection rate. With functional tumors, endoscopic techniques offer comparable rates of hormonal remission and tumor control but with less perioperative morbidity.

FIGURE 2.17
Image of neuronavigation with the probe on the right cavernous carotid artery.

FIGURE 2.18
A and B: Three-month interval postoperative MRI. Arrow points to the pedicled nasoseptal flap.
## PEARLS

- The sphenoid ostium lies just above the sphenoethmoid recess, approximately 1.5 cm above the choana. The shape and size of the sphenoid ostia may vary, but their location is almost constant. In some circumstances, the ostium is covered by a supreme turbinate, which can be gently retracted laterally or resected if necessary. Rarely, in the situation where the sphenoid ostium cannot be identified, entry into the sphenoid sinus can be gained using a blunt instrument or suction tip to exert controlled pressure to the anterior wall at the point of least resistance.
- If the sphenoid rostrum is very thick, it may be necessary to use a diamond burr and drill the sphenoid rostrum for access.
- The extent of removal of the sellar floor varies depending on the size and location of pathology, but a generous removal that extends laterally as far as the carotid arteries is recommended.
- The type of incision made over the dura may vary depending on surgeon’s preference, type and size of the tumor, and exposure necessary to remove the tumor. The incision may be vertical, horizontal, cruciate, diagonal, or made in the shape of a flap reflected inferiorly. Care is taken not to extend the vertical segment of the incision too far superiorly, so as not to encounter the subarachnoid space or the anterior intercavernous venous sinus. Lateral extent of the horizontal incision is limited by the cavernous sinus on both sides, and great caution must be exercised to avoid the carotid artery in the far lateral corners of the exposure. Incising the dura on the diagonal from corner to corner provides a wider opening than a cruciate incision. The upper leaf of dura may be further incised in the midline if exposure over the top of the gland is needed.
- In the event that a CSF leak is recognized intraoperatively, the defect is plugged with a pad of abdominal adipose tissue sandwiched between Surgicel squares and sealed with fibrin matrix (Tisseel; Baxter, Deerfield, IL).
- A wide sphenoidotomy bounded by planum sphenoidale superiorly, the floor of the sphenoid sinus inferi-orly, and the superior turbinates laterally provides adequate access to the sphenoid sinus for removal of most pituitary tumors that do not extend laterally to encase the cavernous sinus.
- The septal branch of the sphenopalatine artery may be preserved by elevating a mucoperiosteal flap from the sphenoid rostrum. We always preserve at least one artery, usually on the left side, should a vascularized nasoseptal flap be required to repair an intraoperative CSF leak or in the postoperative period.
- In cases requiring a nasoseptal flap, the sphenoid rostrum must be adequately prepared with a high-speed irrigating drill to allow the flap and the pedicle to be applied onto the cavity without tenting or twisting. The cavity is then packed with bismuth iodoform paraffin pack to allow the flap to adhere to the surface of the cavity.
- Wide removal of the anterior wall of the sella and a large dural opening facilitate access and removal of the tumor.
- Capsular dissection of the tumor from the arachnoid may be necessary for complete tumor removal.

### TABLE 2.1 Complications of Endoscopic Pituitary Surgery

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<th>Intraoperative Complications</th>
<th>Postoperative Complications</th>
<th>Long-Term Complications</th>
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<tr>
<td>• CSF leak</td>
<td>• CSF leak</td>
<td>• Chronic sinus infection</td>
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<td>• Intracranial injury</td>
<td>• Diabetes insipidus</td>
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<td>• Neurovascular Injury</td>
<td>• Meningitis</td>
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<td>• Carotid artery injury</td>
<td>• Necrosis or displacement of nasoseptal flap</td>
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<td>• Cavernous sinus bleeding</td>
<td>• Secondary hemorrhage</td>
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<td>• Maxillary nerve injury</td>
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<td>• Optic nerve injury</td>
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<td>• Subarachnoid hemorrhage</td>
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PITFALLS

- The surgeon should have adequate experience with endoscopic sinus surgery.
- A clear understanding of the endoscopic anatomy of the sella and the surrounding region is essential.
- The surgeon should be able to manage injury to the cavernous carotid artery.
- Endoscopic technique may not be suitable for large invasive tumors where the surgery may have to be combined with an open approach.
- While extending the sphenoidotomy inferiorly, brisk bleeding may result if the septal branch of the sphenopalatine artery is encountered. This may be controlled by cauterizing the vessel with bipolar diathermy. In the rare situation where bleeding cannot be controlled, it may be necessary to expose and ligate the sphenopalatine artery at the sphenopalatine foramen, which is located in the superior meatus just posterior to the middle turbinate. Most endoscopic sinus surgeons are familiar with the technique.
- If the accessory septa in the sphenoid sinus have to be removed, extreme caution should be exercised, as these often terminate on the carotid canal or the optic canal. It is safer to use Tru-Cut instruments to remove these septa. Injudicious avulsion of the septa with non–Tru-Cut instruments may cause fracture of the thin bone overlying the cavernous sinus or the optic nerve with resultant hematoma, intractable bleeding, or even blindness.
- It is extremely important to be gentle while working on the lateral aspect of the sella, as the medial layer of the cavernous sinus can be extremely thin. Arterial bleeding has been reported due to carotid artery injury but may also arise from a tear of an arterial branch of the carotid, such as the inferior hypophyseal artery or by avulsion of a small capsular artery from the carotid artery. Blunt curettes should be used, as the arachnoid can be extremely thin and CSF leakage may result even with gentle manipulation.

INSTRUMENTS TO HAVE AVAILABLE

General Setup

- Endoscopes: 0, 30, 70 degrees
- Microdebrider (Medtronic straight shot) and console (Medtronic Integrated Power Console)
- Endoscrub sheath, with irrigation tubing
- Sinus instrument tray, including Freer elevator, Blakesley Forceps (straight and 45 degrees), and Tru-Cut forceps (straight and 45 degrees) and ball probe
- Long bayonet bipolar forceps
- Two suction devices

Sphenoidotomy

- Straight sphenoid sinus mushroom-shaped punch
- Kerrison rongeurs: 1 and 2 mm, up-biting and down-biting
- 2-mm osteotome and mallet
- Extended-length skull base burrs:
  - Medtronic 4-mm straight cutting burr
  - Medtronic 5-mm, 15-degree angled diamond burr

Septotomy

- Back-biting forceps

Pituitary Access

- Canal knife/disc elevator
- Retractable blade scalpel

Pituitary Resection

- Endoscopic pituitary tray including
  - Rhoton dissectors No. 3, 5
  - Curette dissectors, large and small
  - Storz curved curette

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CHAPTER 2  Endonasal Approach to the Sella

SUGGESTED READING


INTRODUCTION

The endoscopic endonasal transsphenoidal approach to the sella and parasellar regions is now increasingly used for removal of pituitary adenomas and Rathke’s cleft cysts (RCCs) as well as other parasellar tumors such as craniopharyngiomas, tuberculum sella meningiomas, and clival chordomas. The advantage of the endoscope in removing pituitary and parasellar tumors over the microscope is enhanced visualization. With the light source taken directly into the sphenoid sinus and sella, the improved panoramic view can result in more complete removal of the tumor than is possible with the relatively restricted tunnel vision afforded by the microscopic view through a rigid endonasal or sublabial speculum.

The transition from microscopic to endoscopic sellar and parasellar surgery has occurred gradually. The first rigid endoscope for transsphenoidal surgery with an external light source was used by Guiot in the early 1960s. Hardy also used the endoscope occasionally to explore the sellar cavity after tumor removal to look for residual tumor. In 1977, Apuzzo et al. reported the use of an angled telescope during sellar procedures to assist with visualization for tumor removal or gland ablation. In 1992, Jankowski et al. reported successful endoscopic endonasal resection of pituitary adenomas in three patients. The first clinical series of purely endoscopic pituitary tumor removals in 50 patients without the microscope was described by Jho and Carrau in 1997. Since then, endoscopic pituitary surgery has gained great popularity, and many surgeons doing microscopic pituitary surgery, including our own group, have transitioned to an endoscope-assisted method or fully endoscopic approach for removal of pituitary adenomas and other parasellar tumors. Over the last decade, with further refinements in endoscopic image quality and dedicated instrumentation, the endoscopic approach for pituitary adenomas and related skull base tumors is rapidly becoming the preferred technique, if not the new standard for approaching such lesions.

During this period, most surgeons doing endoscopic pituitary surgery have also transitioned from a single nostril to a binosstral approach affording increased maneuverability and expanded parasellar access. Currently, the two-surgeon approach is most often used in which one surgeon, typically a head and neck surgeon with expertise in sinonasal endoscopy, begins the endonasal surgical approach phase of the procedure and “drives” the endoscope while the neurosurgeon uses bimanual microdissection to remove the tumor and do the skull base closure.

This chapter describes the endoscopic endonasal approach to the sella using a binosstral two-surgeon technique for removal of pituitary adenomas and RCCs. Surgical indications, preoperative planning, room setup, equipment needs, technical nuances, complication avoidance, and postoperative care are described.

HISTORY

All patients with a pituitary tumor or other parasellar lesion should be carefully questioned regarding neurologic symptoms such as loss of visual fields or acuity, diplopia, memory loss, cognitive impairment, and headaches. Patients should also be questioned regarding symptoms of pituitary hormonal excess in cases of...
acromegaly, Cushing’s disease, prolactinoma, and TSH-secreting adenomas. Symptoms of anterior pituitary hormonal deficiency should be evaluated including fatigue, low energy, poor exercise tolerance, depression, weight gain or weight loss, decreased libido, sexual dysfunction, and amenorrhea. Symptoms of frequent urination and excessive thirst suggestive of posterior pituitary failure (diabetes insipidus) should also be sought. For patients with visual complaints and a macroadenoma or other large parasellar tumor, formal evaluation by an ophthalmologist is recommended. For patients with a sellar or suprasellar mass with symptoms or signs of pituitary gland dysfunction, evaluation by an endocrinologist is essential. A history of allergic rhinitis, sinusitis, nasal or sinus surgery/truma, or disorders of smell and taste should be reviewed.

**PHYSICAL EXAMINATION**

A complete general and detailed neurologic examination as well as a rhinologic head and neck examination is indicated for all patients being considered for endonasal surgery. For patients with pituitary macroadenomas or other large sellar and parasellar lesions causing compression of the optic apparatus or cavernous sinus, an examination by an ophthalmologist with attention to visual acuity and fields, pupillary reactivity, and extraocular movements is indicated. If there is visual loss, optic nerve coherent tomography can estimate the degree of optic nerve fiber loss and potential for recovery. In these cases, a neuro-ophthalmology consultation is essential. For patients with Cushing’s disease, attention to body habitus, distribution of adipose tissue, ecchymoses, stria, skin breakdown, infection, and hypertension should be noted. For patients with acromegaly, attention to potential upper airway obstruction, macroGLOSSia, signs of spinal stenosis, advanced cardiac disease, and hypertension should be noted.

**INDICATIONS**

The endoscopic endonasal approach is appropriate for removal of virtually all symptomatic sellar lesions including endocrine-active and endocrine-inactive pituitary adenomas and RCCs.

**CONTRAINDICATIONS**

The endoscopic endonasal approach may not be ideal for the rare highly invasive pituitary adenoma that extends anteriorly far into the frontal fossa or far lateral beyond the supraclavicular carotid arteries. In such cases, a supraorbital or pterional craniotomy could be used instead of or in conjunction with an endonasal approach. Another relative contraindication for the endonasal approach is active and severe sinusitis, which may require antibiotic treatment and a delay in surgery.

**PREOPERATIVE PLANNING**

**Head and Neck Consultation**

Preoperative evaluation, discussion, and additional informed consent should be performed by the otolaryngologist participating in the care of the patient. Prior nasal and sinus conditions should be addressed, and appropriate additional therapy should be discussed. It is not uncommon to have coexisting nasal and sinus disease in patients undergoing endonasal surgery. Evaluation of olfactory function should be included in the evaluation. Simple “scratch and sniff” tests are available to objectively evaluate this function preoperatively. We use the Senosics (Haddon Heights, New Jersey, www.senosics.com) “Brief Smell Identification Test Version A” and repeat it 3 to 6 months postoperatively. We review with the patient the postoperative nasal and sinus care with sinus lavage using the NeilMed Sinus Rinse system (Santa Rosa, California, www.neilmed.com) and the schedule for postoperative debridement. Patients unfamiliar with the sinus rinse begin it preoperatively to familiarize themselves with the process with the added benefit of cleansing the nasal cavity of debris or crusts before surgery. With multiple surgeons and their ancillary staff discussing the procedures, patients tend to be better informed and prepared by the repetition of the details. Prior to the procedure, a surgical team discussion regarding the approach, tumor extent, and strategy for removal and reconstruction with preparation of vascular flaps, if necessary, is mandatory.

**Medical Evaluations and Clearance**

Patients should have a thorough preoperative medical clearance. For those with acromegaly, Cushing’s disease, or other significant risk factors such as smoking, hypertension, or advanced age, a cardiac clearance with stress test is generally warranted. For acromegalic patients with evidence of obstructive sleep apnea
or severe macroglossia, a preoperative pulmonary evaluation is recommended. In acromegalic patients with poorly controlled hypertension, diabetes, and/or obstructive sleep apnea, consideration should be given to a 1- to 3-month preoperative course of a somatostatin analog such as lanreotide or octreotide to lower growth hormone and IGF-1 levels and reduce perioperative morbidity. Those with preoperative adrenal insufficiency, hypothyroidism, or diabetes insipidus should be treated with appropriate hormone replacement before surgery, ideally under the supervision of an endocrinologist.

**Imaging**

A high-quality MRI with gadolinium of the sella including the paranasal sinuses and skull base is indicated for all patients undergoing endoscopic endonasal tumor removal. In anticipation of using intraoperative frameless navigation, a thin-slice axial T1-weighted postgadolinium brain series should also be obtained. Prior to surgery, careful attention to the parasellar and cavernous carotid flow voids should be made. Displacements of the pituitary gland, infundibulum, and optic apparatus by tumor should be noted, as should the location of the diaphragma sellae and whether there is tumor invasion of the cavernous sinus. Although some surgeons advocate doing a thin-cut CT for all patients undergoing endonasal surgery, we generally reserve CT or CTA for predominantly clival lesions or those with significant vascular encasement and for patients with prior surgery in whom bony landmarks may be greatly altered or in patients who have undiagnosed nasal or sinus abnormalities, either pathologic or developmental, found on the preoperative MRI.

**Informed Consent**

Depending upon the presumed pathology, patients should be carefully counseled as to expected outcomes, likelihood of remission, recovery of vision, possible need for tissue grafts and nasoseptal flap, as well as the associated surgical risks. In particular, the potential likelihood of new pituitary failure, CSF leak, visual loss, diplopia, hematoma, carotid or other vascular injury, infection, and anosmia should be discussed.

**SURGICAL TECHNIQUE**

**Overview**

Although the procedure requires two surgeons, the initial nasal approach to the sphenoid sinus is typically done by the otolaryngologist alone; the sellar and parasellar exposure, tumor removal, and skull base reconstruction are done by the neurosurgeon and otolaryngologist together. When both surgeons are operating, the endoscope is generally maneuvered by the otolaryngologist and placed in the upper quadrant of the right nostril while the neurosurgeon uses binostril access, typically with a suction in the right nostril and microdissector, ring curette, or other instrument in the left nostril (Fig. 3.1). With an angled 30- or 45-degree scope looking up, the endoscope often needs to be positioned in the inferior nostril and nasal cavity to minimize conflict of instruments.

**Instrumentation**

Endoscopic equipment includes 4-mm rigid endoscopes (18 cm in length) with 0-, 30-, and 45-degree angled lenses and high-definition (HD) camera and two flat panel monitors (Karl Storz, Tuttingen, Germany). Given the narrow working space afforded by the binostril endoscopic approach, all instruments should be as thin and low profile as possible. They may be straight or bayoneted depending upon the surgeon’s preference. After many years of performing endonasal microscopic pituitary surgery, we prefer bayoneted microinstruments. Microdissectors, ring curettes, and microblades are on bayoneted handles. Similarly, microscissors, tumor grasping forceps (both straight and up angled), and the bipolar cautery are used in a single-shaft pistol-grip design to minimize visual obstruction. High-speed drills, microdebriders, and ultrasonic aspirators also are of the lowest possible diameter with angled handpieces. Straight and curved variable suctions should also be available. A micro-Doppler (Koven, Inc. or Mizuho, Inc.) probe is also used for all cases to localize the cavernous carotid arteries prior to opening the dura. Warm (99°F/37°C) sterile saline is used for irrigation both to clean the tip of the scope and to promote local hemostasis. A 50-cc syringe with a curved irrigation tip is used to deliver the irrigation into the operating field when necessary.

**Preoperative Medications**

Preoperative antibiotics (typically cefazolin) are given and continued for 24 hours. In patients with normal preoperative adrenal function or those with Cushing’s disease, no perioperative glucocorticoids are administered. Those with adrenal insufficiency or borderline adrenal function are given 100 mg of hydrocortisone intravenously.
Positioning, Room Setup, and Prep

Following induction of general anesthesia with the patient in the supine position, the endotracheal tube emerges from the left corner of the mouth, and the anesthesiologists and anesthesia equipment are positioned on the patient’s left side. For patients with Cushing’s disease, acromegaly, other significant medical co-morbidities, or a large and vascular tumor, an arterial line and Foley catheter are placed; for other patients with microadenomas, small macroadenomas, and typical RCCs, an arterial line and Foley catheter are not used.

An ergonomically efficient operating room setup is essential to ensure comfort of both surgeons especially during lengthy procedures. Two video monitors are positioned at almost 90-degree angles to each other: one above the patients’ head and one to the left of the chest; the neuronavigation monitor is placed in between the two video monitors. Our current operating room configuration is depicted in Figure 3.2. The patient’s head is placed in a horseshoe head holder and angled approximately 30 degrees toward the left shoulder. This arrangement...
allows both surgeons to stand comfortably on the patient’s right side, one at the head and one immediately below the head, and able to comfortably view their respective video monitors. The head is inclined in a neutral plane (0 degree) relative to the floor for sellar lesions; for suprasellar lesions, 10 to 15 degrees of neck extension is used, and for infrasellar and clival lesions, 10 to 15 degrees of neck flexion is used. The surgical navigation mask (Stryker Navigation) is placed on the face, and the system is registered to the preoperative MRI and/or CT angiogram. Only in prolonged cases is the head pinned in 3-point fixation, for example, with a craniopharyngioma or tuberculum sella meningioma in which the operative time may exceed 6 hours and there is risk of pressure necrosis with the horseshoe head holder.

The nasal cavity is prepped with decongestant (oxymetazoline 0.05%)-soaked Cottonoids placed in both nares for several minutes. The face, perinasal area, and right lower abdominal area (for a possible adipose tissue graft) are steriley prepped and draped. A clear drape is used to allow visualization of the navigation mask during surgery. If the patient is fixed in pins and the tracking unit for navigation is attached to the Mayfield, a clear drape is not needed. Xylocaine 1% with 1:100,000 epinephrine is injected into the inferior and middle turbinates bilaterally.

**Approach to the Sphenoid Sinus**

The initial approach through the nasal cavity uses a 0-degree 4-mm rigid endoscope and includes handling of the turbinates, raising of bilateral nasoseptal (NS) mucosa-preserving rescue flaps, wide sphenoidotomy, posterior septectomy, and posterior ethmoidectomies. As described below, we rarely use a vascularized nasoseptal flap in the skull base reconstruction and CSF leak repair for pituitary adenomas and RCCs and instead use a NS flap only in larger extended transplanum or transclival approaches. Using a Cottle elevator, the inferior and middle turbinates are out-fractured bilaterally, and the sphenoid ostia are identified. The middle turbinates are not routinely resected. We reserve the resection of the middle turbinate for lateral skull base pathologies such as Meckel’s cave and pterygopalatine fossa lesions. It has been suggested that postoperative debridements are more difficult if the middle turbinate is not resected, but this has not been our experience. Bilateral NS “rescue flaps” based on the posterior nasal artery are created (Fig. 3.3). An extended shaft, manually bent, microtip Bovie (Megadyne E-Z Clean 6.0″/152 mm ref: 0016M, Draper, Utah) is used to incise the mucoperiosteum inferior to the sphenoid ostium preserving the posterior septal artery pedicle, which comprises two arterial branches in 80% of cases and is located 8 to 9 mm below the ostium. The incision is then extended anteriorly using the inferior aspect of the superior turbinate as a horizontal guide to preserve the septal olfactory strip (SOS mucosal flap) for approximately 2 cm along the vomer and posterior nasal septum. This maneuver is performed bilaterally. These bilateral mucoperiosteal “rescue flaps” are then pushed inferiorly toward the nasopharynx with Cottonoids to minimize obstruction and provide access into the sphenoid sinus (Fig. 3.4). The SOS mucosal flaps are pushed laterally and superiorly onto the superior turbinate where they usually become adherent and out of the surgical field. These mucosa-preserving flaps obviate the need to transect the sphenopalatine artery, thereby greatly reducing the potential for postoperative sphenopalatine hemorrhage and epistaxis. With the majority of the
endonasal mucosa preserved and out of the surgical field, any remaining superior mucosa may be excised with the microdebrider but removal of this mucosa is infrequently needed. The sphenoid keel, vomer, and posterior nasal septum are demucosalized and in view. A wide sphenoidotomy is then performed with up and down biting Kerrison rongeurs or the drill. This bone removal can be done from ostia to ostia superiorly and inferiorly to preserve a large piece of keel that can be harvested and retained for possible use in reconstruction of the floor of the sella after removing the tumor. A posterior septectomy of approximately 15 to 20 mm is then performed with a backbiter typically placed through the left nostril. Care should be taken to not extend the septectomy too far superiorly or anteriorly, which can increase the risk of anosmia and nasal deformity. The sphenoidotomy is then further refined based upon the pathology being addressed in the sella. In general, however, removal of bone and mucosa should extend beyond the lateral edges of the ostia bilaterally to allow visualization of the tuberculum sella, floor of the sella, opticocarotid recesses, clival recess, and lateral sphenoid recesses. Posterior ethmoid air cells are also opened and removed to facilitate maneuverability of the endoscope and instrument superiorly.

**Sellar Exposure**

During the sphenoid and sellar portion of the procedure, when the otolaryngologist is driving the endoscope and the neurosurgeon is operating, a sterile-draped pillow on a Mayo stand is positioned just above the head as an elbow rest to reduce arm fatigue while driving the endoscope. After the sphenoidotomy is completed, the face

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**FIGURE 3.4**

Intraoperative photographs with 0-degree endoscope of bilateral nasoseptal “rescue flaps” being created and preserved during tumor removal and at procedure completion. 

**A.** Sphenoid keel exposed and right rescue flap pushed down by long Cottonoid; left rescue flap being pushed downward as Cottonoid is being placed. 

**B.** Posterior septectomy completed, and both rescue flaps pushed downward by bilateral Cottonoids. 

**C.** Sphenoidotomy completed and Doppler probe localizing right cavernous carotid artery. 

**D.** After removing the tumor, view from posterior nasal cavity showing no obstruction from rescue flaps. 

**E.** Adipose tissue graft being placed into sella for reconstruction for CSF leak. 

**F.** After reconstruction is completed with adipose tissue graft and collagen sponge, Cottonoids are removed, and rescue flaps are replaced.
of the sella is identified, and intrasphenoidal bony septations are correlated with the patient’s preoperative MRI. Particular note is made on the coronal images of where these septations reach the posterior wall of the sphenoid sinus relative to the carotid arteries, pituitary gland, and tumor and on sagittal views where such septations reach the planum or sella. Septations that end on the face of the sella are removed with a rongeur or high-speed drill down to the sella; those that end over a carotid artery should be removed with care, and excessive torquing of these septations should be avoided. The mucosa over the sella is removed, but the remaining mucosa of the sphenoid sinus is left undisturbed. The bony face of the sella is then removed from cavernous sinus to cavernous sinus and from the floor of the sella inferiorly to the tuberculum sella superiorly with a Kerrison rongeur or in some instances a high-speed hybrid-diamond bit drill. With large invasive tumors, the bone of the sella may be markedly thinned or absent, and the tumor may be directly under the mucosa or attenuated dura.

**Localization of the Cavernous Carotid Artery**

After opening the bony sella, although the carotid protuberances should be readily visible as should the lateral opticocarotid recesses, reaffirming the course of the carotid arteries with the micro-Doppler probe is recommended. The probe (10-MHz ES-100X MiniDop® with NRP-10H bayonet probe, Koven, St. Louis, MO, or 20-MHz Surgical Doppler, Mizuho America, Beverly, MA) is placed initially at the edge of the bony opening at 90 degrees to the dura. If faint or no audible flow is present, the probe is angled more laterally aiming under the bone edge, and in most cases, the carotid flow will become louder (Fig. 3.5). The probe is then moved superiorly and inferiorly to define the course of the carotid arteries, which typically have their most medial course superiorly and distally near the tuberculum sella before they pass through the dural ring to enter the subarachnoid space. If no Doppler flow is evident, then additional bone can be removed laterally to maximize exposure of the sella. If audible flow is still not evident and visual anatomy and navigation images indicate that the carotid has been exposed, consideration should be given to whether there is a technical problem with the probe.

**Dural Opening**

A wide U-shaped, superiorly based opening is made in the dura of the sella using a straight microblade (Mizuho Inc.). The initial opening in the dura should not transgress the pituitary gland or adenoma if possible. Angled microdissectors are then used to separate the dura from the underlying tumor and pituitary gland. The opening in the dura is enlarged superiorly, inferiorly, and laterally as needed with the use of a right-angled microhook blade or curved microscissors, which allow the cutting force of the blade to be directed away from the sella and cavernous sinus. Care should be taken in extending the opening in the dura too far superiorly in patients with microadenomas who often have a shallow sella and low-lying diaphragma sellae; such an opening can cause an early CSF leak. Laterally, the opening should generally extend to within 1 to 2 mm of the medial wall of the cavernous sinus. Low-pressure cavernous sinus venous bleeding is generally easily controlled using Surgifoam (Ethicon Inc., Johnson & Johnson Co., Piscataway, NJ) or Gelfoam (Pfizer Inc., New York, NY).

**Tumor Removal**

The binostril endoscopic approach is depicted in Figure 3.1A and B. A selective and complete removal of the tumor with preservation or improvement of pituitary gland function should be the goal for patients undergoing removal of an adenoma. In many instances, the tumor pseudocapsule can be identified and a plane established between the adenoma and the normal gland. Using microdissectors, irrigation, and gentle traction on the pseudocapsule, such adenomas can often be removed completely with preservation of the pseudocapsule as
described by Oldfield et al. However, many if not most large macroadenomas are quite soft and require initial internal debulking with ring curettes and suction. After so doing, the tumor “rind” with an intact pseudocapsule can be gently separated away from the normal gland and diaphragma sellae (Fig. 3.6). For firm or rubbery adenomas, initial tumor debulking with curved and straight microscissors may be needed. Adenomas with suprasellar extension should be debulked inferiorly first followed by the suprasellar component. This sequence allows the suprasellar tumor, in part, to deliver itself from above and may minimize the chances of an early CSF leak. For large macroadenomas, it is essential to confirm descent of the diaphragma sellae as an indication that complete tumor removal has been accomplished. Probing the folds of the diaphragma with 45- and 90-degree up-angled ring curettes bilaterally, posteriorly, and anteriorly will help dislodge residual tumor when present in these areas. To further encourage downward descent of a suprasellar tumor, the anesthesiologist can induce a Valsalva maneuver to transiently increase intracranial pressure. Since most macroadenomas, even with a large suprasellar extension, are contained by a thinned but largely intact diaphragma sellae, the diaphragma sellae should completely evert and fall into the enlarged sella once a complete tumor removal is accomplished. If a full “mirror image” descent of the diaphragma sellae is not seen and only a partial descent of the diaphragma is noted, residual tumor is likely present.

![FIGURE 3.6](image)

**FIGURE 3.6**
Large endocrine-inactive macroadenoma with visual loss and anterior pituitary gland failure. **A.** Intraoperative photograph with 30-degree endoscope of pseudocapsular dissection for large macroadenoma using ring curette and suction (D, diaphragma sella; A, pituitary adenoma pseudocapsule). **B.** Preoperative and postoperative coronal and sagittal postgadolinium MRIs demonstrating complete tumor removal.
For tumors with obvious or possible invasion of the cavernous sinus, visualization of the medial wall of the cavernous sinus is essential. Under direct visualization, what appeared to be invasion of the cavernous sinus on MRI may only be tumor compression of the medial wall of the cavernous sinus. However, in many cases, after the tumor in the sella has been removed, a defect in the medial wall of the cavernous sinus is seen. Tumor in the medial cavernous sinus can be removed or at least effectively debulked using gentle suction and angled ring curettes that have smooth outer edges (Fig. 3.7). Given the potential for injury to the cavernous carotid and the abducens nerve lateral to the carotid, aggressive curetting or grasping of tumor tissue along or lateral to the carotid artery should be avoided.

Once the tumor has been removed as completely as possible with a 0-degree endoscope, 30- and 45-degree angled endoscopes can be used to search further for residual tumor. This angled visualization is especially helpful in cases where the diaphragma sellae may not have descended fully into the sella. Removal of such tumor remnants can often be performed with angled suction, tumor grasping forceps, or ring curettes.

**Rathke’s Cleft Cysts**

Since intrasellar and intrasellar/suprasellar RCCs are typically located posterior to the anterior pituitary gland, removing them generally involves a direct approach through the anterior–inferior pituitary gland via a low midline vertical glandular incision or an approach under the gland avoiding an incision in the gland. Through this small working corridor, the cysts are usually easily removed with suction, ring curettes, and gentle irrigation. A 30- or 45-degree endoscope facilitates excellent visualization of the cyst cavity with minimal manipulation of the gland. After complete removal of the cyst, the cavity is inspected for residual cyst contents and cyst lining. Given that the resection cavity generally consists of a normal-appearing anterior and posterior pituitary gland,
no attempt is made to vigorously strip the cyst wall off of these normal structures given the risk of worsening gland function. For purely suprasellar RCCs that are typically intimately attached to the pituitary stalk and often embedded within the superior aspect of the anterior pituitary gland, an extended transtubercular approach is often needed to allow maneuvering over the normal pituitary gland.

Intrasellar Hemostasis

After tumor removal, hemostasis is obtained with Surgifoam (Ethicon Inc., Johnson & Johnson Co., Piscataway, NJ) and full-strength hydrogen peroxide. The peroxide is irrigated directly into the sphenoid sinus and sella for 1 to 2 minutes. We have recently demonstrated that its use is safe from the standpoint of pituitary hormonal function, and it may have additional tumorcidal effects on residual microscopic foci of adenoma. However, it should not be used if there is a large diaphragmatic defect, which could allow it to track into the subarachnoid space. In cases where there is persistent oozing, one should further inspect the sella with the endoscope to look for residual tumor.

Skull Base Reconstruction and CSF Leak Repair

Skull base reconstruction and CSF leak repair can be tailored to the size of the CSF leak and the bony and dural defects. Prior to reconstruction, an assessment of the size of diaphragmatic defect is performed. We grade CSF leaks as grade 0 (no leak), grade 1 (small), grade 2 (moderate), and grade 3 (large). If no obvious defect is seen, a Valsalva maneuver is induced to help visualize an occult or small (grade 1) CSF leak emanating through a small diaphragmatic defect.

All reconstruction involves the use of collagen sponge (Duragen, Helista, or Instat) that acts as a scaffolding for fibroblast ingrowth and a vascularized dural replacement. In patients with no CSF leak (grade 0), a single layer of minimally moistened collagen sponge placed over the exposed diaphragma sellae, pituitary gland, and sellar dura is typically used as the only repair material. For most small (grade 1) CSF leaks, the repair includes intrasellar collagen sponge with an intrasellar extradural buttress of previously harvested sphenoid keel bone or synthetic or absorbable plate and less frequently use of titanium mesh. A second outer layer of collagen is placed over the buttress and adjacent sellar and sphenoid bone. The repair is typically held in position with a small amount of tissue glue (DuraSeal, Confluent Surgical, Inc. or Tisseel, Baxter, Inc.). For medium (grade 2) CSF leaks or grade 1 leaks with a large intrasellar dead space, the repair includes an intrasellar abdominal adipose tissue graft, a layer of collagen sponge followed by a buttress of bone, synthetic plate, or titanium mesh wedged into the intrasellar extradural space. Additional adipose tissue is typically placed over the sella followed by another layer of collagen; the reconstruction is held in position with tissue glue (Fig. 3.8). In some grade 1 leaks in which the sella is filled with adipose tissue and the floor of the sella is intact with at least some anterior lip remaining to help hold the adipose tissue graft within the sella, only collagen sponge is layered over the adipose tissue followed by tissue glue without a rigid buttress. Finally, in cases of large tumors with grade 1, 2, or 3 leaks and a large dead space, in which the bony edges of the sella have been removed or eroded by tumor precluding wedging of a rigid buttress, single or binostril Merocel (Medtronic Mystic, Connecticut) nasal packs are passed into the sphenoid under direct endoscopic visualization up to the sellar reconstruction as a soft temporary buttress for 5 days (Fig. 3.9). All patients with an intraoperative CSF leak are placed on Diamox (acetazolamide) 250 mg, every 8 hours for 48 hours after surgery to diminish CSF production. To further evaluate the adequacy of the repair, prior to placing tissue glue, a Valsalva maneuver is performed to raise the patient’s intracranial pressure; should there be CSF streaming around the repair or movement of the buttress, the repair should be revised. It is important to note that use of tissue glue in this repair paradigm is not for stopping egress of CSF per se but to prevent migration of the reconstruction materials (adipose tissue and collagen) away from the sella. For the large (grade 3) defects, typically seen with extended approaches, consideration should be given to use of a NS flap. However, it is unusual to have a grade 3 leak after removal of pituitary adenoma or RCC. In the minority of patients with a grade 3 leak, a lumbar drain for CSF diversion can be placed for 48 to 72 hours.

Closure

Blood is suctioned from the sphenoid sinus, nasal cavity, and nasopharynx. Nasal hemostasis should be relatively complete to minimize blood being swallowed after extubation, which can cause nausea and vomiting and dislodgement of the materials used for skull base reconstruction. The previously created mucoperiosteal “rescue flaps” including the NS and SOS are returned to their normal anatomic positions. The NS flaps are gently elevated back along the residual sphenoid keel and inferior anterior nasal septum (Fig. 3.4). The middle turbinates are repositioned anatomically if they remain out-fractured. Nasal packing is not used unless a Merocel is needed to help hold the sellar floor reconstruction in position. To minimize chances of a postoperative CSF leak, nasal epistaxis, or intrasellar bleeding, excessive coughing on the endotracheal tube should be avoided during extubation, and blood pressure should be carefully monitored and controlled in the early postoperative period.
POSTOPERATIVE MANAGEMENT

Most patients undergoing removal of an adenoma or RCC are admitted to a non-ICU bed; their arterial line is removed before leaving the recovery room. For the first postoperative night, patients are given a humidified face tent, and decongestants are available upon request. Saline nasal spray is provided for a week after surgery and used based on patient preference. The Foley catheter is removed on the morning of postoperative day 1, and patients are encouraged to ambulate. An early postoperative MRI or CT scan is typically performed within 2 days of surgery for patients with macroadenomas or other larger tumors. All patients with pituitary-related

FIGURE 3.8
Macroprolactinoma with pituitary apoplexy.
A. Pregadolinium sagittal MRI showing subacute hemorrhage.
B. Postgadolinium coronal MRI showing severe compression of the gland and elevation by hemorrhagic tumor.
C and D. Immediate postoperative CT with sagittal reconstruction and post-op day 1 sagittal MRI without gadolinium showing intrasellar and sphenoid sinus adipose tissue grafts with intervening bony buttress (arrow) for grade 2 CSF leak repair.
E and F. Post-op day 1 sagittal and coronal postgadolinium MRIs with adipose tissue suppression sequence (asterisk) showing gross total tumor removal with reexpanded pituitary gland.
Patient's prolactin fell from 286 to 16 ng/mL on postoperative day 2.
lesions are followed in-hospital by an endocrinologist. Patients are monitored for diabetes insipidus based on urine output and urine specific gravity. Adrenal function is monitored by measuring am serum cortisol and adrenocorticotropic hormone (ACTH) levels on the mornings of postoperative days 1 and 2. For patients with acromegaly, prolactinoma or Cushing’s disease, growth hormone, prolactin, and cortisol/ACTH levels are followed on postoperative days 1 and 2 to document early remission based on subnormal hormone levels.

Most patients are discharged home on postoperative day 2 and have a serum sodium level checked on postoperative day 4 or 5 to monitor for delayed hyponatremia. Antibiotics are continued for only 48 hours (until discharge) if no nasal packs are in place or for 5 days when nasal packs are removed. Outpatient endoscopic sinonasal debridements are typically performed 3 times after surgery on approximately post-op days 10, 24, and 38. Neurosurgical follow-up is at approximately day 10 and again 3 months after surgery, including

**FIGURE 3.9**
Invasive endocrine-inactive macroadenoma with large extension into the sphenoid sinus. A and B. Preoperative sagittal and coronal MRIs. C. Grade 1 CSF leak repair—immediate postoperative CT with sagittal reconstruction showing intrasellar and sphenoid sinus adipose tissue grafts held in position by binastral Merocel buttress (arrow). D. Post-op day 1 sagittal MRI without gadolinium showing intrasellar and sphenoid sinus adipose tissue grafts with intervening collagen sponge (arrow). E and F. Post-op day 1 sagittal and coronal postgadolinium MRI with adipose tissue suppression sequence (asterisk) showing gross total removal of the tumor with reexpanded pituitary gland.
a complete pituitary hormonal evaluation. The next follow-up MRI is typically performed at 3 months after surgery and then again at 6- or 12-month intervals depending upon the pathology and patient specifics.

**COMPLICATIONS**

In experienced hands, endoscopic endonasal removal of sellar tumors has become increasingly safe and effective. However, serious complications can occur. Table 3.1 summarizes rates of major complications from several recent studies at experienced centers, including death, carotid or other vascular injury, visual loss from chiasmal or optic nerve injury, diplopia, meningitis, CSF leak, new pituitary gland failure, epistaxis, sinusitis, nasal septal perforation, and anosmia.

**RESULTS**

Outcomes after endoscopic endonasal tumor removal are generally equivalent with microscopic transsphenoidal series, but more recently, improved rates of remission are being reported with the fully endoscopic approach. This trend would not be surprising given the enhanced visualization afforded by the endoscope. Table 3.2 lists expected remission and resection rates for pituitary adenomas and RCCs based upon recent publications.

**PEARLS**

- Carefully review preoperative imaging with attention to pituitary gland location, tumor extension, course of parasellar carotid arteries, exposure needed, and anticipated skull base reconstruction.
- Perform a wide and tall sphenoidotomy, generous posterior septectomy, and wide sellar bony opening to allow maximal instrument maneuverability and access to the tumor.
- To maximize chances of preserving the gland and recovery, use gentle manipulation of the gland, and if need be, incise or sharply remove the attenuated component of the gland to allow better intrasellar access and tumor exposure.

| TABLE 3.1 Complication Rates of Endoscopic Endonasal Surgery for Pituitary Adenoma and RCCs |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Death                                        | <1%                                          |
| Vascular injury                              | <1%                                          |
| New or worsened visual loss                  | <1%                                          |
| New or worsened diplopia                     | <1%                                          |
| Meningitis                                   | 0%–3.7%                                      |
| CSF leak                                     | 0%–12.1%                                     |
| New hypopituitarism                          | 0%–13.6%                                     |
| Sinonasal morbidity (sinusitis, nasal septal perforation, anosmia) | 0%–2%                                         |
| Delayed epistaxis                            | 0%–5%                                        |

| TABLE 3.2 Remission and Resection Rates for Pituitary Adenoma and RCCs |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Microadenoma                                 | Macroadenoma                                 | Overall                                      |
| Acromegaly<sup>a</sup>                       | 75%–100%                                     | 40%–82%                                      | 58%–84%                                      |
| Cushing's disease<sup>z</sup>                 | 54%–100%                                     | 31%–83%                                      | 70%–86%                                      |
| Prolactinoma<sup>a</sup>                     | 92%–100%                                     | 57%–77%                                      | 47%–88%                                      |
| Endocrine-inactive macroadenoma<sup>b</sup>  | 72%–88%                                      |                                               |                                              |
| RCC<sup>b</sup>                              | 93%–100%                                     |                                               |                                              |

<sup>a</sup>Rates are for biochemical remission using standard contemporary criteria. Some for Cushing's disease include microscopic and endoscopic series.

<sup>b</sup>Rates are for gross total resection based on postoperative sellar MRI.
PART I Sphenoid and Parasellar Regions

● Obtain complete hemostasis in the sella with hemostatic agents and brief irrigation with hydrogen peroxide.
● Carefully perform repair of CSF leak and reconstruction of the skull base in multilayered fashion; perform a Valsalva maneuver prior to exiting the sphenoid sinus and closure to evaluate the integrity of the repair.
● Gently handle sinonasal tissues, and use bilateral NS rescue flaps to diminish chances of postoperative sphenopalatine artery bleeding, increase likelihood of preserved olfaction, and simplify postoperative nasal debridements.
● Maximize the safety of the procedure and efficiency using teamwork and communication.

PITFALLS

● A misguided trajectory with resultant injury of the carotid artery can be avoided with the use of neuronavigation and Doppler probe in each case.
● Failure to thoroughly explore sellar, suprasellar, and medial cavernous sinus regions as well as diaphragmatic folds with 0-degree and angled endoscopes can result in leaving residual tumor.

INSTRUMENTS TO HAVE AVAILABLE

● Standard endoscopic sinus surgery set
● Endoscopic skull base surgery instruments
● Endoscopic drill with 3- and 4-mm coarse diamond bits
● Doppler probe
● Dural knife
● Hemostatic materials
● Reconstructive materials

SUGGESTED READING

INTRODUCTION

In skull base surgery, the division between neurosurgical territory and otolaryngology territory is essentially determined by the firm natural compartmentalization that separates the “sterile” and “revered” neurocranium, housing the vital and evolved brain, from the more primitive viscerocranium serving the basic and essential functions of respiration and alimentation.

The demarcation of the borders is created by the cranial base bone and a firm and thick meningeal/dural membrane. The dura has to be understood in its anatomical extension, its functional capacity, and, most importantly, its relationship to the pathology in question. In general, tumors respect this membrane. Basal bone can be thinned, eroded, or destroyed, but the basal membranes remain resistant and intact, demonstrating the biologic superiority of membranes over bones. The membrane may be thinned, may balloon out, or may be buckled, but it is only extremely rarely that it will be transgressed by tumors. Tumors that transgress this membrane are usually malignant in nature and may be present on both sides of the divide. Meningiomas that arise from the membrane can be present on both sides of the membrane and form a discrete group of tumors.

The membrane has to be respected by the surgeon. This understanding forms the basis of deciding the surgical approach. In general, if the tumor is above the dura, a transcranial approach should be adopted, and if the tumor is below it, a nasal or a facial approach is preferred. The recent introduction of a number of vascularized pedicled or free flaps has opened new vistas, permitting surgeons from both specialties to work together and have the freedom to cross this boundary with limited fear. Despite the fact that reconstruction of the skull base can now be done more elaborately and safely, it can never be achieved with the same perfection with which it is naturally designed and configured. For every tumor, there is only one best approach and selection should be based on concepts such as an anatomical and philosophical understanding of the nature of the tumor, its adjoining structures and, most importantly, its relationship to the basal meninges.

There is great potential for the use of an endoscope in the field of skull base surgery. The advantages of endoscopy in the management of extradural lesions in the paranasal sinus, clival region, and medial cavernous sinus are now generally recognized. However, its use after its introduction through the nose for intradural intracranial lesions must take into account various crucial and relevant tumor- and pathology-related issues. Such nasal approaches for intracranial and intradural lesions are controversial to say the least.

Neurosurgical transcranial approaches to a variety of sellar and suprasellar lesions have been developed and refined over decades. Such advances have occurred with contributions from a number of neurosurgeons over many years. Microscopic vision with a possibility of the use of endoscope assistance to look around corners, ease of dissection under controlled conditions, feasibility of drainage of cerebrospinal fluid (CSF) from the cisterns and ventricles, and retraction of the brain for enhancing the exposure are important components of a cranial approach. Moreover, the entire surgery is done under “sterile” conditions, and transgression of the basal divide is not necessary.
**HISTORY**

Clinical history of the nature and duration of progression of symptoms including prior drug or radiation therapy provides significant information about the physical nature of the tumor and the extent of difficulty of its dissection from adjoining neural and vascular structures. The longer the duration of symptoms and worse the presenting signs, in general, the firmer and more adherent the tumor is expected to be, enhancing the chances of injury to adjoining structures. Every tumor has a specific pattern of clinical presentation. If the history of progression of symptoms is appropriately analyzed and studied, the histologic nature of the tumor can frequently be predicted and the surgery planned and executed accordingly.

**PHYSICAL EXAMINATION**

Although meticulous neurologic examination of the patient was critically and diagnostically crucial in the era prior to computer-based imaging, its value even in the modern era of high-resolution imaging cannot be overemphasized as not only does it complement the radiology for assessing the diagnoses, but accurate documentation provides for evaluation of postoperative improvement or complications. In addition, it has a critical role in guiding surgery as the extent and nature of neurologic deficits are guiding parameters through the course of surgery.

Basal tumors can cause a wide range of symptoms, from frontal lobe syndromes with cognitive or personality changes, to specific deficits such as vision loss from direct compression or papilledema, to specific cranial neuropathies depending on the location and involvement. All of these functions must be examined closely to determine the extent and severity of their involvement.

**INDICATIONS**

On most occasions, it is possible for the surgeon to make a working diagnosis regarding the histologic nature of the lesion on the basis of the clinical and radiologic studies. The age and gender of the patient, acuity of the presentation, principal presenting signs, size of the tumor, extent of cranial nerve involvement, nature of carotid artery displacement and/or encasement, imaging characters on computed tomographic (CT) scanning and MRI, and other such features are helpful in estimating the consistency and vascularity of the lesion, site of origin, and direction of its spread. Such information is critically important in guiding the direction of the approach to the lesion and the cavernous sinus, need for carotid artery control, extent of the surgical resection that would be necessary and possible, and prognosticating the ultimate outcome.

With malignant tumors, a history of prior irradiation in the field of surgery makes the tissue more adherent with fragile vessels. Reconstruction may be a difficult and a defining step of surgery. Depending on the histology, surgery on the first attempt often provides the best opportunity for complete tumor resection.

**Anatomical Grading of Giant Pituitary Tumors on the Basis of Their Dural Relationship**

Most pituitary tumors involving only the sella and cavernous sinus are essentially “extradural” in their location. An extradural or a nasal approach (transsphenoidal) is best suited for such tumors. Even when such tumors become large or giant in size, they respect the dura, remain underneath its confines, and only rarely transgress it.

Giant pituitary tumors (>3 cm) can be divided into four grades based on tumor extension and the relationship of the tumor to the sellar dura and the dura of the cavernous sinus.

- **Grade I** (Fig. 4.1) pituitary tumors are those that are located within the confines of the sella, remain inferior to the superiorly elevated diaphragma sellae, and do not invade the cavernous sinus. The diaphragma sellae is stretched superiorly, sometimes even beyond the corpus callosum, but it covers the entire superior dome of the pituitary tumor. Although the suprasellar extension of the tumor is intracranial, it is “subdiaphragmatic.”

- **Grade II** (Fig. 4.2) pituitary tumors are those that invade the cavernous sinus. Although there are other parameters that suggest invasion of tumor into the cavernous sinus, encasement of the intracavernous carotid artery is a clear sign of cavernous sinus invasion. The cavernous sinus is frequently bloated full by the tumor, but its dural walls are not transgressed.

- **Grade III** (Fig. 4.3) giant pituitary tumors are those where the roof of the cavernous sinus is elevated superiorly, sometimes to a considerable degree. Such an elevation of the roof of the cavernous sinus is frequent.
CHAPTER 4  Transcranial Approaches to the Sella, Suprasellar, and Parasellar Area

FIGURE 4.1  A. T1-weighted coronal MRI showing a giant grade 1 pituitary tumor. The tumor does not enter into the confines of the cavernous sinus. The diaphragma sellae is elevated.  B. T1-weighted sagittal view showing the large tumor and the elevated diaphragma sellae.

FIGURE 4.2  A. T1-weighted MRI showing a grade 2 giant pituitary tumor. The tumor invades the cavernous sinus. The diaphragma sellae is elevated.  B. T2-weighted axial view of the scan showing cavernous sinus involvement by a grade 2 pituitary tumor.

FIGURE 4.3  A. Pre-contrast coronal MRI showing a grade 3 pituitary tumor. The diaphragma sellae is elevated. The roof of the cavernous sinus is seen to be elevated by the tumor.  B. Contrast-enhanced coronal MRI showing a grade 3 pituitary tumor. The diaphragma sellae and the roof of the cavernous sinus are elevated.
and can be mistaken as frontal or temporal lobe extension. The dura of the roof of the cavernous sinus is thin, and such elevation usually displaces the third cranial nerve. Although it is not possible to convincingly confirm, it does appear that the tumors that elevate the roof of the cavernous sinus are inherently more aggressive and the recurrence rates in such cases are relatively higher. Primary radiotherapy may be considered in such cases.

Grade IV (Fig. 4.4) pituitary tumors are those that transgress the diaphragma sellae boundary and enter into the subarachnoid spaces of the brain. These tumors encase the arteries of the circle of Willis.

The tumors in grades 1 to 3 are below the diaphragma sellae and the superior wall of the cavernous sinus. As the cavernous sinus is considered to be an extradural entity, these tumors are essentially “extradural” in nature. The tumors in these three grades can and should be resected by an extracranial transnasal route. The exact mode and modality of surgery in grade 4 pituitary tumors is still debated. However, this group of tumors may be operated by a transcranial route. A transcranial route for pituitary tumors is also indicated in cases of functioning pituitary tumors that involve the cavernous sinus and extend lateral to the internal carotid artery. Transcranial surgery is sometimes indicated in cases with tumor recurrence where the cranial component is large and adoption of the nasal route is difficult due to previous operation.

**Trigeminal Schwannomas**

Three distinct types are middle fossa type (type A), posterior fossa root type (type B) where the tumor is in front of the brainstem, and the dumbbell type with both middle and posterior fossa components (type C) (Figs. 4.5 to 4.9). Depending on the nerve of origin, the extracranial part (type D) of the tumor is classified into orbital, infratemporal, and pterygopalatine fossa components. Middle fossa lesions are located within the confines of the dura in the lateral wall of the cavernous sinus and Meckel’s cave and as such termed as “interdural.” Despite the sometimes massive growth of these benign lesions, the confines of the dura are not eroded. The posterior fossa component of the tumor can be “intradural” in nature. However, frequently, even this part of the tumor may be “interdural” in nature. The tumor remains within the confines of dura. The cavernous sinus and internal carotid artery are displaced and a relatively thick wall of dura separates them from the tumor. The extracranial component of the tumor is also surrounded by a layer of “dural” sheath. Despite the frequently large tumor size, the majority of trigeminal nerve fibres are only displaced by the tumor.
FIGURE 4.5
A. Line drawing showing the interdural trigeminal schwannoma in the middle cranial fossa. The trigeminal nerve is displaced on the superior aspect of the tumor. The carotid artery and cavernous sinus are also displaced by the tumor. B. Line drawing showing the dumbbell-shaped trigeminal schwannoma extending both in the middle and posterior cranial fossae. The trigeminal nerve is displaced by the tumor.
FIGURE 4.6
Trigeminal schwannoma located in the posterior cranial fossa.

FIGURE 4.7
Trigeminal schwannoma located in the middle fossa.

FIGURE 4.8
Large dumbbell-shaped trigeminal schwannoma extending both in the middle and posterior cranial fossae.
Chordomas

These tumors destroy bone and displace soft tissue. This character of the tumor distinguishes it from other tumors in the region (Figs. 4.10 and 4.11). Although various authors have noted cavernous sinus invasion by chordomas and chondrosarcomas, it is observed that even in massive tumors the cavernous sinus involvement by these tumors is in the form of displacement rather than invasion. This tumor arises from the clivus or the sphenoid bone and grows eccentrically into the subcavernous sinus region and elevates it on its dome. The functional involvement of the cranial nerves of the region is usually due to stretch. The precavernous and cavernous segments of the carotid artery are displaced anteriorly by the tumor. The tumor is primarily extradural, and actual transgression of the dura is a rare feature. Even in large lesions, a layer of dura separates the tumor from neural and vascular structures, providing a plane of cleavage for surgical resection. The location of the tumor in the extradural space makes an extracranial surgical route a viable surgical option. However, cranial approaches are suitable and safer and are compatible with radical tumor resection in a significant number of these patients. The functional recovery of cranial nerves displaced by these tumors is more remarkable than that following surgery on most other tumors in the region.

FIGURE 4.9  A. T2-weighted sagittal image showing trigeminal schwannoma extending into the extracranial compartment along the mandibular nerve. B. T1-weighted coronal image showing the trigeminal schwannoma extending into the extracranial compartment. The soft tissues are displaced by the tumor.

FIGURE 4.10  Line drawing showing the extradural chordoma (brown) that displaces the internal carotid artery (red) anteriorly/antrolaterally and the nerves of the cavernous sinus (yellow) superiorly.
Craniopharyngiomas

Craniopharyngiomas have been treated by craniotomy for decades (Figs. 4.12 and 4.13). However, recently, several groups recommend an endoscopic approach for such tumors. Presence of infradiaphragmatic craniopharyngioma appears to be a clear indication for a nasal approach. Such tumors have a large extension into the sella that is bloated. However, in the presence of supradiaphragmatic craniopharyngiomas and of a small sella, a transcranial approach may be more suitable. Surgery on craniopharyngiomas continues to be debated. The extent of capsular resection, the need to preserve the pituitary stalk, and the indications of radiation treatment are still debated. The dissection of intracranial intradural tumor and of the arteries of the Circle of Willis from the dome of the tumor is simpler and safer by a transcranial approach than by a nasal endoscopic approach.

FIGURE 4.11
T1-weighted MRI showing the chordoma. The tumor is essentially extradural and displaces the internal carotid artery anteriorly (arrow).

FIGURE 4.12
A. Sagittal contrast-enhanced T1-weighted MRI showing a craniopharyngioma with enlarged sella. The craniopharyngioma in this case is subdiaphragmatic in nature. B. Coronal post-contrast T1-weighted view showing the craniopharyngioma.

FIGURE 4.13
Sagittal contrast-enhanced T1-weighted view of MRI showing a craniopharyngioma with a small sella. The craniopharyngioma is essentially suprasellar in nature.
Sellar and Suprasellar Meningiomas

Tuberculum sellae meningiomas are relatively common and are a formidable surgical problem (Figs. 4.14 to 4.17). They represent approximately 4% to 10% of all intracranial meningiomas. These tumors arise from the region of the tuberculum sellae, chiasmatic sulcus, limbus sphenoidale, and diaphragma sellae and grow in a subchiasmatic location. As with most other cranial base lesions, tuberculum sellae meningiomas have a relatively innocuous clinical presentation despite their commonly large size. The neurologic, visual, and long-term outcomes are determined by the success of the surgical endeavor. The extent of surgical resection will determine tumor recurrence and regrowth. If they are treated properly and in a timely manner, the results of surgery are gratifying and the long-term outcome is extremely good. Conversely, any surgical mishap can lead to a disastrous outcome. Intradural origin and ease of neurovascular dissection make them well suited for a transcranial approach.

**FIGURE 4.14**
Contrast-enhanced T1-weighted coronal MRI showing a suprasellar meningioma.

**FIGURE 4.15**
A. Axial contrast-enhanced T1-weighted MRI of a suprasellar meningioma showing encasement of the internal carotid artery.
B. Coronal contrast-enhanced T1-weighted MRI showing a meningioma having encasement of the anterior cerebral artery.
Nasopharyngeal Angiofibromas

These lesions are primarily extracranial and extradural (Figs. 4.18 and 4.19). In larger lesions, the basal bones are eroded, thinned out, and elevated superiorly. Dural and cavernous sinus involvement is usually in the form of superior elevation and seldom as invasion. The entire cavernous sinus with its contained neural and vascular structures is pushed superiorly by the tumor. This character of the tumor assists in developing a plane between the tumor and basal dura even with blunt dissection. Although transcranial approaches have been described and become popular, an extracranial approach is the rational surgical approach in a vast majority of these cases.
CONTRAINDICATIONS

In general, identification of the correct indication for surgery is crucial for the overall outcome. Surgery is most often done for affecting resolution of symptoms and seldom for correction of radiologic abnormality. When the conduct of surgery is wrought with potential risks that will be more dangerous than the natural course of the disease process, surgery should be avoided. Some patients are physically unable to tolerate the rigors of a long or complex surgery. Finally, certain malignancies may fare better with nonsurgical treatment. Other than these rare situations, there are no contraindications to a transcranial approach.

**CONTRAIINDICATIONS**

In general, identification of the correct indication for surgery is crucial for the overall outcome. Surgery is most often done for affecting resolution of symptoms and seldom for correction of radiologic abnormality. When the conduct of surgery is wrought with potential risks that will be more dangerous than the natural course of the disease process, surgery should be avoided. Some patients are physically unable to tolerate the rigors of a long or complex surgery. Finally, certain malignancies may fare better with nonsurgical treatment. Other than these rare situations, there are no contraindications to a transcranial approach.
PREOPERATIVE PLANNING

The entire surgery should be appropriately planned and executed. The extent of skin incision, bone opening, dural incisions, and strategy for tumor resection and reconstruction must be planned prior to surgery. The better and more effective the preoperative discussion, the better the surgical conduct. The need for preoperative tumor embolization must be evaluated.

With the current sophistication in imaging techniques, surgery is rarely focused on the region, but rather is orchestrated on the basis of the histologic nature of the tumor. Imaging characteristics on CT scanning and MRI demonstrate size of the tumor, extent of cranial nerve involvement, nature of carotid artery displacement and/or encasement, and other such features that are helpful in estimating the consistency and vascularity of the lesion, site of origin, and direction of its spread.

**Estimation of Consistency of the Tumor:** Tumor consistency usually dictates the extent and ease of surgical excision and ultimate outcome. Estimation of consistency of the tumor on the basis of clinical and radiologic features can guide the planning and execution of the operation. Duration of symptoms and the extent of neural involvement provide useful clues. For example, in cases of meningiomas in the region of the anterior clinoid process, the longer the duration of symptoms and worse the visual impairment, the firmer the tumor consistency. Intensities on T1- and T2-weighted images can also provide a reasonable clue about consistency. Hypointensity on T1-weighted and hyperintensity on the T2-weighted images suggest that the tumor is soft. Softer tumors frequently encase the blood vessels and nerves, while firmer varieties will displace these structures. A softer tumor will encase the artery but may not narrow its lumen, whereas when the lumen is narrowed, the tumor is likely to be firm.

**Estimation of Vascularity of the Lesion:** The vascularity of the tumor is an important variable that may decide the course of the operation. Although contrast enhancement is not a firm guide, some idea about the degree of vascularity can be gleaned from the extent of enhancement. Presence of punctate or linear flow voids in and around the tumor on MRI predicts increased vascularity of the tumor and the nature, size, direction, and source of the feeding vessels. Firm tumors are typically less vascular. With firm tumors, delayed films may be more useful, as the contrast takes time to enter into and clear from the tumor. Tumors with extensive adjoining edema are usually more vascular.

**Estimation of Arachnoidal Plane:** Presence or absence of arachnoidal plane around the tumor can usually be seen on a good quality MRI. Rounded or irregular borders of the tumor, tumor bosselations, enhancement of surrounding vessels, and peritumoral edema can provide a clue as to the presence of an arachnoidal plane, which could affect the ability to dissect surrounding structures.

SURGICAL TECHNIQUE

General Considerations in Craniotomy for Sellar/Suprasellar Tumors

**Patient Position:** Patient and head position and the site and size of the scalp incision should be planned meticulously. The principal operating surgeon should personally observe and approve the patient and head position and mark the incision before prepping and draping is allowed. The patient should preferably be placed in a neutral, supine position, as if “sleeping” comfortably, avoiding stretch on any body part. The operating area should be in the superior most part of the field so that the surgeon can operate in a comfortable sitting position without the need for twisting his or her own body or neck. Considerations of adequate venous drainage, and whenever possible necessary provision for an avenue for lumbar CSF drainage, should be made.

**Scalp Incision:** The incision should not only be cosmetically acceptable but should also provide an adequate exposure for the entire lesion in one operative field (Figs. 4.20 to 4.22).

**Anatomical Considerations:** The frontal and temporal branches of the facial nerve, after their course through the lobes of the parotid gland, traverse superiorly over the anterior aspect of the zygomatic arch. The nerve traverses superficially to the superficial layer of the temporalis and masseteric fascia; by remaining deep to these layers, a subperiosteal dissection over the zygomatic arch provides the best chance of preservation of these tiny nerve branches. Subperiosteal exposure of the zygomatic arch should be in a posterior to anterior direction. It is also advisable to avoid using cautery while exposing the zygomatic arch as the heat can result in compromise of neural function. Retraction of the everted scalp with hooks or stitches needs to be gentle and avoid the region of the course of the nerve. While elevating a bifrontal scalp flap, it is preferable to elevate the flap in a subgaleal plane. The thicker the elevated scalp flap, the better is its vascular nourishment and the chance of preservation of thin nerves within the scalp layers.

The incision for pterional exposure should be made posterior to the superficial temporal artery so that the scalp can receive vascular supply from the artery. In situations where there is no danger of compromise of the scalp circulation, an incision taken anterior to the course of the superficial temporal artery and to its anterior branch and posterior to the course of the facial nerve branches over the zygomatic arch may be suitable. Such
FIGURE 4.20
Conventional scalp incision for a frontotemporal craniotomy. The zygomatic bone is shaded to show the area of the osteotomy needed to enhance the basal exposure.

FIGURE 4.21
Relatively small and anterior basal exposure for a pterional craniotomy. The posterior half of the lateral and superior walls of the orbit and the entire lesser wing of the sphenoid bone are removed.
an incision may be about 20 mm anterior to the tragus. The preservation of the entire superficial temporal artery can be crucially important in some instances where there is a possibility of operative trauma to the major middle cerebral artery branch and the need for vascular anastomosis is considered.

**Direction of Approach to the Tumor:** In general, the direction of the approach should be such that the site of origin of the tumor is exposed in the initial phase of the operation rather than the dome of the tumor. This policy holds true not only for meningiomas but also for most other tumors like craniopharyngiomas, pituitary tumors, and chordomas. The dome is the region where the normal neural and vascular tissues are stretched maximally and are liable to be injured. To detach the tumor from the site of origin and debulk it in the direction of the growth provides a better opportunity to preserve the function and integrity of the stretched vessels and nerves.

**Anterior Cranial Base Surgical Approaches:** Subfrontal approaches are used for midline lesions generally located in the sellar and suprasellar areas. Usually, conventional approaches, wherein the craniotomy is placed above the frontal sinus or including its upper half, are adequate for safe and radical resection of these lesions. Unilateral frontal craniotomy can be centered over the lateral aspect of the orbital rim (Fig. 4.23). Such a lateral exposure avoids opening of a large part of the frontal sinus. Retraction of the frontal lobes is usually safe after drainage of CSF from basal subfrontal, chiasmal, and Sylvian cisterns. After such a maneuver, a large space can be obtained for a comfortable dissection in the sellar region. Extensive manipulation of the frontal sinuses and the supraorbital rims may be avoided and should not be performed as a routine. For some lesions, which involve a prolonged microsurgical dissection, anterior cranial basal approaches can be useful. Basal extension of a conventional frontal craniotomy can be done in various ways.

**Basal Extension of a Unilateral Frontal Craniotomy:** A bicoronal scalp flap for performing basal extension of the conventional frontal craniotomy needs to be slightly longer so that an exposure of the orbital rim may be obtained (Figs. 4.23 and 4.24). If the circulation of the forehead is jeopardized (by procedures like radiation treatment or external carotid artery embolization), the flap should include the superficial temporal artery (by making the incision posterior to it) in the exposure. The superficial temporal vessels must also be preserved in the situation where the lesion is in proximity to the internal carotid or middle cerebral arteries, which could be damaged during the surgery. These vessels may be preserved while taking the incision either anterior or posterior to the trunk of the superficial temporal artery. Dissection in appropriate planes and mobilization of the artery can help to increase the exposure while preserving the artery. The supraorbital nerves and vessels must also be preserved. This can be done by careful subperiosteal dissection in the region of the supraorbital rim.

**FIGURE 4.22**
Exposure after bone removal. The orbit, optic nerve, paraclinoid carotid artery, and frontal and temporal lobes are exposed. Surgery in the region of the clinoid process can be carried out with minimal need to retract the brain.
Whenever a foramen is encountered through which these nerves and vessels pass, a small osteotome may be used to open up the foramen. Subperiosteal dissection is continued, and the orbit is exposed, preserving the periorbita. Electric saws can be used to make osteotomies in the superior rim of the orbit. During these maneuvers, the orbital contents and frontal lobes and dura are adequately protected. The roof of the orbit should be cut as posteriorly as possible. One can remove the entire orbital roof lateral to the cribriform plate, or only a partial, supralateral removal may be done, depending on the extent of the exposure needed. The medial osteotomy will
often traverse through the frontal air sinus, and adequate precautions need to be taken to seal it at the end of the operation (Figs. 4.25 and 4.26). This medial osteotomy provides a significantly improved basal exposure without disturbing the sense of smell. The globe can be depressed inferiorly to gain additional exposure. The orbital roof can be removed posteriorly up to the optic canal. The optic nerve can be mobilized if truly necessary. This exposure can significantly limit the extent of frontal lobe retraction.

FIGURE 4.25
View of the skull base from above showing the site of the osteotomy of the roof of the orbit.

FIGURE 4.26
View of the skull base from above after the roof of the orbit is resected.
Basal Extension of a Bifrontal Craniotomy: Fashioning a supraorbital bar craniotomy extension assists in basal extension of the bifrontal craniotomy (Figs. 4.27 to 4.29). However, the need for such additional exposure is only rarely necessary for resection of basal tumors. The surgical technique for a supraorbital bar osteotomy has been elaborately discussed elsewhere.

**FIGURE 4.27** A. Low bifrontal craniotomy. Areas depicted in purple are the supraorbital rims, which will be removed using an oscillating saw. On some occasions, the bifrontal craniotomy can be extended far inferiorly, a procedure that can avoid removal of the supraorbital rims. B. Basal bifrontal craniotomy exposure after removal of the supraorbital rims on both sides. The bone in the region of nasion is not removed.

**FIGURE 4.28** View of the skull base from above after the orbital roofs are removed on both sides. The area of bone in the region of the cribriform plate is preserved.
Preservation of Olfaction in Anterior Cranial Basal Exposure: Unilateral frontal craniotomy and resection of the supraorbital bar following a slight lateral corridor to the planum sphenoidale without elevation of the dura in the region of the cribriform plate can allow preservation of olfaction and provide adequate exposure to the sphenoid sinus, sella, and superior and midclivus in an extradural perspective. Intradural extensions of the lesion can be dealt with after opening the dura and elevating the frontal lobe off the orbital roof. Such a limited approach to midline lesions is satisfactory in most cases for large parasellar lesions where transsphenoidal approaches are considered to be unsuitable. Bilateral exposure leaving both cribriform plates undisturbed can be performed if needed. A larger exposure may be required for malignant tumors where radical en bloc excisions are indicated.

Keyhole Approaches: Advances in microsurgical techniques have led to reduction in the extent of surgical incisions and the successful application of keyhole approaches. These approaches should be employed only if they do not compromise the extent of tumor removal or patient safety with respect to neurovascular control. For lesions in the sellar and parasellar areas where a pterional approach may be selected, extensive temporal or frontal lobe exposure may be unnecessary. If so, the incision can be moved anteriorly toward the lesser sphenoid wing or even to the eyebrow. The basal extension of the approach can be obtained by removing the entire lesser wing and part of the roof and lateral wall of the orbit (Fig. 4.22). This keyhole approach can provide a basal view to the lesion and also avoids unnecessary and avoidable scalp incision or bone removal.

Considerations in Cranial Approach to Sellar/Suprasellar Meningiomas

In the majority of patients with suprasellar meningiomas, a basal unifrontal craniotomy is performed on the side of worse vision (Figs. 4.14 to 4.17). The patient is placed in the supine position with the head extended. The craniotomy extends to the orbital roof inferiorly. A more lateral basal frontal approach is usually necessary and avoids the frontal sinus though the sinus should be opened when needed to achieve adequate basal exposure. The frontal lobe is dissected from the orbital roof, and all attempts are made to preserve the olfactory tract. The medial part of the Sylvian fissure is opened to drain CSF and relax the brain. The tumor is then exposed, and the optic nerves and internal carotid arteries are identified whenever possible. The tumor is progressively disconnected from the site of dural attachment. Space for basal dissection and coagulation is obtained by tumor debulking, avoiding the optic nerves, anterior cerebral arteries, anterior communicating artery, and pituitary stalk. The optic nerves and anterior cerebral arteries should be identified early in the course of dissection. Radical removal of all tumors is attempted, but if the dissection of tumor from the anterior cerebral arteries and internal carotid artery entails undue risk of damage, that portion of the tumor is left behind. Some surgeons...
prefer to open the optic canal early in the operation to resect the portion that extended into it. However, we prefer to open the canal after the majority of the suprasellar tumor is resected. This provides the ability to observe the canalicular extension directly and allows more space for drilling the canal under direct vision. The site of tumor attachment to the dura is widely coagulated, and the part of the dura grossly involved by tumor is resected. No special attempt is made to remove the bony hyperostosis unless it interferes with visualization. Various authors have advocated resection of the involved dura and bone in patients with meningiomas. However, the possibility of CSF leakage and consequent problems led us to adopt a relatively conservative approach. The skull base is reconstructed, and the open frontal sinuses are separated from the intracranial space with vascularized pericranial and galeal flaps.

The degree of surgical exposure in each patient in our suprasellar meningioma series did not correlate with the extent of basal tumor involvement. Frontobasal craniotomy on the side of the more severe visual deficit was appropriate even for more extensive tumors. There was no need to section the anterior part of the superior sagittal sinus or perform a dissection in the interhemispheric region in any patient. A unifrontal approach is superior to pterional exposure in that it provides wide, symmetric exposure and direct access to both internal carotid arteries. It has the advantage over a bifrontal exposure of avoiding handling of and potential damage to the contralateral olfactory tract.

The difficulty in surgically excising a tuberculum sellae meningioma stems from its relationship to the optic nerves and chiasm and to the anterior cerebral and internal carotid arteries and their perforators, which are frequently encased and/or displaced. The success of surgical resection hinges on the preservation of these vessels. Despite en캠ase of the internal carotid artery seen on MRI, it is often observed that tumor lobulations engulf the artery, and the dissection is relatively simple. All of our patients who worsened after the operation had intraoperative damage to the anterior cerebral artery or its large perforator branch, making early identification of the anterior cerebral artery critical. The arterial supply of these tumors usually comes from the ethmoidal arteries. Rarely, small branches of the anterior cerebral artery can also contribute to the vascular supply. Also, the arterial wall in the vicinity of the tumor can be thinned out and can even have an aneurysmal dilation. In case of damage, an immediate Anastomosis should be carried out, though this procedure is difficult given the nature and size of the involved artery.

Considerations in Surgery for Trigeminal Schwannomas

The dura is relatively separate from the gasserian ganglion in the region of Meckel’s cave, and normally, there is a large subarachnoid space in the region. Anterior to the gasserian ganglion, the dura is adherent to the divisions of the nerve and then continuous with their epineurium. Adhesion of the dura is more firm to the first division than the second and third. Schwannomas usually arise in the region of the gasserian ganglion, and the growing tumor can be accommodated within the confines of Meckel’s cave, which becomes distended. Anterior extension along the mandibular branch into the infratemporal fossa is rare, probably due to natural adhesions of the dura and the nerve. The intracavernous carotid artery is displaced medially and the petrous carotid artery inferiorly by the tumor. As a result, working within the dural boundaries is relatively safe and effective. There is seldom any need to have proximal arterial control for tumor excision in these cases. In addition, the outer dural sheath of the gasserian ganglion can be opened without exposing the temporal lobe. Therefore, trigeminal schwannomas can be resected using a relatively small exposure if the dural wall and its relationship to the tumor is understood and respected.

The extracranial portion of the tumor follows the divisions of the trigeminal nerve, and despite the fact that some of the extensions of the tumor can become large, the tumor remains within the confines of the perineural layer (extension of the dural layer) of the divisions. These tumors never encase any major blood vessel or cranial nerve in the infratemporal fossa or in the orbit. As a result, a “reverse skull base approach” that involves a limited “transcranial” extradural avenue can be used to resect the majority of tumors. The surgical strategy is to perform a small basal temporal craniotomy, resect the floor of the middle cranial fossa, and expose both the middle cranial fossa and the infratemporal fossa components in the same exposure. Depending on the nature and extension of the tumor, the basal temporal craniotomy can incorporate drilling of the root of the zygoma, roof of the mandibular condyle, and roof of the external ear canal and partial mastoidectomy up to the mastoid antrum as needed. As the temporalis muscle and the other muscles of the infratemporal fossa are atrophied in most cases, their retraction is relatively straightforward. The temporalis muscle can be retracted anteriorly, posteriorly, and inferiorly or be split into two parts for exposure. Addition of a zygomatic osteotomy provides significant additional space for muscle retraction. When there is orbital involvement, a lateral orbitotomy is performed and the bone over the lateral aspect of the superior orbital fissure is widely resected to expose both the orbital and middle fossa components of the tumor in the same surgical field. Dural incision is then made in the outer wall of the tumor and the tumor debulked taking care not to violate the deep layer of dura, which forms a firm protective layer over the carotid artery and cranial nerves. The tumor does not involve all the fibers of the nerve. Some fibers are invariably spared and can usually be preserved. Working within the tumor, using blunt dissection with the help of suction or Caviton ultrasonic surgical aspirator (CUSA), and avoiding coagulation as much as possible can avoid injury to these fibers.

After resection of both the middle fossa and the extracranial components of the tumor, wide exposure of the posterior cranial fossa portion is also possible through this exposure. Lateral and superior dissection...
provides exposure of the tumor, temporal lobe, brainstem, and petrous carotid artery simultaneously in the surgical field allowing dissection of the tumor from these structures under direct vision and control. Moreover, these structures are closer in the surgical field when compared to most other available surgical approaches.

This type of transcranial approach is suitable to resect schwannomas and many other parasellar tumors. Intraoperative lumbar drainage is used to relax the brain, and its superior retraction provides additional exposure to the infratemporal fossa and even any orbital component of the tumor. Maintaining and working outside the middle fossa dura adds protection to the temporal lobe. The strategy of retraction of the brain to expose an extracranial tumor, although against the principles of skull base surgery, in this case can provide an easy, quick, and wide access to the entire tumor. In anterior transfacial and anterolateral approaches, such an elaborate and simultaneous exposure may not be possible.

**POSTOPERATIVE MANAGEMENT**

Patients are observed in the ICU in the initial postoperative period. Anticonvulsants are generally used prophylactically for any transcranial approach. The dressing needs to be kept dry until the sutures are removed. Appropriate antibiotic prophylaxis based on personal preferences and experience is used. If cerebral edema and neural manipulation are concerns, perioperative steroids can be used.

**COMPLICATIONS**

All the potential avoidable complications are a result of either inappropriate planning or less than optimal performance of the surgical procedure. The initial complication is when poor selection of a surgical candidate is made. When selecting a patient for surgery, the only consideration is the need of the patient. Although the physical presence of the tumor is sometimes a consideration, surgery is generally done for symptoms.

For ultimate avoidance of complications, the entire operation, including reconstruction, has to be planned carefully to be successfully executed.

*Dealing with Air Sinuses:* The paranasal sinuses are practically sterile but potentially infective spaces as they may contain commensal organisms. The sinuses ultimately communicate with the nasal cavity, and opening the sinuses during intracranial surgery provides communication between the intracranial compartment and the nose. Opening of these sinuses should be avoided as much as possible, but the frontal sinuses are frequently opened during basal frontal exposures. When this occurs, it is critical that the communication with the sinus be adequately sealed. The frontal sinus communicates with the nose through the frontonasal duct, which can be packed with a small bone strut. If the duct is sealed, residual mucosa in the excluded sinus must be removed as it can lead to collection of secretions and formation of a mucocele or a pyocele and can invite ascending infection. Ideally, the sinus should be packed with a vascularized pedicled flap obtained either from the pericranium or galea.

Stroke and visual compromise remain the major complications associated with suprasellar or parasellar surgery. Visual compromise can result from optic nerve injury, hypoperfusion, or cranial nerve manipulation. Stroke is usually avoidable, but the risk depends on the adherence of the tumor to the involved artery.

**RESULTS**

The results of craniotomic approaches to the supra- and parasellar regions are well described in the literature and remain the gold standard. Maintenance of these results requires careful selection of indication and surgical route and care to conduct safe and effective surgery. The expected result of surgery depends on the type of tumor in question. In general, surgery for pituitary and other suprasellar tumors results in excellent symptomatic recovery. Radical resection is the aim for each tumor, but this may need to be tempered, and patient safety should always be the highest priority.

Cranial approaches to suprasellar tumors need to be tailored to anatomical and physical characteristics of the tumor that vary with the pathology. Understanding of the growth pattern of the tumor and its relationship with the meninges forms the basis of approach selection and guides the surgery.

**PEARLS**

- The basal meningeal divide determines the direction of surgical approach; tumors above the divide need a transcranial approach, and those below the divide need a transnasal or facial approach. The endoscope is an invaluable tool for nasal approaches to skull base lesions.
- Pituitary tumors have a well-defined dural relationship. Even massive pituitary tumors can be approached by a transnasal route if the dural relationships of these tumors are adequately understood.
In the middle cranial fossa, trigeminal schwannomas are located within the dural confines of the lateral wall of the cavernous sinus or are interdural in location. The surgical exposure can be minimized if the dural relationship is appropriately understood.

Chordomas grow by destruction of bone and by displacement of soft tissues that include cranial nerves and blood vessels.

Nasopharyngeal angiofibromas are generally extradural and extracranial tumors.

Suprasellar meningiomas are above the meningeal divide and therefore best removed by transcranial surgery.

Infra diaphragmatic craniopharyngiomas are best suited for the endoscopic endonasal approach, whereas all others are above the meningeal divide.

**PITFALLS**

- The course of the frontal branch of the facial nerve should be understood and carefully protected during frontotemporal exposure to avoid palsy.
- Knowledge of and preservation of perforating branches at the base of the skull is critical for avoiding vision loss and other neurologic injury.
- Arterial tumor involvement should be identified pre- and intraoperatively to avoid injury. When thinning of the artery is present, this should be identified at the time of surgery and repaired if possible.
- The paranasal sinuses must be properly sealed and excluded mucosa removed to avoid mucocele, CSF leak, or infection.

**INSTRUMENTS TO HAVE AVAILABLE**

- Standard microneurosurgical tools
- High-speed drill
- Surgical microscope

**SUGGESTED READING**


INTRODUCTION

Approaches to the anterior skull base have evolved radically over the past three decades. With dramatic technologic innovations in neuroendoscopy, endoscopic endonasal approaches (EEAs) to the anterior skull base have emerged as a viable and less invasive alternative to open transcranial or transfacial approaches. While endonasal approaches to the sella have been successfully performed for decades with microscopic visualization, endoscopy offers several advantages, including improved up-close visualization, superior illumination, and the option to use an angled line of sight. This final advantage allows surgeons to visualize and operate in regions beyond the straight line of sight provided by the operating microscope.

One such region is the medial cavernous sinus. Due to its association with numerous critical neurovascular structures, the cavernous sinus continues to present serious surgical challenges. Nevertheless, with the use of an angled endoscope in experienced hands, selected lesions of the medial cavernous sinus can now be addressed safely through the endonasal corridor. This approach relies exclusively on the endoscope for visualization. Therefore, familiarity with endoscopic-controlled endonasal surgery with angled endoscopes is a prerequisite to performing this approach.

HISTORY

There are two lines of questioning that are important when evaluating a patient for an EEA to the cavernous sinus. Firstly, it is important to ascertain if the patient has had previous surgery or sinus pathology that may complicate the approach. Previous surgery may have exposed the carotid artery, optic nerve, or pituitary gland. Previous pathology, such as sinusitis, or procedures, such as rhinoplasty, may have vital bearing on the preferred surgical corridors. Secondly, preoperative documentation of cranial neuropathies may give some indication of the pathology of the lesion and location. For example, if there is significant facial dysesthesia, then the lateral wall of the cavernous sinus is likely involved. Given the close proximity of the optic nerves and pituitary gland, visual function may be affected.

PHYSICAL EXAMINATION

Preoperative nasal endoscopy will yield important information about which nostril to use, the potential mucosal flaps that may need to be elevated, and the presence or absence of infection. A complete neurologic examination should focus on cranial nerves II to VII. Preoperative formal visual field examination and endocrinology consultation are mandatory.
INDICATIONS

Lesions of the cavernous sinus are notoriously challenging to treat. The indications for treatment depend upon several factors. These include the location and size of the lesion, suspected pathology, need for tissue for diagnosis, growth patterns of the lesion, compression of surrounding neurovascular structures, symptoms, and preexisting cranial nerve deficits. The three most common pathologies encountered in the medial cavernous sinus are meningiomas, pituitary adenomas, and schwannomas.

In general, the surgical treatment of cavernous sinus meningiomas is associated with a high rate of cranial nerve palsies when the cavernous sinus is entered surgically. For this reason, many surgeons reserve surgery for growing or symptomatic cavernous sinus meningiomas and only remove the extracavernous portion of the tumor. In general, I agree with this conservative approach for suspected cavernous sinus meningiomas, especially those that are asymptomatic, stable in size, and with a significant intracavernous portion. At the same time, in cases where the medial cavernous sinus is involved, the endonasal corridor is well suited to biopsy, debulking, and possible gross total resection if the degree of intracavernous involvement is limited. Because meningiomas of the cavernous sinus tend to surround the carotid artery and adjacent cranial nerves, complete removal is generally not advisable if a substantial degree of intracavernous involvement exists.

In contrast to meningiomas, pituitary adenomas are usually amenable to surgical treatment even when they invade the cavernous sinus. The typical soft consistency and medial-to-lateral spread (from the pituitary gland outward) of these lesions make the endonasal corridor an ideal approach for addressing pituitary adenomas with cavernous sinus extension. An advantage of this pattern of growth is that the carotid artery and cranial nerves are typically displaced laterally by the tumor. In such cases, the tumor plane offers a safe surgical corridor into the medial cavernous sinus, and a soft, “suckable” adenoma can be removed with much less risk to neurovascular structures.

The indications for an EEA to the medial cavernous sinus include a lesion that is localized to the medial wall of the cavernous sinus or one that has grown in a medial-to-lateral fashion to displace the carotid artery laterally. Other anatomic features that must be considered prior to selecting this approach include the degree of pneumatization of the sphenoid sinus, the presence of intradural spread or subpial invasion by the tumor, and the position of cranial nerves III through VI. The ideal conditions for an EEA to the medial cavernous sinus include a large pneumatized sphenoid sinus, an entirely extraaxial pathology, and lateral displacement of all cavernous sinus neurovascular structures. A crucial tenet of this approach is that the angled endoscope offers a direct view of the medial wall of the cavernous sinus that is not achievable with standard microscopic visualization. Thus, familiarity with the nuances of endoscopic-controlled surgery is required when planning to address this region via the endonasal corridor.

In summary, indications for the EEA to the medial cavernous sinus include:

- Lesions based on the medial wall of the cavernous sinus
- Medial-to-lateral extension of a pituitary adenoma
- Lateral displacement of the carotid artery and cranial nerves

Another approach to the cavernous sinus is a paramedian, transmaxillary approach that involves expert knowledge and familiarity with the structures within the pterygopalatine fossa. This approach is mostly used to remove lesions of the lateral cavernous sinus but may be used with medial lesions and as such will be discussed below in some detail.

CONTRAINDICATIONS

The primary contraindications to this approach reflect anatomic constraints that would place the carotid artery and cranial nerves at high risk. Lesions based within the cavernous sinus, which encase the carotid artery and cranial nerves or displace them medially, are not well suited to an endonasal approach. An asymptomatic benign meningioma with such characteristics may best be observed rather than treated surgically. Other lesions with significant involvement of the surrounding neurovascular structures whose diagnosis is unclear may best be treated with a biopsy rather than complete removal. The goal of treatment for any cavernous sinus lesion involves a thoughtful analysis of the need for complete removal and the degree of risk of neurovascular injury that is justified. Finally, the presence of active sinus infection is a relative contraindication to surgery. Of course, if the operation is considered urgent, it may be done under antibiotic coverage, especially as most lesions are extracranial. If there is no urgency, then time should be spent treating the active infection in the sinuses. As mentioned previously, the endonasal approach to the medial cavernous sinus relies on angled endoscopic visualization. Therefore, lack of familiarity with endoscopic techniques is a contraindication to this approach.

Common contraindications to this approach include the following:

- Encasement of the neurovascular structures in the cavernous sinus
- Medial displacement of the carotid artery and cranial nerves
- Lack of familiarity with endoscopic-controlled techniques
PREOPERATIVE PLANNING

Prior to surgery, a careful review of all pertinent imaging is mandatory. This includes a preoperative MRI, preferably one with thin coronal cuts through the pituitary fossa and adjacent cavernous sinus. The location and extent of the lesion of interest should be assessed, in addition to possible involvement or displacement of surrounding neurovascular structures. These include the carotid arteries, the optic nerves, the pituitary gland and stalk, and the cranial nerves of the cavernous sinus. Normal anatomy should be carefully evaluated. An assessment of the position of the carotid arteries is critical. The flow voids of the carotid arteries are readily noticed on T2-weighted sequences. Special consideration should be taken to assess the position and medial extent of the cavernous portion of the carotid arteries, which may approach the midline in up to 8% of patients. The extent of cavernous sinus involvement by the tumor should be assessed, in addition to the pattern of displacement of all cavernous sinus neurovascular structures.

A CT scan provides an excellent overview of the bony anatomy. An MRI may also provide invaluable anatomical information and is used by many instead of CT. The size and position of the sphenoid sinus as well as the presence and location of septations within the sinus should be noted. Importantly, many sphenoid sinus septations are not in the midline and are often based over one of the carotid protuberances laterally. Lesions that involve the sella demand a full preoperative endocrinologic workup. Likewise, formal visual field testing is necessary for lesions compressing the optic nerves, even in the absence of frank visual complaints. Before surgery, patients should be counseled regarding the risk of nasal deformity, CSF leak, endocrine disturbances, and injury to the carotid artery and cranial nerves.

SURGICAL TECHNIQUE (VIDEO 5.1)

The endonasal approach to the medial cavernous sinus is an endoscopic-controlled technique, meaning that all operative visualization relies on the endoscope and surgical instruments are manipulated outside of the endoscope, but in its field of view. This is in contrast to endoscopic-assisted surgery, where an endoscope is temporarily introduced to inspect a surgical field following a standard microscopic approach, or purely endoscopic surgery, where all instruments are manipulated through a working channel attached to the endoscope. I prefer high-definition endoscopes offering 0, 30, and rarely 70 degrees of angled viewing. While bayoneted instruments are useful in microsurgery because they prevent the surgeon’s hand from blocking the microscope’s line of sight, they are unnecessary and even detrimental in EEs. Bayoneted instruments quickly crowd the working area of the surgeon’s and assistant’s hands, and attempts to rotate bayoneted instruments may cause the surgeon’s hand to bump the endoscope. For this reason, straight endonasal instruments should be used. Angled non-bayoneted instruments, such as the angled bipolar and suction, allow the surgeon to access lateral structures when viewed with a 30-degree endoscope. Also, the use of multifunctional “hybrid” instruments greatly improves the efficiency of the EEA by allowing an instrument in one hand to perform multiple functions. Examples include suction bipolar, debriders with built-in irrigation and suction, and some instruments with multiple functions including suction, irrigation, bipolar, and tissue ablation. For the endonasal approach, I prefer a two-surgeon method where one surgeon holds and guides the endoscope, allowing the operating surgeon bimanual control of all endonasal instrumentation. In addition, collaboration with an experienced otolaryngologist is critical in optimizing the safety and efficacy of the approach.

Because the endonasal approach involves multiple surgeons and a diverse array of equipment, including high-definition endoscopes and monitors, an image-guidance system, and specialized endonasal instrumentation, the proper setup of the operating room is critical in optimizing the flow of the procedure. The high-definition monitor is positioned behind the head of the bed, allowing the surgeon to look directly at the image while maintaining a natural ergonomic operating stance. The image-guidance system is placed just to the side of the monitor, also at the head of the bed. Both surgeons are positioned to the right of the supine patient, while the scrub nurse is positioned to the left of the patient. This allows the nurse and surgeon to efficiently transfer instruments without the surgeon turning from the monitor. The anesthesiologist is positioned toward the foot of the bed on the patient’s left side.

The patient is positioned in the supine position. The abdomen is prepped and draped in preparation for harvesting adipose tissue, muscle, or fascia. The head is fixed in a Mayfield holder, extended and turned laterally so that the surgeon has a direct view through the nares. The frameless image-guidance system is registered and confirmed. Frameless stereotaxy is used to confirm the surgical trajectory, to assess normal anatomic landmarks during the operation, and to identify structures that should be avoided during the course of surgery.

The patient’s nose is prepared with Cottonoid strips soaked in 1:2,000 adrenaline. After a few minutes, the strips are removed and the middle turbinate and septal mucosa are infiltrated with 1% bupivacaine with 1:100,000 adrenaline. In general, I prefer a two-nostril two-surgeon approach. The lower half of the middle turbinate is resected or in some circumstances simply displaced laterally. If intradural extension of the tumor is suspected, a vascularized nasoseptal flap is prepared. This flap is elevated from the nasal septum based on a pedicle containing the posterior septal artery. A partial posterior septectomy is made, and both sphenoid ostia are identified. Using a combination of Kerrison rongeurs, high-speed drill, and endonasal debrider,
a wide bilateral sphenoidotomy is performed. The sphenoid sinus is entered, and after careful removal of sinus septations, the relevant anatomy is inspected, including the carotid and optic prominences, the medial and lateral opticocarotid recesses, and the sella. Image guidance and ultrasound Doppler can be useful adjuncts in identifying the at risk anatomic structures. The surgeon should be aware of possible bony dehisence over the carotid arteries. The position of the carotid arteries can be confirmed with image guidance or ultrasound. In cases where large tumors distort the surrounding anatomy, image guidance is indispensable.

Once within the sphenoid sinus, the bony opening depends on the size and location of the lesion of interest. For pituitary adenomas with lateral extension into the cavernous sinus, the floor of the sella is first removed, followed by extension of the bony opening to the lateral wall of the sphenoid sinus. The position of the carotid artery must be carefully assessed prior to drilling laterally. Adenomas, which displace the carotid artery laterally, create a zone of safety for drilling of the lateral wall of the sphenoid sinus. This maneuver and all subsequent work performed laterally are enhanced with the use of an angled endoscope and angled instruments to provide good visualization of the lateral wall and medial cavernous sinus. Depending on the location of the lesion and the trajectory offered by the nasal sinuses, the use of the contralateral nostril may offer a more direct approach to the ipsilateral wall of the medial cavernous sinus. Once the lateral wall of the sphenoid sinus is removed, the medial cavernous sinus is visible and the pathology of interest is addressed. Often, a natural cleavage plane may be exploited on the outer margin of the tumor. Respecting this plane during surgery significantly reduces the risk of injury to the neurovascular structures of the cavernous sinus. In the case of pituitary adenomas, entrance into the cavernous sinus may be achieved by using the natural fenestration(s) that exists between the pituitary fossa and the sinus, usually behind the anterior genu of the carotid artery. If there are no windows into the sinus, then direct access through the anterior face of the cavernous sinus may be performed safely using frameless stereotactic guidance and intraoperative Doppler ultrasound to ensure that the anterior loop of the intracavernous carotid artery is not inadvertently damaged. Bleeding from the cavernous sinus is usually minimal. However, once the tumor has been removed, the sinus may reopen and bleeding may be copious. The first thing to remember about venous bleeding is that it is readily controlled. Therefore, do not panic. The initial maneuver is to elevate the head of the bed. This simple step is sometimes enough to control the hemorrhage. The next maneuver is to inject hemostatic agents such as Floseal (Baxter) or Surgiflo (Johnson and Johnson) directly into the sinus and then cover this with a Cottonoid and apply gentle pressure. If hemostatic agents are not available, then compressive agents such as Gelfoam and Surgicel may be used. In the case of other lesions such as schwannomas and meningiomas, this more direct approach is augmented by a transmaxillary dissection. Instead of lateralizing the turbinate, this is medialized and the hiatus semilunaris is identified and used as a landmark to gain entry into the maxillary sinus. Once the medial wall of the maxillary sinus is opened, the lateral part of the face of the sphenoid sinus is opened, lateral to the ostium. To gain more exposure inferiorly and to identify the V2 branch of the trigeminal nerve, the posterior wall of the maxillary sinus may be removed. This will reveal the contents of the pterygopalatine fossa. Once the lesion has been addressed, a careful closure is of utmost importance. I prefer a layered reconstruction of the sphenoid sinus, with use of an abdominal adipose tissue graft and/or vascularized nasal septal flap if CSF is encountered during the operation. The basic tenets of closure include the following:

- A multilayered closure is superior to a single layer.
- A vascularized graft is superior to a nonvascularized one.
- An autologous graft is superior to a synthetic graft.
- Counter pressure may be applied via an intranasal balloon or nasal packing.
- Glue or dural sealant is a useful adjunct to seal the defect.
- Routine lumbar drainage is discouraged although single lumbar puncture serves to reduce CSF pressure immediately and for several days after surgery. CSF will continue to leak out of the dural hole into the epidural space, acting as a temporary “escape valve.”

**POSTOPERATIVE MANAGEMENT**

The endonasal approach to the medial cavernous sinus is, in general, associated with less morbidity and shorter hospital stays than open cranial approaches to this region. Postoperative evaluation of pituitary function is essential for lesions involving the pituitary gland or stalk. All patients should be assessed for a possible CSF leak. In the absence of endocrine dysfunction or CSF leak, most patients are discharged home within 48 hours of surgery. I typically do not use lumbar drainage to prevent a CSF leak, as appropriate skull base reconstruction is the mainstay of avoidance of a CSF leak.

**COMPLICATIONS**

Potential complications of the endonasal approach to the medial cavernous sinus include the following:

- CSF leak/meningitis
- Pituitary dysfunction
CHAPTER 5  Endoscopic Endonasal Approach to the Medial Cavernous Sinus

- Visual loss
- Ophthalmoplegia
- Injury to the carotid artery
- Approach morbidity such as synechia, poor humidification, and sinus ostia obstruction

RESULTS

Between 2006 and 2010, I have treated 160 pituitary adenomas. Of the 160 cases, 22 were recurrent tumors, 76 lesions were endocrinologically active, and 34 lesions extended laterally into the cavernous sinus. Using an endoscopic-controlled technique, without an operating microscope, I achieved a 78% cure rate for active tumors (defined as gross total resection and biochemical remission) and an 88% cure rate for inactive tumors (defined as gross total resection). In a logistic regression analysis, cavernous sinus invasion was not a negative predictor of cure. These results demonstrate that an excellent outcome is achievable using the EEA for pituitary adenomas regardless of extension into the cavernous sinus (Fig. 5.1). For appropriately selected cases, cavernous sinus involvement should not be considered a contraindication to curative surgery.

PEARLS

- The angled endoscope and angled instruments are essential to visualize and reach the medial cavernous sinus from a midline transsphenoidal approach. Conversely, 0-degree scope and straight instruments are used for the more lateral transmaxillary approach.
- Special consideration of the position of the contents of the cavernous sinus is critical. The ideal lesion for this approach displaces the carotid artery and cranial nerves in a medial-to-lateral fashion.
- The texture and consistency of tumors dictates the ease and safety of removal. Soft pituitary adenomas may be completely removed from the cavernous sinus with gentle suction, whereas radical resection of fibrous meningiomas may not be possible.
- Venous bleeding should be expected and is generally easily controlled by head-up positioning of the patient, hemostatic agents, and gentle pressure.
- The surgeon should be aware of possible dehiscent bone over the cavernous carotid arteries.

**FIGURE 5.1**  A–F. Preoperative (A,C,E) and postoperative (B,D,F) MRI of a patient with a prolactin-secreting pituitary macroadenoma extending laterally into the right cavernous sinus. The preoperative images demonstrate the extent of the tumor and the lateral displacement of the cavernous portion of the internal carotid artery (arrow). Given the size of the tumor and lack of response to medical treatment, the patient underwent a midline EEA. After removal of a portion of the lateral sphenoid sinus wall, medial to the ICA, the medial wall of the cavernous sinus was entered. The tumor was removed with angled instruments under visualization with a 30-degree-angled endoscope. The postoperative MRI demonstrates an excellent resection. The abdominal adipose tissue graft is demonstrated in the sphenoid sinus (asterisk). Following surgery, the patient's prolactin level returned to well within normal range, indicating a biochemical cure.
When operating under endoscopic visualization, the surgeon should be cognizant of more superficial structures out of the view of the scope that may be restricting the operative corridor and limiting surgical freedom.

A 2-surgeon, 3- or 4-handed approach allows the surgeon to employ standard bimanual microsurgical techniques. This requires an assistant to hold and guide the endoscope.

Meticulous and durable reconstruction is absolutely essential to avoid CSF leak.

**PITFALLS**

- **Vascular injury.** The most feared vascular complication is injury to one of the carotid arteries. This may be avoided by proper planning and recognition of the position of the cavernous carotids on preoperative imaging. The surgeon should be wary of possible dehiscent bone over the carotid prominences when drilling in the sphenoid sinus. In addition, firm and fibrous tumors should not be pulled from the cavernous sinus without first carefully and completely dissecting the lesion from surrounding structures. When operating within the cavernous sinus, “blind” pulling of tumor from a region beyond the view of the endoscope should be avoided. If injury to the carotid artery occurs, the technique that appears to be most effective is direct packing with macerated muscle obtained from the patient’s abdominal wall or temporalis muscle.
Inadequate visualization. The midline endonasal approach to the medial cavernous sinus relies on an angled line of sight; therefore, the use of angled endoscopes and instruments is essential to visualize the region of interest.

CSF leak. Meticulous layered skull base reconstruction is essential to avoid the most common complication of this approach, which is CSF leak.

INSTRUMENTS TO HAVE AVAILABLE

- Endoscopic shaver
- Endonasal drill with cutting and diamond bits
- Micro–Doppler ultrasound with malleable probe
- Selection of ring curettes
- Angled suctions with smooth atraumatic tips
- Endonasal bipolar forceps

SUGGESTED READING


INTRODUCTION

The traditional approach to midline anterior intracranial skull base lesions such as pituitary macroadenomas, meningiomas, and craniopharyngiomas has been through a craniotomy. Although results with craniotomy in experienced hands have generally been satisfactory, a less invasive and strictly midline approach has the potential advantages of less brain retraction, the ability to devascularize the tumor from below, and the avoidance of inadvertent damage to the optic nerves and optic chiasm.

The evolution of the transsphenoidal approach to the anterior skull base has been a major contribution in the development of neurosurgery. Building on the revelation that transsphenoidal microsurgery could deal with pituitary lesions in a highly effective manner, technologic advances and conceptual advances together have allowed us to extend our surgical skills beyond the sella and into the suprasellar space (Fig. 6.1). Critical to this advance has been introduction of the operating endoscope, image guidance, and the maintenance of the basic principles of skull base surgery including the use of microneurosurgical technique.

HISTORY

Suprasellar tumors can present with a wide range of symptoms, from vision loss, to mental changes from secondary hydrocephalus, to pituitary hormonal abnormalities. For example, a typical adult patient with a craniopharyngioma may or may not have normal visual function but also may have headache, memory difficulties, fatigue, and mild sexual dysfunction. They will usually not have symptoms of diabetes insipidus.

PHYSICAL EXAMINATION

The physical examination in patients with suprasellar lesions concentrates on disorders of pituitary function and physiology and on abnormalities related to visual function. If the lesion has produced hypopituitarism from compression of the normal gland, physical signs may be those of pallor, generalized weakness, and changes in the texture of the skin. There may be associated cognitive deficits and occasional psychological disturbances.

The visual field examination may reveal a typical bitemporal hemianopsia, decreased visual acuity, enlargement of the physiologic blind spot, or scotomas. These findings may be quite subtle in the early stages of compression of the optic nerves and chiasm. Ocular computed tomography may be useful, as it can demonstrate the thinning of the retinal fiber layer that accompanies chiasmal compression.
INDICATIONS

Ordinarily, the major indication for surgery is progressive visual loss. Patients may also have intractable headache, pituitary hormonal failure (hypopituitarism), mental or memory changes from compression of the hypothalamus, or hydrocephalus, usually from obstruction of the foramina of Monro.

CONTRAINDICATIONS

The relative contraindications to the endoscopic endonasal transsphenoidal microsurgical approach to the suprasellar space are dependent upon the anatomy of the lesion and the anatomy of the skull base. If the sella turcica is small and the lesion is primarily suprasellar, the limiting factors of exposure are the distances between the cavernous carotid arteries and the optic canals. If these are narrow, and not expanded by the lesion, maneuverability may be compromised. More importantly, if the lesion engulfs arteries of the circle of Willis, or if it extends into the lateral optic canals intracranially, then a craniotomy approach may be a wiser strategy. These assessments depend upon neuroradiologic imaging with MRI and CT scans, which are essential to the preoperative planning. The position of the optic chiasm in relation to the sella and the lesion is often a major determinant of the surgical approach. The endoscopic transsphenoidal approach is best suited to the removal of retrochiasmatic lesions as the chiasm and optic nerves do not need to be displaced to expose the lesion.

PREOPERATIVE PLANNING

The majority of the preoperative planning should include a complete endocrine laboratory evaluation and extensive, sophisticated imaging studies. The endocrine evaluation includes measurement of serum levels of the primary hormones of the anterior pituitary and assessment of the patient for diabetes insipidus. It is imperative to normalize any preexisting hormonal deficits and to use perioperative corticosteroids to protect the patient and his/her vision when necessary. A high-resolution pituitary-centered MRI study should be performed to evaluate the lesion and the anatomic distortions produced by it. The position of the optic nerves, optic chiasm, and
optic tracts should be carefully evaluated with imaging, as well as the relationship of the dorsal aspect of the tumor to the ventricular system. The sella itself can be enlarged, providing a natural pathway for the extended transsphenoidal approach. A CT scan should also be done to evaluate the presence of calcifications within a suprasellar tumor. An MRI may be adequate for the evaluation of the vessels of the circle of Willis and their tributaries. If not, image guidance using high-resolution CT angiography can be incorporated into the surgical planning and the operative procedure.

SurGICAL TECHNIQUE (video 6.1)

The image-guidance system is calibrated and used to determine the trajectory of approach and the important anatomic landmarks.

Ideally, a nasal septal flap (see Chapter 42) based posteriorly upon the sphenopalatine artery is raised and placed in the nasopharynx safely away from the operative pathway, without kinking its blood supply. This is an important step for craniopharyngiomas and other lesions where a large intraoperative cerebrospinal fluid (CSF) leak is created.

Through the right and left nostrils, using the operating endoscope, the ostia of the sphenoid sinus are identified by gently laterally displacing the middle and superior turbinates. In my experience, it is rarely necessary to resect a turbinate in order to achieve satisfactory exposure for midline lesions.

The mucosa around the ostia is cauterized, and the ostia are enlarged using bone punches. After a submucosal injection of Xylocaine and epinephrine, the mucous membrane over the posterior septum is incised and a submucosal flap can be raised to expose the vomer. Using a Cottle elevator, the posterior nasal septum is crossed and the mucosa over the anterior wall of the sphenoid sinus on the opposite side is elevated. Careful dissection will mobilize the mucosa away from the inferior aspect of the anterior wall of the sphenoid sinus, diligently protecting the sphenopalatine arteries. The mucosa posteriorly can be resected using a microdebrider.

The anterior wall of the sphenoid sinus is then removed with appropriate bone punches and rongeurs. The sphenoidotomy is enlarged to accommodate the operating endoscope and to provide a satisfactory panoramic view of the sella, the clivus, and the planum sphenoidale. The bony sella is then opened with a chisel (or a drill), and careful resection of bone is carried out from one cavernous sinus to the other laterally and from the tuberculum down to the junction of the sella with the clivus in the superior–inferior plane. Wide exposure of the dura is necessary, and using the high-speed drill and appropriate bone punches, a portion of the planum can be resected in order to allow access to the suprasellar compartment anteriorly. The limiting factors are the carotid arteries and the optic canals, so careful attention must be paid to imaging studies and the anatomic details as the bone is resected and the dura exposed.

Next, the superior intercavernous sinus should be carefully uncovered and the dura opened superior and inferior to this structure. Bipolar cautery can then be used to obliterate the superior intercavernous sinuses. The dural openings are connected so that the dura can be opened like a book, exposing the arachnoid of the chiasmatic cistern (Fig. 6.2). Tumors such as meningiomas will present directly arising from the dura, whereas encapsulated craniopharyngiomas will lie beneath the arachnoid. Careful resection in the subarachnoid plane should then be carried out, with cauterization of the lateral vessels feeding the capsule of the lesion. It is important to identify and preserve the superior hypophyseal artery and its branches feeding the inferior aspect of the optic chiasm. Cystic portions of craniopharyngiomas can be drained by entering through the capsule, further decompressing the lesion. Following decompression, mobilization of the lateral walls, and the superior aspect of the tumor, where it is connected to the optic chiasm with arachnoidal adhesions, can be performed. These are taken down with sharp dissection, freeing the chiasm and allowing it to move superiorly. In the sella, the superior aspect of the pituitary gland is dissected free from the inferior aspect of the tumor and dissection posteriorly will reveal the relationship of the tumor to the pituitary stalk. When the stalk is intimately involved, as in many craniopharyngiomas, sharp sectioning of the stalk to free the inferior border of the tumor is advisable. The decompressed tumor can then be carefully mobilized, and attached or incorporated cysts can often be delivered through the transsphenoidal aperture, which usually measures approximately 2 cm in diameter. This aperture is almost always larger than the exposure one achieves through the lamina terminalis using a craniotomy. Additionally, it allows removal of the tumor from behind the optic chiasm, preventing excessive manipulation of the chiasm and the optic nerves and tracts.

Once the tumor is removed and thorough endoscopic evaluation using angled endoscopes shows no remnants intracranially, hemostasis is assured, and a multilayer closure can be constructed. A free graft of fascia lata or rectus abdominis fascia can be used as an inlay graft, and it is my practice to plug the aperture in the skull base with a suitably tailored adipose tissue graft placed in a “collar stud” fashion and buttressed by a carefully tailored plastic plate. The previously raised septal flap is then placed over the exposed sphenoid bone at the margins of the skull base aperture and held gently in place with Gelfoam. Nasal packs are used when necessary. It is not my usual practice to use lumbar drainage pre- or postoperatively; however, this can be done in select cases.
POSTOPERATIVE MANAGEMENT

Because most craniopharyngiomas directly involve the pituitary stalk, the surgeon must anticipate the development of diabetes insipidus if it was not present before surgery. This requires careful monitoring of fluid balance, electrolytes, and replacement therapy, along with the judicious use of DDAVP desmopressin. Periodic imaging may be necessary to trace the absorption of intracranial air and the status of the operative site. The anterior pituitary hormones must be measured and replaced if abnormal.

COMPLICATIONS

The most common complication of the extended endoscopic transsphenoidal approach is that of postoperative CSF leak. The necessarily large aperture at the base of the skull requires careful multilayer closure to provide a secure barrier against CSF rhinorrhea. The relatively recent adoption of the nasal septal flap technique has significantly lowered the risk of this complication.

The one complication that is more common following endoscopic transnasal procedures than the former microscopic technique is that of postoperative epistaxis. This usually is related to branches of the sphenopalatine artery that are frequently encountered in the endoscopic dissection of mucosa away from the vomer. Intracranial hemorrhage can also occur if vessels related to the suprasellar lesion are violated. This includes the feeding vessels and branches of the circle of Willis.

If the suprasellar tumor is intimately associated with or adherent to the optic chiasm, then visual loss can be a complication of the procedure. Every effort should be made to visualize the intracranial structures clearly and to use sharp dissection under endoscopic view to remove fragments of tumor.

Nasal airway complications including sinusitis, sinus occlusion, mucocele formation, inflammatory change, adhesions, and synechiae may also occur, and appropriate postoperative nasal care is necessary to prevent these problems.

RESULTS

In general, the results of this procedure in experienced hands are very good and provide outcomes that are at least comparable, and in many cases superior, to a variety of open craniotomy techniques (Fig. 6.3). One may
anticipate recovery of vision in up to 87% of patients. The rate of preservation of normal pituitary hormonal function varies with the nature of the lesion—very good for meningiomas and pituitary adenomas but poor for craniopharyngiomas.

**PEARLS**

- If the sella is enlarged and the lesion is a craniopharyngioma, one can conclude that the origin of the tumor was infradiaphragmatic.
- The optic chiasm and hypothalamus are not adherent to most of these tumors, and a gross total removal can be accomplished by resecting the diaphragm and tumor capsule from below.
- Maximizing transsphenoidal exposure by removing bone between the carotid arteries, over the superior intercavernous sinus, between the optic canals, and ascending forward along the planum sphenoidale is important in obtaining the necessary visualization and exposure of the tumor.
- Angled endoscopes can provide a superior view of the pathologic anatomy.
- Careful occlusion and opening of the intercavernous sinus is often a key to maintaining the proper trajectory and exposure.
- Effective bipolar cautery may be necessary to control intracranial bleeding sites, and angled instruments may be necessary to reach fragments of tumor that are not in a direct line of sight.

**PITFALLS**

- Multilayered closure and bone reconstruction of the operative defect must be done carefully and securely, and the nasal flap needs to be approximated to bare bone surrounding the defect.
- Because we still lack truly effective bipolar cautery instruments, bleeding from the intracranial space may be difficult to control. Hemostasis must be assured in an incremental fashion as the surgeon progressively devascularizes the lesion.
- Regular monitoring of serum sodium is necessary since symptomatic postoperative hyponatremia can occur as a result of surgery for any suprasellar lesion.

**INSTRUMENTS TO HAVE AVAILABLE**

Surgical Instruments for Endoscopic Transsphenoidal Operation

1. Short (18 cm) and long (30 cm) 0-degree endoscopes, 4-mm diameter
2. Long (30 cm) 30-degree endoscope, 4 mm diameter
3. Standard sinonasal instruments
4. Bipolar cautery Aesculap GK560R
   a. Pistol grip with variable tips
5. Pituitary rongeurs: Codman 53-1230; Miltex 20-572; Miltex 20-570
6. Kerrison punches: Aesculap FF724R
   a. 1- to 3-mm Storz 662121–23
   b. Down-biting (2 mm) Storz 662132
PART I Sphenoid and Parasellar Regions

7. Fukushima suction tips—6F (Ruggles R-8994), 7F (Ruggles R-8995), and 8F (Ruggles R-8996)
8. Frazier suction tips—7F, 9F, and 10F Codman 70-1088
9. Drill
   a. High-speed nasal extension (70,000 RPM)
   b. 3-mm diamond bit
10. Chisels (Mueller [4 mm] B04-RH1400, Aesculap [7 mm] OL302R) and mallet (Codman 88-2520)
11. Straight and angled ring curettes
12. Microscissors (pistol grip)
13. Micro-Doppler
14. Stammberger punches
15. Nerve hook Codman 381030
16. Hardy: Boss 72-2150; 72-2155
17. Micro hook Storz 28164H

SUGGESTED READING

INTRODUCTION

The sphenoid sinus has attracted growing attention over the past 10 years. Development of diagnostic techniques and the introduction of selective endonasal endoscopic approaches to the sinus have established the sphenoid sinus as the corridor to sellar and parasellar areas as well as to the middle and posterior cranial base. The sinus borders on many important structures as well as the pterygomaxillary fossa and infratemporal fossa (ITF). Pneumatization of the pterygoid plate (PP) is a known variation of the anatomy of the sphenoid sinus. In the literature, pneumatization of the PP was reported in 25% to 57% of some series. Noticeably, there is a correlation between PP pneumatization and protrusions of both the vidian canal and foramen rotundum (Fig. 7.1).

The traditional approaches to the sphenoid and its lateral recess (transantral, transpalatal, transfacial, and transcranial approaches) are considered invasive and disfiguring procedures. The development of intranasal endoscopic techniques offered a practical alternative to the traditional methods and direct access to the sphenoid sinus while preserving nearby anatomical structures. Endoscopic endonasal surgery of the middle and posterior cranial base is becoming increasingly refined, and the sphenoid sinus is considered the main anatomical landmark for a variety of approaches.

HISTORY

Isolated diseases of the sphenoid are rare according to the literature. Generally, there are no specific symptoms associated with sphenoid sinus disease. Nasal blockage and/or discharge, especially when unilateral, should always be investigated to exclude benign or malignant tumors with extension to the lateral recess of the sphenoid sinus, involving the pterygopalatine fossa or nasopharynx. Notably, when this symptom is associated with epistaxis in a young male patient, the possibility of juvenile nasopharyngeal angiofibroma (JNA) always has to be taken into account.

Headache is a general symptom that, in certain conditions or associated with other symptoms, can lead to the diagnosis of skull base disease. Often, this kind of headache is located at the vertex or retroorbital and does not respond to conventional treatments.

Watery unilateral nasal secretions could be a warning symptom, especially in a patient with previous episodes of meningitis. In this regard, female sex, postmenopausal age, and obesity are considered as risk factors for spontaneous cerebrospinal fluid (CSF) leaks associated with meningo-encephaloceles. In these latter cases, the possibility of persistence of Sternberg canal has to be considered. In young patients with previous episodes of meningitis, it is mandatory to exclude a congenital malformation or syndrome even for patients who look phenotypically normal. Lesions of the maxillary or vidian nerves due to compression (fibro-osseous lesions, meningoencephaloceles, inflammatory or benign lesions such as schwannomas) or infiltration (malignancies) may cause numbness of the face and dry eye, respectively.

Invasive or expanding lesions of the sphenoid might destroy the adjacent vital structures. The presence of diplopia could be a sign of involvement of cranial nerve III, IV, or VI. Decreased visual acuity or light perception is an alarming sign of optic nerve involvement.
PHYSICAL EXAMINATION

Nasal endoscopy is now considered an essential diagnostic step in the evaluation of cranial base anatomy and pathology. Endoscopic exploration of the nasal fossa, nasopharynx, and cranial base is necessary for any tissue abnormality or liquorrhea. Watery nasal secretions should always be collected to detect β-2 transferrin protein, for patients with a high suspicion of CSF leak. The traditional neurologic examination of cranial nerves is always included for lesions of the cranial base. The audiometric examination could also be helpful in selected patients with a suspicion of involvement of the petrous apex.

In cases of a cranial base malformation, a thorough evaluation of the head and cranium is necessary. Most of these patients must be evaluated in a multidisciplinary manner with maxillofacial and neurosurgeons. Similarly, careful endocrinologic and neurosurgical assessments are required in case of pituitary pathology to properly plan the minimally invasive and major effective therapeutic option. A multidisciplinary approach is necessary as well for patients with orbital manifestations with screening by an ophthalmologist. Examination of the neck is required to evaluate the presence of lymphadenopathy, especially with malignant lesions of the cranial base.

INDICATIONS

The transpterygoid approach is indicated for accessing pathologies of the lateral recess of the sphenoid sinus or used as a corridor to reach pathologies of the middle cranial fossa (MCF) and posterior cranial fossa. Fibrous lesions, JNA, meningo-encephalocele, schwannoma, and inverted papilloma are some examples of the diseases that can originate from or extend into the lateral recess of the sphenoid sinus. Pathologies of the paramedian–lateral structures of the middle cranial base such as the sella, parasellar area, and lateral portion of the cavernous sinus can be accessed by this approach as well (particularly in case of highly pneumatized lateral recess of the sphenoid).

The indications for this approach depend upon the location, type, and consistency of the lesion; they are generally indicated when the neurovascular structures are not involved. Tumors with limited vascular supply and/or that compress and devascularize the cavernous sinus are most favorable for endoscopic resection. Preoperative embolization of hypervascular tumors of the cranial base can be useful. The possibility of this minimally invasive approach for biopsy procedures is particularly advantageous. Furthermore, the transpterygoid approach is indicated as a corridor to target different areas such as the medial petrous apex, infrapetrous region, inferior cavernous sinus, petroclival area, and ITF (Table 7.1).

CONTRAINDICATIONS

Contraindications for an exclusively endoscopic approach include the encasement of vital vascular structures (internal carotid artery [ICA] or perforating vessels) and the impossibility to treat or remove the lesion.
CHAPTER 7 Transpterygoid Approach to the Lateral Recess of the Sphenoid Sinus

through the nasosphenoid corridor, as in the case of a tumor with a hard consistency and pial adherence. A purely endoscopic approach is also contraindicated in cases in which neurovascular surgery (ICA shunting) or orbital exenteration is needed. In these cases, a combined cranioendoscopic approach is preferable.

Nevertheless, the most important contraindication when choosing the type of approach remains the surgeon’s insufficient experience in the endoscopic management of these anatomical regions and overall inability to manage complications.

PREOPERATIVE PLANNING

The routine use of nasal endoscopy, CT scans, and MRI has improved the accuracy of the diagnosis of disease of the sphenoid sinus. Endoscopic and radiologic examinations allow for evaluation of the localization, size, and extent of lesions and, in some cases, can provide preoperative diagnosis (e.g., cholesterol granuloma, JNA) without resorting to biopsy. Preoperative endoscopic examination, together with CT scans, provides details on anatomic features (e.g., septal spur, concha bullosa, pneumatization of the sphenoidal rostrum, and pneumatization of the superior turbinate) that can influence the choice of the ideal surgical corridor. Identification of radiologic landmarks such as the vidian nerve, V2, ICA, optic nerve, and pneumatization of the PP is needed to avoid potential surgical hazards.

CT is extremely helpful in delineating the integrity of the bone and the variations of density. The finding of remodeling of the bone or erosion on CT requires careful evaluation of complementary soft tissue details on MRI. MRI plays a prominent role in imaging of the sphenoid sinus and the adjacent structures. Its high-contrast resolution combined with multiplanar capability makes it a valuable tool not only in the evaluation of benign and malignant neoplasms but also in the evaluation of aggressive inflammatory lesions. MRI allows identification of intracavernous structures in extreme detail and perfectly highlighting the intracavernous portion of the cranial nerves. The boundaries of the cavernous sinus, dura, and CSF are well defined. CT and MRI with contrast and angiography are particularly important to determine the consistency of the lesion, which helps to form the differential diagnosis. The imaging also helps to understand the relationship between the lesion and adjacent blood vessels. PET–CT is necessary for staging in malignant lesions prone to regional or distant metastasis.

Tissue biopsy is an essential step of the pretreatment evaluation. However, some pathology can be diagnosed based on clinical and radiologic assessment such as highly vascular lesions and meningo-encephalocele when biopsy is contraindicated. Before planning removal of a lesion, it is important to consider the histology of the tumor to avoid unnecessary surgery.

Early diagnosis is crucial because the presenting symptoms are both delayed and nonspecific, and often, diagnosis is made after the complication arises.

In order to avoid excessive bleeding during surgery, the patient should suspend all anticoagulant drugs and nonsteroidal anti-inflammatory drugs. Infectious sinonasal conditions should be resolved prior to surgery.

The patient must be informed about the possible risks of this operation, the hazards of neurovascular injury, and the possibility of duraplasty and that an external approach might be used as an alternative or complementary approach.

<table>
<thead>
<tr>
<th>TABLE 7.1 Indications for Transpterygoid Approach</th>
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<tbody>
<tr>
<td>Transpterygoid approach to the lateral recess</td>
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<tr>
<td>of the sphenoid sinus</td>
</tr>
<tr>
<td>Lesions originating from or extending to this</td>
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<tr>
<td>region (inverted papilloma, fibro-osseous</td>
</tr>
<tr>
<td>lesions, JNA, extensive inflammatory disease)</td>
</tr>
<tr>
<td>Trans-ethmoid-pterygoid-sphenoid (TEPS)</td>
</tr>
<tr>
<td>approach to the cavernous sinus and middle</td>
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<tr>
<td>cranial base</td>
</tr>
<tr>
<td>Selected cases of tumors:</td>
</tr>
<tr>
<td>• Pituitary macroadenomas or meningiomas</td>
</tr>
<tr>
<td>refractory to radiotherapy or with</td>
</tr>
<tr>
<td>preexisting cranial nerve deficits</td>
</tr>
<tr>
<td>• Tumors of CN V and VI (e.g., schwannomas)</td>
</tr>
<tr>
<td>• CSF leaks of the MCF (e.g., Sternberg canal)</td>
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<tr>
<td>Transpterygoid/transsphenoid approach to the</td>
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<tr>
<td>medial petrous apex</td>
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<tr>
<td>Lesions that expand the petrous apex toward</td>
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<tr>
<td>the clivus and the lateral recess of the</td>
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<tr>
<td>sphenoid sinus (e.g., extradural cholesterol</td>
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<td>granulomas, cholesteatomas, dermoid tumors)</td>
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<tr>
<td>Transpterygoid/sphenoid sinus approach to the</td>
</tr>
<tr>
<td>petroclival region</td>
</tr>
<tr>
<td>• Intradural or extradural lesions situated</td>
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<tr>
<td>along the medial portion of the</td>
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<tr>
<td>petroclival junction (e.g., chondrosarcomas,</td>
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<tr>
<td>chordomas, petroclival meningiomas,</td>
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<tr>
<td>lesions coming from the sinonasal region)</td>
</tr>
<tr>
<td>• CSF leaks of the petroclival junction</td>
</tr>
<tr>
<td>Trans-ethmoid-pterygoid-sphenoid-antral</td>
</tr>
<tr>
<td>approach (TEPSA)</td>
</tr>
<tr>
<td>For large lesions extending laterally</td>
</tr>
</tbody>
</table>
procedure. Of course, treatment should be based on multidisciplinary input including an otorhinolaryngologist, neurosurgeon, neurovascular interventionist, maxillofacial surgeon, neuroradiologist, and other related specialists.

**SURGICAL TECHNIQUE**

The patient should be anesthetized and placed in the supine position. A magnetic neuronavigation system is applied using CT angiography or CT/MRI fusion for better delineation of the vascular structures during dissection. A 0-degree endoscope is used to perform a wide maxillary antrostomy in order to expose the posterior wall of the maxillary sinus. Then, an anterosterior sphenoidectomy is performed. This approach is a lateral extension of the tranethmoidal approach to the medial wall and apex of the orbit, and the base of the pterygoid should be exposed. During this step, attention must be paid to cauterization of the descending palatine artery encountered during posterior enlargement of the maxillary antrostomy toward the PP. Subtotal resection of the middle turbinate with preservation of the superior attachment is required.

The site where both the nasal branch and septal branch of the sphenopalatine artery emerge is identified and electrocoagulated with bipolar forceps. The sphenopalatine foramen is then identified, and the pterygomaxillary fossa is opened with Kerrison forceps. Good lateral vision is obtained using a 45-degree endoscope. By lateralizing the contents of the pterygomaxillary fossa, the vidian foramen and the foramen rotundum can be seen. After electrocoagulation of the vidian artery, the base of the pterygoid and the base of the sphenoid sinus are exposed, especially at the bony margin that links the two ostia (vidian and rotundum). In this manner, it is possible to have a complete view of the pterygoid recess of the sphenoid. In the case of a well-pneumatized PP, the posterior wall of the maxilla can be removed to expose the ITF. Subsequently, the vidian canal has to be well exposed as an important safety landmark for the medial genu of the paraclival ICA (Fig. 7.2).

In the four-handed technique (Table 7.2), an ipsilateral approach is considered sufficient for treatment of minor lesions. A contralateral paraseptal approach is performed for medium and large lesions, by removing the intersphenoid septum and sphenoid rostrum. Thereafter, a portion of the vomer is removed to reach the floor of the contralateral MCF and for better accessibility of instruments in case of a four-handed technique. If this approach has to be extended to the ITF, an endoscopic medial maxillectomy is added to gain as much lateral exposure as possible.

In the case of a meningo-encephalocele or iatrogenic CSF leak occurring at the level of the MCF, reconstruction of the cranial base with a multilayer technique is necessary. I prefer using autologous materials such as temporalis (or abdominal) fascia, fascia lata, septal or mucoperiosteum of the septum or turbinate, quadrangular cartilage, or turbinate bone although heterologous materials can be used as well. The choice of material depends on the type of surgical approach employed, the location, and the degree of the dural defect. Middle turbinate bone and mucoperiosteum can be used as free grafts. The reconstruction technique depends upon placing the grafts in a multilayer manner (extradural intracranial layer, then an extradural layer) to guarantee a watertight closure. Another extradural intracranial layer is applied only for large dural defects. In critical areas where neurovascular structures are close by, this technique might be risky to apply. Gasket seal closure gives better results in such situations. The technique is to simply spread a large graft in an overlay fashion. A piece of cartilage that is slightly larger than the defect is introduced over the graft and gently pushed intracranial, while the edges of the graft are kept extracranial to prevent any contact between the graft and adjacent neurovascular structures.

**FIGURE 7.2**

Anatomical cadaveric representation of the lateral recess of the sphenoid sinus and the surrounding surgical landmarks that the endoscopist has to recognize. (C, clivus; ICA, internal carotid artery; V2, maxillary nerve; VC, vidian canal; SPA, sphenopalatine artery; IrSS, lateral recess of sphenoid sinus.)
Larger defects require a larger flap such as the nasoseptal flap (Hadad-Bassagasteguy flap). In order to harvest this flap, the surgeon should preserve the septal branches of sphenopalatine artery with section of the arterial branches passing through bony canals (i.e., descending palatine artery, palatovaginal artery, and vidian artery). This allows preservation of the vascular pedicle of the flap and permits more freedom of movement.

At the end of the procedure, fibrin glue should be applied over the grafts/flaps and not between them to avoid creating empty spaces and consequently the possible recurrence of a CSF leak once the glue is absorbed. Some surgeons like to use a balloon stent in the sphenoid sinus as a support for the graft. Silicone sheets are placed paraseptally, and nasal packing is inserted.

Obliteration of the sphenoid sinus, alone or with an overlay graft, has been often used to close defects located in the lateral sphenoidal recess. This option can be used in small sphenoid cavities where accurate removal of mucosa can be obtained, but in the case of well-pneumatized sphenoid sinuses, this might be a burden. In our series, the first seven cases with adipose tissue obliteration did not have a CSF leak recurrence. However, one patient developed pain related to the V2 distribution area. An arachnoid cyst arose under the temporal lobe very close to the bone defect and V2 canal. We have considered this condition (arachnoid cyst formation) a very rare complication of adipose tissue obliteration of the sphenoid sinus. Since then, we have not performed sinus obliteration because the efforts should be directed toward repairing the bony defect in the cranial base, which is not achieved by sinus obliteration alone.

Lumbar drainage is not routinely indicated at the time of surgery unless the patient has signs of intracranial hypertension. In case of preexisting intracranial hypertension, the possibility of placing a ventriculoperitoneal shunt should be considered. Some authors find lumbar drainage helpful during the postoperative course for 5 to 6 days in case they are suspicious of a CSF leak.

**POSTOPERATIVE MANAGEMENT**

Nasal packing is removed on the first or second postoperative day. Silicone sheets, which are placed paraseptally at the end of the surgery to avoid synechiae and crust formation, are removed two weeks later. Nasal irrigation with mucolytic and saline solution allows for better cleansing of the nasal fossae. During hospitalization, CT scan or MRI is usually carried out 24 hours after surgery to check for any intracranial hemorrhage, ischemia, or pneumocephalus as well as to screen for any gross residual tumor.

Patients should undergo a regular follow-up program according to the pathology. Malignant lesions should have a strict clinical and radiologic screening based on monthly endoscopic examination and MRI every 4 months during the 1st year; endoscopic examination and MRI every 2 and 6 months, respectively, during the 2nd year; and, subsequently, both examinations at 6-month intervals.

During the first follow-up, the surgical cavity should be cleansed of residual crusting, and the state of the flap, if used, should be examined. The presence of infection and macroscopic CSF leak should be sought.

**COMPLICATIONS**

**Risks**
- CSF leak
- Internal carotid artery injury
- Cavernous sinus injury
- Orbital apex–optic nerve injury
- Maxillary nerve injury
- Nerve injury V2
- Dry eye (vidian nerve)

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**TABLE 7.2 Transsphenoidal Approaches**

<table>
<thead>
<tr>
<th>4-Handed Transsphenoid Approach</th>
<th>Anatomical Areas Reached</th>
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</thead>
<tbody>
<tr>
<td>Bilateral direct paraseptal</td>
<td>Sellar and inferior parasellar area</td>
</tr>
<tr>
<td>Bilateral tranethmoidal</td>
<td>Superior and medial parasellar area</td>
</tr>
<tr>
<td>Trans–ethmoid–pterygoid–sphenoid (TEPS)</td>
<td>Lateral parasellar, MCF, and petrous bone apex</td>
</tr>
<tr>
<td>Trans–ethmoid–pterygoid–sphenoid–antral approach (TEPSA)</td>
<td>MCF, ITF, nasopharynx (lateral genu of ICA)</td>
</tr>
</tbody>
</table>
A complete understanding of anatomical relationships is a fundamental prerequisite. The basic extra- and intracranial landmarks must be constantly kept under control during surgery to guarantee safe access to deep structures.

When accessing the sphenoid sinus, the surgeon should keep in mind the need to identify the superior border of the choana and the sphenoid rostrum along with the tail of the superior and supreme turbinals. Opening of the cavernous sinus is made after the exposure of the vidian canal and foramen rotundum, recognizing that cranial nerve VI runs freely crossing the cavernous sinus from medial to lateral and inferior to superior direction. While accessing the petrous apex, the medial pterygoid lamina, vidian canal, and medial genu of the ICA must be identified (Fig. 7.3). This is necessary to avoid CSF leak from the posterior cranial fossa and to prevent severe damage to the internal carotid artery or inferior hypophyseal artery. Hemorrhage from the internal carotid artery or major vessels can result in devastating neurologic deficits or death.

Many reports in the literature show a significant reduction in CSF leak complications with the use of the nasoseptal flap. When this is not feasible, using a temporoparietal flap passed through the pterygopalatine fossa is a reliable alternative. The use of temporary lumbar subarachnoid drainage during the postoperative period does not seem to decrease the rate of recurrence of CSF leak. Generalized epilepsy due to intraoperative massive CSF loss and consequent pneumocephalus has been observed.

**FIGURE 7.3**
Huge cholesterol granuloma of the right petrous apex (marked with asterisk). Preoperative MR scan (with contrast enhancement, T1 weighted) in axial (A), coronal (B), and sagittal (C) views is characterized by hyperintensity in the capsule of the lesion. Parasagittal transsphenoidal approach with vidian canal dissection above medial PP, leaving the ethmoid sinus intact, allowed marsupialization of the lesion. Nasoseptal flap was harvested to maintain the patency of the surgical corridor (marked with white arrows). The 2-year follow-up MR scan in axial (D), coronal (E), and sagittal (F) views confirmed good ventilation of the surgical cavity. (PG, pituitary gland; SS, sphenoidal sinus; ICA, internal carotid artery.)
CHAPTER 7 Transpterygoid Approach to the Lateral Recess of the Sphenoid Sinus

Cranial nerves can be damaged either directly or by injury to the vessels supplying them. Temporary or permanent paralysis is possible. We have observed temporary paralysis of CN VI in one case in the absence of direct surgical trauma. This occurred after lavage of the cavernous sinus to facilitate complete removal of a dermoid lesion. Another serious complication is injury to the optic nerve with subsequent mono-binocular blindness. Facial and palatal numbness and dry eye are possible complications when V2 and vidian nerve, respectively, are damaged. Other complications include ascending bacterial meningitis, infections of the paranasal sinuses, postoperative epistaxis, and nasal airway narrowing due to scarring.

A key aspect in surgical training is the acquisition of three-dimensional anatomical knowledge. This basic familiarity should allow the surgeon to achieve intraoperative orientation based on the integration of macroscopic, radiologic, and tactile perception to recreate a complete three-dimensional mental scheme. In this sense, neuronavigation offers an additional advantage to avoid complications but is not a substitute for anatomical knowledge and good surgical technique.

RESULTS

Transsphenoidal endonasal endoscopic approach for solid and cystic lesions of the lateral sphenoid recess is a highly conservative procedure (Fig. 7.4). The results are comparable to those obtained with traditional microscopic transfacial-transcranial approaches (lateral rhinotomy/Caldwell-Luc-midfacial degloving-transtemporal-transcranial lateral approaches). The endonasal endoscopic approach avoids disfiguring facial scarring, risks to the facial nerve, and interference with cochlear and vestibular functions. Furthermore, no external skin incision is required, and it offers less hospitalization and intensive care admission. This minimally invasive approach allows for a larger and more natural corridor through the sinuses, which makes endoscopic postoperative follow-up easier for the detection of recurrences (Fig. 7.5). In addition, the endonasal endoscopic approach provides visual magnification of deeper lesions and the anatomical structures.

In contrast, extensive lesions involving the cavernous sinus cannot always be completely removed by transnasal neuroendoscopic techniques. As a consequence, medical therapy and radiotherapy (stereotactic radiotherapy and radiosurgery) are still used as primary treatment for most lesions of the cavernous sinus. External intra-extradural approaches allow for the best surgical control in the 1% to 4% of pituitary tumors, which extend to areas inaccessible by a purely endoscopic route. In cases of large tumors with critical anatomic relationships, radiosurgery can be used after neuroendoscopic transnasal subtotal resection to provide long-term tumor control.

In our published series of 15 patients with defects of the cranial base located at the lateral sphenoid recess, no CSF leaks or serious complication has been observed. We rely on multilayer technique or gasket seal closure for most of our cases without a need for sinus obliteration or balloon stenting.

PEARLS

- Intranasal “four-handed” technique has offered otorhinolaryngologists and neurosurgeons the opportunity of “between-specialist” surgical training that leads to a profitable exchange of technical skills.
- It is important to use a neuronavigation system with CT/MR fusion images or angio-CT for better visualization of adjacent vascular structures. Surgical Doppler ultrasound is a helpful device for detection of major vessels.
- Preservation of the cranial part of the basal lamella (common lamella) and olfactory neuroepithelium is recommended.
- During opening of the lateral wall of the sphenoid sinus, the intrasphenoidal anatomical landmarks have to be identified.
- The posterior wall of the maxillary sinus, vidian foramen, foramen rotundum, Eustachian tube, and sphenoid indentation of ICA are important landmarks.
- The VI cranial nerve runs through the cavernous sinus in a midlateral direction.
- The use of fibrillar collagen and fibrin glue permits management of venous bleeding.

PITFALLS

- Before the decision is made to operate, it is important to establish a tentative diagnosis by considering the radiologic characteristics and then confirm this by tissue biopsy.
- It is important to determine the relationship of the lesion with the surrounding neurovascular structures. Investigate the presence of any vascular adherence or invasion in order to avoid iatrogenic damage or pointless surgical removal.

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PART I Sphenoid and Parasellar Regions

It must be stressed that every time an endonasal endoscopic approach is encountered, thorough knowledge of the anatomy of the area is the primary prerequisite. Training by cadaver dissection is one way for better understanding this complex anatomy. The surgeon should have a thorough knowledge of the traditional external approaches to be able to handle any complications that may arise.

Patients should be always informed about the possible surgical approaches, whether endonasal, external, or combined approaches. A thorough discussion about the risk of complications and sequelae of the operation should be clarified. Patient education is important for a better perioperative period and long-term follow-up.

It is extremely important to practice in a teamwork fashion. Treatment decisions should be approved by a multidisciplinary group to provide the patient with the maximum benefits of the expertise.

FIGURE 7.4
Left sphenoid sinus fluid lesions with different MR intensities (marked with the symbols asterisk and hash) reflect different fluid/protein content. The hyperintensity on T2-weighted MR scan in axial (A) and coronal (B) views demonstrates the liquid component of the lesion. The maintained hyperintensity on FLAIR-T2 sequence with suppression of CSF signal (in coronal view) (C) is very useful to exclude CSF leaks. The TEPS endoscopic endonasal corridor allows us to reach the fluid lesion localized in the lateral recess of the left sphenoid sinus, up to the cystic lesion in the temporal region that was marsupialized just below V2. Postoperative CT scan in axial (D), coronal (E), and sagittal (F) views. Radiologic identification of the consistency of the lesion allowed us to spare additional transantral approach (the preserved posterior maxillary wall is marked with white arrows).
CHAPTER 7 Transpterygoid Approach to the Lateral Recess of the Sphenoid Sinus

INSTRUMENTS TO HAVE AVAILABLE

- Neuronavigation system with CT/MR fusion images or angio-CT
- Surgical Doppler ultrasound
- Dedicated cranial base surgical equipment (straight and angled endoscopes, dedicated cutting instruments, and suctions)
- High-speed intranasal drill
- Intranasal bipolar cautery
- Hemostatic materials

SUGGESTED READING


INTRODUCTION

The petrous apex is the most medial portion of the temporal bone. The temporal bone is a pyramidal structure with the base composed mostly of the bony labyrinth (semicircular canals and cochlea); the superior surface makes up a large portion of the middle cranial fossa floor. The posterior surface forms the anterolateral wall of the posterior cranial fossa where petrous apex lesions may impinge on Dorello’s canal affecting the function of the abducens nerve. Inferiorly, the petrous pyramid is bounded by the jugular bulb and the inferior petrosal sinus. The internal carotid artery (ICA) canal and the transverse (petrous) portion of the ICA traverse the petrous pyramid.

The petrous apex can be divided into anterior and posterior areas by a vertical plane through the modiolus of the cochlea and the internal auditory canal. Most lesions of the petrous apex are located anterior to this plane because posteriorly, the compact bone between the internal auditory canal and the vestibular apparatus rarely pneumatizes. Approximately 10% of the population has pneumatization of the anterior portion of the petrous apex.

Traditional otologic approaches to the petrous apex include surgery through or around the labyrinth (translabyrinthine, infralabyrinthine, retrolabyrinthine, retrocochlear) or approaching it from above (middle fossa routes). Drawbacks to these otologic approaches are the following: They are technically demanding, the view and access are often narrow and restricted, there is real or potential risk of audiovestibular loss, brain retraction may be required with potential neurologic sequelae, and there is no natural drainage pathway postoperatively. As an alternative approach, lesions in the petrous apex often bulge medially into the medial sphenoid sinus and are therefore potentially amenable to endoscopic transsphenoidal approaches in selected patients.

Transsphenoidal surgical access to the petrous apex is useful for biopsy and drainage purposes. It can be particularly helpful in selected cystic lesions such as cholesterol granuloma because marsupialization, rather than complete excision of the lesion, is the goal of therapy. The transsphenoidal approach usually avoids injury to the audiovestibular apparatus and provides a drainage pathway into the sphenoid sinus if required. Some lesions approached endoscopically may also require a transpterygoid approach with or without mobilization of the ICA. Lesions arising from the central petrous apex are considered “primary” and account for approximately 40% of petrous apex disease. Secondary lesions encroach on the petrous apex from bordering regions or may be metastatic.

Cholesterol granulomas are one of the most common benign pathologic lesions of the petrous apex, followed by mucoceles and cholesteatomas. Malignant tumors of the petrous apex are uncommon. The most common primary malignant tumor is a chondrosarcoma characterized by intratumoral chondroid calcification and bone destruction on computed tomography (CT) and low to intermediate signal on T1 and high signal on T2 magnetic resonance imaging (MR) images. Neoplasms originating in other sites may also spread to the petrous apex. For example, nasopharyngeal carcinoma may reach the petrous apex by direct extension, and hematogenous metastases from elsewhere in the body are occasionally seen.
HISTORY

Slow-growing or small lesions in the petrous apex may remain asymptomatic for years. Cholesterol granuloma is typically asymptomatic and is often an incidental discovery on imaging. Fast-growing or large lesions left untreated may continue to expand and cause increasing signs and symptoms including headache, balance problems, vertigo, diplopia, progressive hearing loss, facial weakness, and lower cranial nerve neuropathies.

PHYSICAL EXAMINATION

The examination of the head and neck, including fiberoptic nasal endoscopy, is usually normal. Examination of the cranial nerves may identify subtle cranial nerve palsies; of importance is an ipsilateral lateral rectus (CN VI) palsy. Typically, the examination of the ear is normal. Palpation and imaging of the neck help to rule out metastases to the cervical lymph node in cases of malignancy.

INDICATIONS

The endonasal, endoscopic transsphenoidal approach is safe, providing a low rate of recurrence and durable marsupialization of cystic lesions and a means to biopsy solid lesions. Lesions of the petrous apex may require a biopsy to arrive at a diagnosis in order to direct future therapy. If the imaging appearance is “classic” for a common cystic disease process (e.g., cholesterol granuloma) and the patient is asymptomatic, then observation with periodic imaging is a reasonable option. If the patient is symptomatic or the nature of the lesion is unclear on imaging, then biopsy, drainage, or decompression is indicated.

The transsphenoidal approach is appropriate for lesions that create a definite impression or “mass effect” on the posterolateral wall of the sphenoid sinus (posterior to the carotid artery) (Fig. 8.1). If the optic nerve and carotid artery can be identified and kept in view, the transnasal endoscopic approach to the petrous apex is relatively straightforward. The area of the “bulge” can be opened, marsupialized, or biopsied depending on the situation. The difficulty comes when the lesion is not so obvious in the sphenoid, the sphenoid is poorly pneumatized, or the lesion does not “bulge” into the lateral sphenoid sinus and is situated posterolateral to the clival carotid artery. Endoscopic lateralization of the carotid artery has been performed in certain centers but is technically demanding and requires a great deal of endoscopic skill to perform safely. For more lateral pathology, a transpterygoid infrapetrous approach with dissection of the eustachian tube and drilling of the bone of the petrous apex inferior to the horizontal petrous ICA can be performed but again is technically demanding and applicable only to surgical teams with extensive endoscopic skull base experience (Fig. 8.2).

**FIGURE 8.1** Endoscopic view of the anatomic features of the sphenoid sinus. The clival recess is bounded by the carotid arteries laterally and sella superiorly. The relationship of the internal carotid artery (ICA) and optic nerve (ON) is often accentuated by a well-pneumatized anterior clinoid (opticocarotid recess [OCR]). The petrous apex may be approached medially (direct access or lateral displacement of ICA) or inferior to the petrous ICA (arrows).
CONTRAINDICATIONS

Relative contraindications to an endoscopic endonasal approach include the usual patient comorbidities precluding surgery and difficult patient anatomy. If the patient has serviceable hearing, a transsphenoidal or traditional hearing sparing otologic approach should be considered (e.g., infralabyrinthine, transcanal infraco-chlear, or middle fossa approach). If the patient has minimal serviceable hearing and/or vestibular loss or if the direct endoscopic approach is technically difficult, then a transtemporal approach should be considered. For transtemporal operations, the temporal bone should be sufficiently pneumatized to navigate around or through the labyrinth. The middle fossa approach is technically demanding, there is no permanent drainage option, and some degree of brain retraction is required with the potential for injury to the brain. The transsphenoidal approach is better suited if continuous drainage is desirable (e.g., cholesterol granuloma).

PREOPERATIVE PLANNING

The success of any endoscopic skull base procedure depends on a thorough history, preoperative evaluation, and an informed consent conversation with the patient about the risks, benefits, and alternatives of various forms of treatment. Patients must understand the goals of surgery, which may only be diagnosis (biopsy) and the likelihood of achieving relief from symptoms. The surgical team needs to be prepared for the unexpected and have a well-developed plan in place for life-threatening complications including injury to the carotid artery.

CT and MRI are commonly used to assess petrous apex lesions. Cholesterol granuloma will typically appear on CT as an expansile lesion of the petrous apex with bony erosion and scalloping (Fig. 8.3A). Thinning of the posterior wall of the sphenoid and petrous carotid artery dehiscence may also be seen. Cholesterol granulomas have a characteristic appearance on MRI that is hyperintense on both T1-weighted and T2-weighted images.

**FIGURE 8.2** Schematic 3D figure to provide subjective comparison between both approaches (EEA and TICA) to petrous apex. Frontal view simulating the endoscopic endonasal approach in the operation room. Note the limits of each zone of petrous apex and the structures surrounding it, as well as the main direction provided by each approach. I, zone I of petrous apex; II, zone II; III, zone III; VI, abducens nerve; AE, arcuate eminence; CO, cochlea; JV, jugular vein; ET, eustachian tube; C, carotid canal; L, lacerum; VN, vidian nerve; P. genu, posterior genu petrous ICA; Horiz., horizontal petrous ICA; pICA, paracaval ICA; A. genu, anterior genu petrous ICA; ICA, internal carotid artery; EEA, endoscopic endonasal approach; TICA, transcanal infraco-chlear approach.
sequences, owing to the lipid and fluid content of these lesions (Fig. 8.3B and C). In contrast, a petrous apex cholesteatoma on MR will show a smooth, expansile mass with low signal intensity on T1-weighted imaging and high signal on T2-weighted imaging. A variety of MR pulse sequences have been described to help differentiate various petrous apex pathologies (e.g., graded recall echo).

It is important to study the CT and MR to define the anatomy including the location of the carotid artery, optic nerve, jugular bulb, and facial nerve as well as the pneumatization of the sphenoid sinus and temporal bone (Fig. 8.4). The position and degree of bone covering/thinning of the petrous and clival portions of the carotid artery are very important. It is critical to ensure that the petrous apex pathology is not a vascular lesion such as a thrombosed aneurysm before any biopsy or drainage procedure is considered. The degree to which the pathology will be visible medial to the ICA after bone removal can be estimated on axial images by drawing a line from the pyriform aperture to the cyst (Fig. 8.4). The medial boundary is the medial edge of the pathology, and the most lateral boundary is the lacerum segment of the ICA, which cannot be retracted laterally.

**SURGICAL TECHNIQUE (VIDEO 8.1)**

The patient is placed supine on the operating room table with the head in a neutral position. The nasal mucosa is topically decongested with 1:1,000 epinephrine-soaked Neuro Patties. The image guidance system is appropriately set up, calibrated, and used to confirm important anatomy during the operation. A 0-degree 4-mm rigid nasal telescope attached to a high-definition video system is used for the majority of the operation. Angled telescopes (e.g., 30 degrees to 70 degrees) are often used to look into marsupialized cysts (e.g., cholesterol granuloma) once they have been opened.
It would be rare to need to place a nasoseptal flap for a complication such as a cerebrospinal fluid leak, but the surgeon should anticipate this ahead of time so that it can be raised initially and safeguarded in the nasopharynx or maxillary sinus. Alternatively, the posterior septal artery pedicle can be preserved on one side, allowing a viable nasoseptal flap to be raised later should it be required. A small nasoseptal flap can also be inserted through a marsupialized cholesterol granuloma as a substitute for a temporary silastic stent to keep the cyst opening patent.

A large, well-pneumatized sphenoid sinus with a lesion in the ipsilateral petrous apex can be approached through a wide unilateral sphenoidotomy. However, this usually means that the surgeon has to hold the scope and instruments as for standard sinus surgery without the ability for a second surgeon to help. Most lesions in the petrous apex are approached with an expanded endoscopic binarial technique similar to the exposure performed for endoscopic pituitary surgery (Fig. 8.5). This may require removal of a portion of one middle turbinate depending on the dimensions of the nasal cavity and the surgeon’s preference. Ethmoidectomy and antrostomy are usually not required unless there is coexistent sinus disease or a transpterygoid approach is being performed. The posterior bony septum is disarticulated from the sphenoid rostrum, and the posterior 1 to 2 cm of septum is removed. The anterior wall of the sphenoid sinus is removed with Kerrison rongeurs and high-speed drill with a 3- or 4-mm coarse diamond burr. Care is taken to cauterize the posterior nasal branches of the sphenopalatine arteries coursing across the sphenoid rostrum to prevent postoperative epistaxis (on one side only if a nasoseptal flap has been raised). As with any endoscopic skull base approach, it is important to widely open the sphenoid sinuses and make them into a rectangular box so that the bony edges do not limit mobility of the instruments. The surgeon should always be aware of the location of the optic canal and carotid artery siphon during this step of the dissection.

Sphenoid septations are removed with angled Kerrison rongeurs +/- high-speed drill following the septations onto the bone covering the carotid arteries. The sphenoid sinus landmarks are identified visually and with image guidance as required. The surgeon should look for the clival recess, optic nerves, planum sphenoidale, medial and lateral opticocarotid recesses, and the indentation of the sella. An intraoperative Doppler probe may be helpful to confirm the location of the clival carotid artery if there is any doubt. It is absolutely critical that the surgeon is confident of the location of the carotid artery before any instrumentation of the petrous apex lesion is commenced.

It is helpful to remove the mucosa of the sphenoid sinus, which reduces bleeding and helps to define the bony anatomy. If the petrous apex lesion extends into the sphenoid sinus, there is often bone over the lesion, which can be evaluated by palpation with a blunt instrument such as a ball probe. If there is bone over the lesion, it must be removed, usually starting with a high-speed drill and coarse diamond burr of appropriate size for the dimensions of the area (Fig. 8.6). It is important not to rest the drill shaft on the carotid artery during the drilling process to avoid inadvertent injury or heat transfer. Drilling starts at the medial surface of the lesion running vertically and parallel to the carotid artery. When the bone is thin enough to fracture, the small pieces are removed with a small Kerrison rongeur (e.g., 1 or 2 mm). The suspected pathology and surgical access required will dictate how much bone is removed over the lesion.

If the lesion is suspected to be cystic (e.g., cholesterol granuloma), then as much bone as possible over the lesion is removed. A sharp sickle knife is used to open the cyst wall and drain the contents (Fig. 8.7). The exposed cyst wall is removed with angled thru-cutting forceps and the specimen sent for permanent pathology. Some surgeons use a cruciate incision and drape the cut surfaces over the bony edges. If bleeding from the...
**FIGURE 8.5**
A bilateral sphenoidotomy with resection of the rostrum and posterior 1 cm of the nasal septum provides increased exposure for instrumentation and improves the angle of visualization.

**FIGURE 8.6**
After identification of the wall of the cholesterol granuloma, the bone on the medial aspect of the cystic cavity is carefully thinned with a 3-mm coarse diamond drill. The opening is enlarged with Kerrison rongeurs. Circle, cholesterol granuloma; parallel lines, paraclival internal carotid artery. (Figure and legend reprinted with permission from Snyderman C, Kassam A, Carrau R, et al. Endoscopic approaches to the petrous apex. *Operative Techniques in Otolaryngology* 2006;17(3):168–173.)

**FIGURE 8.7**
The contents of the cholesterol granuloma are removed with curettes, suctions, or irrigation. (Figure and legend reprinted with permission from Snyderman C, Kassam A, Carrau R, et al. Endoscopic approaches to the petrous apex. *Operative Techniques in Otolaryngology* 2006;17(3):168–173.)
capsule of the lesion is anticipated, then bipolar electrocautery can be used to outline the incision. The interior of the cyst is inspected with angled telescopes and irrigated with saline to remove any additional debris as required (Fig. 8.8). If the lesion is solid and all that is required is a biopsy or debulking, then appropriate angled instruments are used to carry out the biopsy. Intraoperative frozen section analysis is helpful to confirm that tissue representative of the lesion has been obtained and to give an initial indication as to the nature of the lesion (e.g., benign vs. malignant). If temporary or permanent drainage from the petrous apex into the sphenoid sinus is desirable, a rolled piece of thin pliable silastic sheeting is cut and tailored to the defect to sit securely through the marsupialized defect into the sphenoid sinus. Care is taken to avoid resting the cut surface on the opposite carotid artery or optic nerve to prevent pressure erosion and injury. Some surgeons have also described leaving a pediatric tracheal T tube or other small catheter to stent the area. There is no consensus on how long to leave the stent in place, but the usual time period is 3 to 6 months.

If the above standard approach will not allow access to the petrous apex because of poor sphenoid pneumatization or posterolateral location of the petrous apex pathology, then decompression and lateralization of the carotid artery can be considered, or alternatively, an otologic approach can be used. To decompress and lateralize the carotid artery, a wide middle meatal antrostomy is performed. The sphenopalatine artery is identified, and the bone over the posteromedial maxillary sinus is removed to expose the pterygopalatine fossa. The sphenopalatine and posterior nasal arteries are ligated and divided. The vidian canal and its contents are identified in the base of the pterygoid plates (pterygoid wedge). The bone medial and inferior to the vidian canal is removed, and the vidian artery is traced to the second genu of the carotid artery. The bone of the vertical clival carotid is thinned with a diamond burr and removed allowing several millimeters of lateral displacement of the clival carotid artery. If this is enough exposure based on the preoperative and intraoperative assessment of the petrous apex lesion, then the lesion can be managed as described above for the expanded binarial transsphenoidal approach.

Nasal packing is usually avoided unless there is excessive bleeding at the end of the operation. Absorbable packing gently placed around the operative site may help to minimize minor postoperative bleeding.

**POSTOPERATIVE MANAGEMENT**

Patients may be discharged the same day if the surgery is uncomplicated. The surgeon’s standard postoperative regimen for routine sinus surgery can be followed. Typically, this involves 1 week of avoiding strenuous activity, nasal saline irrigations multiple times each day, and possibly a broad-spectrum antibiotic such as amoxicillin–clavulanate. Nasal debridement is performed depending on the surgeon’s preference and patient tolerance. In most uncomplicated cases, gentle debridement is required every 2 to 3 weeks for approximately 6 to 8 weeks or until the cavity has healed (Fig. 8.9).

**COMPlications**

The most feared complication is inadvertent injury and hemorrhage from the ipsilateral carotid artery, which is a rare but life-threatening event. Management is beyond the scope of this paper but requires the surgeon and team to have a plan in place to tamponade the bleeding (e.g., fresh muscle patch), manage intravascular volume and blood replacement, and involve interventional radiology. Avoidance is key and requires a thorough knowledge of the anatomical variations of the carotid artery, visualization intraoperatively, and careful instrumentation around the artery. Intraoperative image guidance and Doppler probe assessment help to confirm the clinical impression of the location of the artery.
Postoperative hemorrhage is uncommon unless the posterior nasal arteries are not adequately cauterized. Transient cranial nerve palsies, especially the abducens nerve or audiovestibular nerve, have been reported. Symptomatic dry eye requiring artificial tears occurs uncommonly from sacrificing the vidian nerve if a transpterygoid approach is used. Injury to the orbit and cerebrospinal fluid leaks are also uncommon with this type of surgery. Stenting of cystic lesions helps to keep the marsupialized area open, but stenosis and recurrence of symptoms can still occur months to years later requiring reoperation. Adhesions may block access for transnasal removal of the silastic stent necessitating a second operation for removal.

RESULTS

Transsphenoidal surgery for petrous apex lesions has been popular for only the last 15 to 20 years. For benign cystic lesions of the petrous apex, the endoscopic transsphenoidal approach to the medial petrous apex offers a high degree of success with a low recurrence rate, low risk to inner ear structures, and a natural drainage pathway into the sinonasal cavity.

There are multiple case reports or small case series reported in the literature. One of the largest case series of cholesterol granulomas described by Gore et al. stated the rate of clinical and/or radiologic recurrence of petrous apex cholesterol granulomas following endoscopic drainage to be in the range of 5% compared with approximately 15% for transtotic approaches. Most authors prefer to leave stents from the petrous apex into the sphenoid sinus, usually made of medical grade silicone, and most leave the stents in for several months. Placing a small nasoseptal flap as a stent has been reported with good results in a small number of patients. Topical mitomycin has been used around the edges of marsupialized cystic lesions in the petrous apex with the goal of preventing postoperative stenosis. There are no good data on whether this antineoplastic agent is effective for this indication or if there are long-term sequelae associated with its use. Concerns of malignancy associated with mitomycin have limited its use.

PEARLS

- Open the sphenoid rostrum widely to maximize exposure, and permit a two-surgeon, four-hand technique.
- Optimal visualization is important throughout the procedure; maintain good hemostasis with one or more methods such as warm irrigations, topical vasoconstrictors, and topical hemostatic agents.
- Confirm the location and position of the carotid artery by multiple methods before making any incisions or taking a biopsy of lesions in the lateral sphenoid sinus.

FIGURE 8.9

After several months, a well-mucosalized and widely patent opening into the petrous apex persists (A); Closer view of A (B). (Figure and legend reprinted with permission from Snyderman C, Kassam A, Carrau R, et al. Endoscopic approaches to the petrous apex. Operative Techniques in Otalaryngology 2006;17(3):168–173.)
• Have a plan of action developed and known by the surgical team in case of injury to the carotid artery.
• If the patient requires lateralization of the carotid artery, consider another approach or referral to a center with significant experience or expertise.
• If the lesion is solid, obtain a frozen section early, which may indicate pathology (e.g., lymphoma) that will not require further or more extensive surgical intervention.

PITFALLS

• Attempting to access the medial petrous apex through a unilateral or small sphenoidotomy will usually give suboptimal exposure of the lateral wall of the sphenoid sinus. This will result in poor marsupialization of a cystic lesion (and a higher chance of postoperative stenosis) and increase the chance of injury to neurovascular structures.
• Cystic lesions that have been marsupialized are much more likely to stenose without postoperative stenting.

INSTRUMENTS TO HAVE AVAILABLE

• Standard endoscopic skull base and sinus instruments
• Image guidance system
• High-speed endoscopic skull base drill
• Intraoperative Doppler probe

SUGGESTED READING

INTRODUCTION

The most common lesions encountered in the suprasellar cistern are skull base tumors such as meningiomas, pituitary tumors, and craniopharyngiomas. Several less common entities involve the region of the pituitary stalk and the hypothalamus, which may require biopsy or excision. Any lesion in the suprasellar cistern with mass effect on the pituitary stalk and optic chiasm requires a thorough radiographic and laboratory evaluation.

HISTORY

The most common symptoms related to a mass in the suprasellar space are hypothalamic/pituitary dysfunction or loss of vision. Lesions arising in the suprasellar cistern compress the optic chiasm from below. In this regard, the classic presentation for lesions such as a pituitary tumor, Rathke cleft cyst, or midline meningioma is bitemporal hemianopsia, with visual loss usually beginning in the superior quadrants. Any lateralization of the lesion such as with a meningioma may affect one optic nerve more than the other, producing asymmetry in the loss of visual fields.

A complete endocrinologic evaluation should include testing of all of the hormones of the hypothalamic–pituitary axis (Table 9.1). These include prolactin, adrenocorticotropic hormone, fasting morning cortisol, thyroid-stimulating hormone, free thyroxine, gonadotropic hormones (luteinizing hormone/follicle-stimulating hormone), sex hormones (estrogen/progesterone in females, testosterone in males), growth hormone, and insulin-like growth factor. In a female patient of reproductive age, the loss of menstrual periods and galactorrhea may be common presenting symptoms. This may be due to pituitary insufficiency or to mass effect on the pituitary stalk producing the so-called “stalk” effect with moderate hyperprolactinemia, resulting from lack of tonic inhibition of prolactin release. This must be differentiated from a true prolactin-secreting pituitary adenoma because a nonfunctional pituitary adenoma would not be expected to respond to dopamine agonist therapy.

PHYSICAL EXAMINATION

Careful evaluation of visual function, including both acuity and visual field examination, should be performed to detect any loss of visual acuity or reduction of visual fields. This is usually verified with a formal ophthalmologic evaluation. Extraocular movements should be evaluated to rule out any dysfunction of the third (oculomotor), fourth (trochlear), and sixth (abducens) nerves. Olfaction should always be tested to rule out the
possibility of an anterior skull base lesion, such as a meningioma of the cribriform plate or planum sphenoidale, extending posteriorly.

**INDICATIONS**

Tumors such as pituitary tumors, craniopharyngiomas, midline meningiomas, or a Rathke cleft cyst causing symptoms from mass effect (vision loss, pituitary or hypothalamic dysfunction) all require surgical decompression and/or resection. Even vascular lesions such as aneurysms can cause compression of the optic apparatus or other associated structures. In addition, certain suprasellar lesions involving the infundibulum or hypothalamus may require biopsy. All of these can be accomplished through a frontotemporal or subfrontal craniotomy, with wide exposure and access.

**CONTRAINDICATIONS**

There are few, if any, absolute contraindications to craniotomy for suprasellar tumors, assuming the patient is medically sound for surgery. Significant tumor burden in the sella may be challenging to remove completely through a craniotomy, but suprasellar tumors can always be accessed albeit with varying degrees of difficulty depending upon the relationship to the optic nerves and chiasm.

**PREOPERATIVE PLANNING**

Any surgical procedure should be well planned, particularly the anticipated trajectory to remove the lesion. It is important to obtain as much information as possible regarding endocrine status, visual status, and preoperative imaging prior to planning a surgical procedure in this region, which is replete with cranial nerves, proximal major arteries with perforating vessels, and the hypothalamic–pituitary axis. In addition, a rare compressive mass lesion such as a giant aneurysm must be ruled out because the surgical planning would demand preparation for management of this lesion. If a large aneurysm is anticipated, preoperative angiographic studies such as a digital subtraction or computed tomography (CT) angiogram should be performed. The surgical procedure may require more proximal control of the artery in the neck.

Magnetic resonance imaging is the best study to define the nature of the suprasellar mass; a fine-cut T1-weighted study should be obtained with and without contrast enhancement. Careful attention should be paid to involvement of the sella in addition to the suprasellar area, which may indicate a primary pituitary lesion, such as a pituitary adenoma or a cyst. Similarly, the relationship of the lesion to the third ventricle should be carefully examined. Coronal imaging allows evaluation of the optic nerves extending posteriorly from the posterior orbit through the optic canal and the suprasellar cistern and of the relationship of the lesion to the optic chiasm and tracts. Extraaxial lesions causing compression of the optic nerves should be visible in relationship to the nerves; an intrinsic lesion of the chiasm or hypothalamus may envelop and involve the optic nerves.

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**TABLE 9.1 Serum Hormones of the Hypothalamic–Pituitary Axis Tested During Endocrinologic Evaluation**

<table>
<thead>
<tr>
<th>Endocrine serum tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estradiol</td>
</tr>
<tr>
<td>Free testosterone (male patients)</td>
</tr>
<tr>
<td>Free thyroxine</td>
</tr>
<tr>
<td>Growth hormone</td>
</tr>
<tr>
<td>IGF-1</td>
</tr>
<tr>
<td>Luteinizing hormone (female patients)</td>
</tr>
<tr>
<td>Morning fasting cortisol</td>
</tr>
<tr>
<td>Prolactin</td>
</tr>
<tr>
<td>Thyroid-stimulating hormone</td>
</tr>
<tr>
<td>Total testosterone (male patients)</td>
</tr>
</tbody>
</table>

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Any involvement and encasement of major vessels (i.e., the internal carotid arteries, the proximal middle cerebral arteries, and the anterior cerebral arteries) should be delineated. The location and displacement of the pituitary stalk should be noted.

Occasionally, a CT scan may add complimentary information, especially to identify acute hemorrhage (such as pituitary apoplexy) or calcium within the tumor. This latter finding may be extremely helpful in identifying a craniopharyngioma, especially in patients in the pediatric age group.

There are several options for approaching lesions in the suprasellar region. The majority of the tumors in my practice are removed using a frontotemporal or subfrontal craniotomy (Fig. 9.1). The subfrontal approach may be unilateral or bilateral. The location of the tumor, its area of attachment, direction of displacement of the pituitary stalk, and its relationship to the optic nerves and canals are noted and included in the decision-making process.

**Frontotemporal Approach**

The frontotemporal approach offers a more anterolateral trajectory to the suprasellar cistern, with early detection of the carotid artery and pituitary stalk behind or lateral to the tumor (Fig. 9.2). It also offers the shortest distance to the region of the suprasellar cistern along the axis of the sphenoid ridge. For various tumors, a narrow or wide corridor can be chosen depending on the size of the craniotomy. Smaller lesions or those with limited attachment may allow a much smaller approach for access. For tumors with more superior extent, a frontotemporal orbitozygomatic modification may be chosen to allow the surgeon an inferior-to-superior trajectory to view and remove the most superior aspect of the tumor. This is especially helpful in tumors such as meningiomas and craniopharyngiomas, which may have significant suprasellar extension.

**Frontal Approach**

The frontal approach to the suprasellar cistern may be unilateral or bilateral. It is chosen when the tumor is in the midline and the surgeon believes that a lateral approach is not necessary for identification of the carotid artery and pituitary stalk.
Surgical Technique

Frontotemporal Approach

For the frontotemporal approach, the patient is placed supine on the operating table, and a shoulder roll is placed under the ipsilateral shoulder. Pressure points are padded, and the patient is placed in a Mayfield 3-pin head holder. The head is turned 30 to 45 degrees, depending on the amount of lateral access desired. I prefer head rotation of less than 30 degrees when optic nerve decompression and removal of the anterior clinoid process is planned, as it allows a more direct visual access along the core of the clinoid. Somatosensory evoked potentials and motor evoked potentials are used invariably. Other cranial nerve monitoring may be added depending upon the extent of the tumor and the cranial nerves at risk.

The skin incision usually begins just anterior to the tragus of the ipsilateral ear and either superior to the midline or beyond the midline depending on the amount of frontal access desired. Usually, just two burr holes are placed, one in the McCarty burr hole location (pterion) and the other in the deep temporal fossa. The sphenoid ridge is drilled using a high-speed diamond burr. The amount of drilling of the sphenoid ridge varies depending on the pathology addressed but may include an extradural (anterior) clinoidectomy as well. Meningiomas involving the tuberculum and the optic canal are invariably exposed within the canal, and I perform a complete clinoidectomy and optic canal decompression to remove as much of the tumor as possible.

Figure 9.2
A 40-year-old woman presented with bilateral visual loss. This midline tumor has significant suprasellar extension. The tumor could be approached from either a frontotemporal or a subfrontal corridor. The frontotemporal approach was chosen here to enable early detection of the pituitary stalk and to provide the shortest distance to the suprasellar cistern. The frontotemporal approach also avoids any manipulation of the olfactory tracts, which could result in loss of the sense of smell. Preoperative T1 weighted post-contrast (A) coronal and (B) axial MR images demonstrate a meningioma with compromise of the optic chiasm. C. Postoperative image demonstrates complete removal.
possible in this vulnerable location. The choice of which side to approach the meningioma from is made considering the predominant location of the tumor. If the tumor involves the anterior clinoid process lateral to the optic nerve and the ipsilateral optic canal is involved, then a unilateral approach on the same side of the tumor is chosen. If the tumor is entirely midline, a right unilateral approach is usually used. If the tumor is attached just medial to the optic nerve, consideration is given to a contralateral approach, which offers better visualization of the area of attachment without obstruction by the optic nerve or carotid artery on that side (i.e., look crosscourt) (Fig. 9.3). Careful attention is paid to all perforating vessels, especially those emanating from the proximal carotid artery feeding the underside of the optic nerves and chiasm, posterior communicating artery, and anterior choroidal artery. Meticulous microsurgical dissection is carried out to remove the tumor completely (Fig. 9.4). In the case of meningiomas, I perform early detachment of the tumor from the skull base to devascularize the tumor, and I strive to remove the entire tumor and the involved attachment of dura. In tumors involving the optic canal, I drill the canal completely up to the region of the annulus of Zinn; the posterior orbit is removed on the involved side (Fig. 9.5). Occasionally, with a tuberculum meningioma, bilateral optic nerve decompression is necessary. Any involved bone is drilled, and sometimes it may be necessary to drill more extensively into a pneumatized clinoid or the sphenoid sinus, which will require formal repair of the base of the skull in this region to avoid a cerebrospinal fluid leak. If this occurs, I use autograft fascia and muscle to close the defect, which is usually covered with fibrin glue and sutured in place if necessary. In the case of craniopharyngioma, careful dissection of the tumor off of the region of the pituitary stalk and hypothalamus under direct vision is mandatory (Fig. 9.6). Attention is paid to the glial plane at the hypothalamic interface, which represents the demarcation of the tumor from the

**FIGURE 9.3**
Coronal MRI.  
**A.** T1, postcontrast.  
**B.** T2 showing a recurrent meningioma in a 46-year-old man who presented with recurrent visual loss in his right eye after surgical resection at an outside institution. This tumor could be removed via a transnasal approach with endoscopic guidance or a transcranial approach. This was approached transcranially from the contralateral side to provide an optimal view of the region of tumor attachment.  
**C.** Postoperative, postcontrast T1-weighted MR showing complete resection.
neural structures, and this should be followed under high magnification. Complete removal is our goal when possible, but the lack of a dissectible plane may indicate that a subtotal resection may be a better option to avoid damage to the hypothalamus. The dura is then closed, with a graft if necessary after removal of the meningioma. The bone flap is replaced and fixed with a titanium miniplate; a cranioplasty with porous

**FIGURE 9.4** Intraoperative photographs using the operating microscope showing a right frontotemporal approach to a suprasellar lesion with (A) dissection of the arachnoid within the opticocarotid cistern to reveal the underlying tumor mass (T), (B) opening of the tumor capsule, and (C) central debulking of the tumor between the optic nerve (ON) and internal carotid artery (ICA).

**FIGURE 9.5** Intraoperative photograph using the operating microscope showing a right frontotemporal approach to a suprasellar lesion with invasion of the optic canal demonstrating decompression of the optic nerve by (A) removal of the bone of the optic canal and (B) opening of the falciiform ligament.

**FIGURE 9.6** Intraoperative photograph using the operating microscope of a right frontotemporal approach to a suprasellar craniopharyngioma demonstrating (A) dissection and (B) removal of tumor (T) from the infundibulum (I), leaving the entire structure intact. (ON, Optic nerve.)
polyethylene is placed in the temporal defect where the bone has been drilled or hollowed with rongeurs. This provides an excellent long-term outcome with minimal morbidity.

**Frontal Approach**

The incision used may be a unilateral frontotemporal scalp incision or a bicoronal incision depending on the amount of bone removal desired. If possible, a unilateral approach is chosen to avoid risk to the contralateral olfactory tract resulting in anosmia. The frontal sinus, if sizable, is invariably entered and cranialized when possible with this approach. Careful attention must be paid to removal of the posterior table of the frontal sinus and all associated mucosa both in the base of the skull and in the bone flap.

**POSTOPERATIVE MANAGEMENT**

Postoperatively, the patient is monitored in the intensive care unit. Attention must be paid to postoperative fluid management and diabetes insipidus (DI) in many patients who have undergone resection of suprasellar tumors. This is especially true of craniopharyngiomas and hypothalamic lesions in which postoperative DI is the rule. I have serum sodium measured every 6 hours and urine output measured continuously. If the sodium level rises higher than 147 with a high urine output (>300 mL per hour), treatment with desmopressin is initiated. Vision and blood pressure are carefully monitored postoperatively. I am very careful to avoid hypotension, especially in patients with DI and potential dehydration, as this may exacerbate any potential for vascular compromise to the optic chiasm with resultant poor visual outcome. Depending on the nature of the lesion, the major risks are damage to the hypothalamic–pituitary axis or visual apparatus. In the vast majority of patients with compressive lesions of the optic chiasm, visual stabilization or improvement will ensue after the tumor is removed. In patients who have a craniopharyngioma, worsening of endocrine function may be anticipated with the resection of larger lesions, and supplementation of appropriate hormones such as thyroxine and cortisol may be necessary.

**COMPLICATIONS**

The major complications related to removal of tumors in the suprasellar space are loss of vision, vascular complications, and pituitary dysfunction. It is important for the surgeon to remember that the main vascular supply to the optic chiasm and nerves enters from below the optic apparatus; as such, fine microsurgical dissection must be performed to avoid interruption of the vascular supply to these structures and the risk of inducing visual deficit. In addition to these vascular considerations, the optic chiasm and nerves should be manipulated as little as possible during surgery. Less common cranial nerve palsies that may occur in this area are injury to the oculomotor (III) and trochlear (IV) nerves during their course through the suprasellar cistern and along the tentorium, respectively.

Vascular complications may be due to manipulation and interruption of small perforating vessels from the posterior communicating artery, anterior cerebral arteries, and proximal middle cerebral artery in addition to the anterior choroidal artery. Careful dissection technique, using fine microdissectors and sharp dissection, is the key to avoiding these devastating complications. I use dilute papaverine (1:10 mL saline) after all skull base and vascular dissections in this area to avoid vasospasm from manipulation of microvessels in the suprasellar cistern.

Endocrine deficits may be more difficult to avoid. The pituitary stalk must be preserved if possible; however, this structure is fragile, and manipulation with dissection may result in decreased pituitary function, at least transiently. The usual indicator for this is DI occurring postoperatively. Careful attention must be paid to other hormonal axes (especially adrenocorticotropic hormone–cortisol and thyroid-stimulating hormone–T4) in the postoperative period.

**RESULTS**

The most common tumors in this location—meningiomas and pituitary adenomas—are predominantly benign with slow growth. Visual deterioration from compressive optic neuropathy responds well to surgical decompression from these tumors. Pituitary tumors may be accompanied by hypopituitarism or functional overproduction, and thus, these axes are monitored carefully in the postoperative and follow-up periods. If adequate resection is obtained with either of these tumors, then I prefer a “watch-and-wait” approach postoperatively, and adjuvant treatment, usually fractionated radiation therapy or stereotactic radiosurgery, is administered if
there is tumor recurrence or regrowth of residual. More aggressive variants of meningioma or atypical pituitary adenomas may require adjuvant treatment with radiation therapy after surgery.

The situation with craniopharyngioma is more controversial. I prefer to take an approach of maximal safe surgical resection whenever possible and use radiation therapy for subtotal resection or recurrence.

It must be remembered that radiation treatment (either fractionated or stereotactic radiosurgery) is associated with the potential complications of optic neuropathy or hypopituitarism, the latter in a large percentage of patients. Thus, the patient should be monitored over an extended period of time for the occurrence of hypopituitarism involving critical hormonal axes.

PEARLS

- Prior to surgery, a rigorous evaluation, including neuro-ophtalmologic examination, endocrine evaluation, magnetic resonance imaging, and sometimes CT imaging, is undertaken.
- Preoperative counseling of the patient should include a thorough discussion of the possibility of endocrine dysfunction, especially in patients with lesions that have a relationship to the hypothalamic–pituitary axis such as craniopharyngioma and hypothalamic glioma.
- Meticulous bimanual microsurgical dissection is the rule and is the best option for safe surgical removal. Blunt dissection is to be avoided, and careful attention is paid to all perforating vessels emanating from the proximal carotid arteries to the undersurface of the optic nerves and chiasm.
- Use copious irrigation when drilling the optic canal and removing the clinoid process to avoid thermal damage to the optic nerve.
- Careful management of the patient in the intensive care unit requires blood pressure management, fluid management, and replacement of vital hormones as necessary.

PITFALLS

- Failure to completely decompress any tumor in the optic canal when removing a meningioma could result in early recurrence with visual loss.
- Overly aggressive dissection techniques (especially blunt dissection) can result in injury to the optic nerve or chiasm or vascular compromise.
- Tumor can be left in blind spots from this approach; angled endoscopy can help visualize these.
- Try to anticipate the location of the pituitary stalk early in dissection to avoid injury or interruption.
- Caution should be used in patients who have been radiated for meningioma as tissue and dissection planes may be difficult to establish, and subtotal resection of tumor may be prudent to avoid injury.
- Invasion of tumor into the carotid artery or its branches is possible, especially in tumors with cavernous encasement of the carotid. Revascularization may be necessary in cases with inadvertent injury to the carotid. Plan ahead for this possibility.

INSTRUMENTS TO HAVE AVAILABLE

- Thirty- or seventy-degree endoscope to enable visualization of blind areas behind the optic nerves or chiasm, carotid arteries, or pituitary stalk
- Full set of microdissectors and fine microscissors to enable sharp dissection around critical vessels and nerves
- Dilute papaverine solution to bathe vessels after dissection to reduce ischemia related to manipulation of perforating vessels.
- Various drills (especially diamond) to remove all the bone of the optic canal if tumor has invaded this region
- Fine-tipped ultrasonic aspirator to remove tumor from various surgical corridors

ACKNOWLEDGMENTS

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SUGGESTED READING

INTRODUCTION

The pterional approach, a modification of the frontotemporal approach, was popularized by Yasargil who described the pterional craniotomy in detail and used it for different pathologies involving the frontotemporal region and basal cisterns. Recent advances in our understanding of the anatomy of the skull base region expanded our abilities with the pterional approach in the depth of the surgical field. The pterional approach is one of the most commonly used approaches by any neurosurgeon performing cranial surgery. It is centered over the Sylvian fissure region, and in its classic description, it has more frontal than temporal exposure. However, different modifications of the pterional approach with more frontal or temporal extensions help to expand the reach of the approach and help to improve our ability to maximize the potential of the approach while improving safety and minimizing risk.

HISTORY

The history of a patient needing a pterional approach or one of its variations varies significantly because of the wide spectrum of pathologies involving this region. Due to the proximity of the lesions to the sellar and parasellar region, many patients will present with visual problems. Examples are tumors such as tuberculum sellae meningiomas, pituitary adenomas, and craniopharyngiomas. Vascular lesions such as paraclinoid aneurysms may also result in visual loss. Aneurysms of the posterior communicating artery may present with third nerve palsy. Seizures may be a presentation of larger lesions in the sellar and parasellar region. Gliomas involving the temporal lobe or the limbic and paralimbic regions most commonly present with seizures. Also, pituitary endocrinopathies are a common presentation, especially in tumors arising from or compressing the pituitary gland. Large tumors may present with signs and symptoms of increased intracranial pressure such as severe headaches, papilledema, nausea, and vomiting.

PHYSICAL EXAMINATION

The physical examination of patients with pathologies that will need a pterional approach or one of its variants varies with the different disease entities being treated. Patients with meningiomas may present with visual loss and visual field deficits that vary according to the location of the origin of the meningioma. On physical examination, patients with tuberculum sellae meningioma may present with bitemporal hemianopsia. The visual loss related to some of these tumors is more pronounced on the side that is closer to where the meningioma arises. Olfactory groove meningiomas present with diminished or absent olfaction due to compression of the olfactory nerves. They may also develop psychobehavioral changes due to frontal lobe dysfunction. Proptosis is commonly seen with sphenoid wing meningiomas extending into the lateral orbital wall. Cavernous sinus meningiomas present with diplopia and sixth nerve palsy. This is more typical with
meningiomas involving the posterior medial compartment of the cavernous sinus because of tumor extension into the region of Dorello’s canal. Anteriorly located cavernous sinus meningiomas may present with third nerve palsy.

Patients with pituitary adenomas usually present with headaches, decreased visual acuity, and bitemporal hemianopsia on examination of the visual field. Physical changes related to hormonal hypersecretion such as Cushing’s syndrome and acromegaly are found on physical examination depending on the tumor type. The physical examination of patients with craniopharyngioma is not very different from that of patients with other suprasellar tumors except some patients may not exhibit signs and symptoms of diabetes insipidus.

INDICATIONS

The pterional approach and its variations have the potential to safely reach numerous pathologies involving the frontotemporal region and the skull base and basal cistern region. The following is a list of the different pathologic entities that can safely and effectively be treated using the pterional approach or one of its variants:

I. Tumors
   1. Extraaxial
      A. Meningioma
         - Lateral sphenoid wing meningioma
         - Medial sphenoid wing meningioma
         - Clinoidal meningioma
         - Dorsum sellae meningioma
         - Tuberculum sellae meningioma
         - Diaphragma sellae meningioma
         - Planum sphenoidale meningioma
         - Olfactory groove meningioma
         - Anterior tentorial meningioma
         - Anterior middle fossa meningioma
         - Cavernous sinus meningioma
      B. Pituitary adenoma
         - With significant suprasellar and parasellar extensions
         - Involving the cavernous sinus
      C. Craniopharyngioma
         - Suprasellar craniopharyngioma
         - Retrochiasmatic craniopharyngioma
      D. Others
         - Dermoids
         - Epidermoids
         - Pituicytoma
         - Arachnoid cysts
         - Rathke cleft cyst
   2. Intraaxial
      A. Gliomas
         - Insular gliomas
         - Fronto-orbital gliomas
         - Mesial temporal gliomas
         - Temporal gangliogliomas
         - Hypothalamic gliomas
         - Fronto-opercular gliomas
         - Temporo-opercular gliomas
   II. Vascular lesions
      A. Aneurysms
         - Middle cerebral artery
         - (M1, M2, and M3 segment aneurysms)
         - Internal carotid artery
         - Paraclinoid
         - Posterior communicating artery
         - Anterior choroidal artery
         - Anterior communicating artery
         - Basilar apex artery
         - Superior cerebellar artery
B. Vascular malformations
   - Arteriovenous malformations (AVMs)
   - Fronto-orbital AVM
   - Insular AVM
   - Fronto-opercular AVM
   - Temporo-opercular AVM
   - Mesiotemporal AVM
   - Lateral anterior temporal AVM
   - Lateral frontal AVM
   - Cavernous malformations (frontal & temporal lobes)

CONTRAINDICATIONS

Given its extraordinary versatility, there are few absolute contraindications to a pterional approach. However, it is an anterolateral approach, so tumors of the anterior midline can be difficult to access completely. Also, many lesions of the posterior fossa, especially more caudal, cannot be reached through a pterional approach.

PREOPERATIVE PLANNING

The preoperative planning for patients undergoing pterional craniotomy varies with the circumstances of the involved pathology and the presence or absence of symptoms. Patients with signs and symptoms of increased intracranial pressure are usually started on IV or PO steroids in the preoperative period. Patients presenting with seizures are started on anticonvulsants. In most patients with visual symptoms, preoperative ophthalmologic evaluation with visual fields is done. Pituitary function blood tests are performed when indicated. Angiography is occasionally done, especially in patients with vascular lesions. It may also be indicated in patients with tumors to verify the flow in the cerebral vasculature and the extent of the collateral flow in cases of significant cerebral arterial stenosis or occlusion. In most patients with brain tumors, a preoperative thin-cut MRI is done for intraoperative neuronavigational guidance.

SURGICAL TECHNIQUE

Skin Incision

The skin incision for the pterional approach and its variants is planned based on two important factors: (1) the cosmetic aspect of the location of the incision as it relates to the location of the hairline in each individual patient and (2) the craniotomy site as it relates to the pathology involved. In general, trying to follow a very rigid rule about the location of the incision compromises the cosmetic result if the difference in the shape of the patient’s head is not taken into account. My skin incision is usually tailored to the location of the craniotomy and its extension as is needed in every specific case. The main rule to follow is that for all pterional craniotomies, the pterion region has to be comfortably reached after reflecting the skin flap. For this reason, we make sure that a straight line connecting the beginning and the end of the skin incision is not more than 1 cm away from the junction of the root of the frontal zygoma with the orbital rim (Fig. 10.1).

In this way, the starting point of the incision at the preauricular region can extend superiorly or inferiorly based on how much temporal extension of the craniotomy is needed. The frontal end of the incision is decided
based on the straight line mentioned above while at the same time achieving a good cosmetic result. In a receded hairline, the incision may need more posterior extension. When a more frontal craniotomy is needed, the skin excision is extended more frontally. Extension beyond the midline is sometimes needed if a full cranio-orbital craniotomy is needed (Fig. 10.1).

**Temporalis Muscle Dissection**

The preservation of the integrity of the temporalis muscle is of utmost importance for a good cosmetic outcome. It is very important to preserve the bulk of the temporalis muscle as well as its blood and nerve supply. The blood supply of the muscle arises from the deep temporal artery, the branches of which run along the inner surface of the muscle. This is why it is very important that the deep fascia of the temporalis muscle be dissected very carefully from the bone. This maneuver will help to preserve the underlying blood and nerve supply to the temporalis muscle. The use of cautery to elevate the temporal muscle has a higher risk of heat injury to the nerve supply of the muscles as well as compromise of the blood supply. I prefer to leave a small cuff of fascia along the superior temporal line without leaving much of the muscle fibers along its insertion, to be used for suture reconstruction of the muscle at the end of the surgery (Fig. 10.2). The muscle is reflected inferiorly and anteriorly along the course of its origin.

Occasionally, the temporalis muscle is large, and when more temporal exposure is needed, the zygomatic arch is drilled to achieve better inferior reflection of the temporal muscle (Fig. 10.3). This maneuver can improve the exposure to lesions involving the middle temporal fossa and the region of the cavernous sinus and anterior upper one-third of the posterior fossa. It would also provide a more superior exposure to the suprasellar region from a lateral to medial projection.

**The Craniotomy**

The extent of the craniotomy changes with the pathology involved. There are three variations of the pterional approach craniotomy: the standard craniotomy, craniotomy with frontal extension, and craniotomy with temporal extension (Fig. 10.4).

**Burr Hole**

Although one burr hole may be enough to establish the needed craniotomy, it has a higher risk of tearing the dura, especially in older patients who have significant adhesions between the dura and the inner surface of the skull.
I generally like to drill three burr holes as indicated in Figure 10.4, all of which would be covered by the temporalis muscle during the closure and reconstruction. The location of these burr holes will help bridge the sharp, bony prominences on the inner aspect of the skull and dissect the dura before using the craniotome to create the bone flap.

Once the burr holes are made, the craniotome is used to create the craniotomy by connecting the burr holes and drilling the medial aspect of the sphenoid wing to weaken its attachment. This allows the bone flap to be reflected easily. Hemostasis in the epidural space is then established using gel foam powder along the bone edges followed by tack-up sutures. Further work is now done under magnification using the operating microscope.

**Epidural Dissection and Exposure**

The extent of removal of the bone of the skull base varies with the exact location of the pathologic entity being treated. In general, to gain access to the basal cisterns and to be able to open the arachnoid over the optic nerve to release spinal fluid and achieve early brain relaxation with minimal brain retraction, the sphenoid wing has to be drilled flat with the orbital roof (Fig. 10.5). The extent of removal of the sphenoid wing varies with different pathologies. In the standard pterional approach, removal of the sphenoid wing can be stopped at the level of the meningo-orbital artery. In cases where further exposure of the temporal fossa is needed, or when the anterior clinoid process needs to be removed, the epidural dissection needs to be extended in both the subfrontal and the pretemporal regions. This is done by coagulating and cutting the meningo-orbital artery and followed by dissecting the dura propria of the temporal lobe away from the region of the superior orbital fissure (Fig. 10.6). This dissection can be extended to the lateral wall of the cavernous sinus for lesions that need to be approached either in or through the cavernous sinus (Fig. 10.7). Occasionally, during this step, brisk bleeding from the cavernous sinus may occur. This is easily controlled by injecting fibrin glue into the cavernous sinus region. When performing this step, caution should be taken to prevent reflux of fibrin glue into the Sylvian veins via the sphenoparietal sinus, which may connect to the cavernous sinus. This is done by applying pressure with the suction device or with a Cottonoid over the sphenoparietal sinus to prevent retrograde reflux of fibrin glue.

During this step, a good understanding of the anatomy of the middle fossa is essential. Familiarity with the plane between the temporal lobe and the lateral wall of the cavernous sinus is crucial to avoid inadvertent entry into the cavernous sinus or into the intradural space on the temporal side.

The above-mentioned steps with dissection of the disconnected dura on the frontal side will lead to full exposure of the anterior clinoid process as far as its tip.

**FIGURE 10.4** Shows the three variations of the pterional approach craniotomy. The upper middle picture shows the standard pterional craniotomy. The lower left shows a pterional craniotomy with more frontal extension, and the lower right shows a pterional craniotomy with a more temporal extension.
Removal of the Anterior Clinoid Process

Removal of the anterior clinoid process requires an in-depth understanding of its anatomy. This is very crucial because of the extensive variations of its anatomy and its relationship to the adjacent neural and vascular structures including the internal carotid artery, optic nerve, and oculomotor nerve. The anterior clinoid process has three surgical anatomic connections that need to be removed for it to be safely disconnected (Fig. 10.8). Those connections are (1) the medial sphenoid wing connection to the orbit, (2) the optic roof, and (3) the optic strut. Removal of the posterior third of the roof of the orbit will disconnect the anterior clinoid process from the sphenoid wing. This is followed by drilling the optic roof using the high-speed drill with a diamond drill bit to release the second connection. This is followed by drilling the optic strut with extra caution to avoid the clinoidal internal carotid artery and the optic nerve. This is done by using copious irrigation and frequent stops.
During the drilling process, the bulk of the clinoid process is decreased in volume, especially in patients who have a very large and elongated clinoid (Fig. 10.9). This will render the clinoid tip free from its attachments and can easily be scooped out of its bed. In a few cases, a middle clinoid process connecting the anterior clinoid process is present and will prevent the clinoid tip from becoming mobile after disconnecting its attachments. In this case, the clinoid process should be drilled along its posterior extension toward the posterior clinoid process as needed.

**FIGURE 10.8**
Shows the three surgical attachments of the right anterior clinoid process. (a, sphenoid ridge; b, roof of optic canal; c, optic strut.)

**FIGURE 10.9** Steps of drilling the right anterior clinoid process. A. Removal of the optic roof. B. Exposure of the anterior clinoid between the optic canal and superior orbital fissure. C. Drilling of the optic strut after unroofing the optic canal. D. View after removal of the anterior clinoid process. (ON, optic nerve; FD, frontal dura; OS, optic strut; III, oculomotor nerve; SOF, superior orbital fissure; O, orbit; ICA, internal carotid artery.)
The Dural Opening

The dural opening is tailored according to the pathology involved. For lesions needing a standard pterional approach, a C-shaped curvilinear incision of the dura with the flap reflected anteriorly over the sphenoid wing region is used. In lesions involving the sellar and paraseellar regions and the clinoid and the paraclinoid regions, I prefer an incision extending along the indentation of the sphenoid wing as indicated in Figure 10.10. It is then followed by medium subfrontal and/or lateral subtemporal extensions as needed. This will allow direct access to the basal cistern area without any retraction of the brain. It will also take advantage of all of the bone work previously done to get wide access to the deeper anatomic corners.

Intradural Steps

Once the dura is opened, the initial steps are focused on opening the arachnoid of the basal cisterns, releasing spinal fluid, and achieving brain relaxation. This is usually started by opening the arachnoid over the optic nerve followed by opening the arachnoid over the carotid cistern. Further dissection is carried out depending on the pathologies involved. In patients with subarachnoid hemorrhage, further brain relaxation is achieved by opening the lamina terminalis. In patients with anteriorly projecting anterior communicating artery aneurysms, this may not be possible, and dissection must be directed toward Liliequist’s membrane to release spinal fluid from the preopticine cistern and between the internal carotid artery and oculomotor nerve.

Further dissection is carried out depending on the pathology involved. For lesions involving the region of the Sylvian fissure, the fissure will need to be opened. The extent of the opening of the Sylvian fissure also depends on the location and the size of the lesion. For example, insular gliomas need a wide opening of the Sylvian fissure, whereas a posterior communicating artery aneurysm may only need opening of the proximal aspect of the Sylvian fissure. The Sylvian fissure is best opened as described by Yasargil from inside to outside. This is usually started by finding an M4 branch of the middle cerebral artery leading to the Sylvian fissure (Fig. 10.11). The arachnoid is opened, and the dissection is carried to the depth of the Sylvian fissure in the direction of the limen insulae to find the M3 and M2 branches and then to follow the M1 branch along its proximal course in the direction of the bifurcation of the internal carotid artery. Once the deep hollow part of the fissure (the vallecula) is opened, then the dissection is carried to the more superficial part of the frontal and temporal operculae. Opening of the Sylvian fissure is a step that is essential for the safe handling of many pathologies approached through the pterional approach. The safety of the dissection is enhanced by an in-depth understanding of the vascular anatomy of the blood vessels in the Sylvian fissure and their variations.

Pterional Transcavernous Route

The pterional approach can be used to access lesions involving the cavernous sinus region. It can also use the transcavernous route to lesions involving the suprasellar region and the interpeduncular fossa. For lesions involving the region of the cavernous sinus, a pterional approach with more temporal extension is used. The extradural dissection is performed as described above. In many pathologies, a wider extradural window is needed. This can be achieved by coagulating and cutting the attachment of the middle fossa subtemporal dura.
CHAPTER 10  Pterional /Orbital–Pterional Craniotomy

The bone reconstruction after a pterional approach is also important to be attended to in order to avoid any cosmetic defects in the region of the temporalis muscle. This is especially so when the junction of the zygoma to the middle meningeal artery at the level of the foramen spinosum. This is followed by further dissection of the dura propria of the temporal lobe from the lateral wall of the cavernous sinus all the way posteriorly, over the Gasserian ganglion, and to the level of the Meckel’s cave. This step provides access to most pathologies involving the cavernous sinus region, without having to open the intradural compartment.

For lesions involving the suprasellar region and the anterior superior aspect of the posterior fossa, the transcavernous route can be very valuable. This is done by combining the extradural exposure with the intradural dissections. This is further enhanced by dissecting the oculomotor nerve along its whole length from the brainstem to the superior orbital fissure. This maneuver allows the oculomotor nerve to become more mobile and enlarges the window to the interpeduncular fossa. This will provide an unobstructed view of this region with minimal to no retraction of the brain (Fig. 10.12).

Closure

Attention to the closure of the pterional craniotomy should be as important as the attention to the opening. Tack-up sutures are applied at the edges of the craniotomy to avoid excessive collection of blood in the epidural space. In cases where the pretemporal space is dissected along the lateral wall of the cavernous sinus, pretemporal tack-up sutures are applied. This would prevent the occurrence of a pretemporal hematoma. The closure of the dura should be watertight. In many cases when the anterior clinoid process is removed and the clinoidal dura is excised, a defect remains in the dura which usually spans the space between the optic nerve medially and the oculomotor nerve laterally. I usually close this defect with either a piece of temporalis muscle or a piece of adipose tissue harvested from the subcutaneous tissue of the abdomen. While performing this closure and in patients in whom the sphenoid sinus has been opened while removing the anterior clinoid process, extra attention is paid to obliterate the window to the sphenoid sinus between the optic nerve and the internal carotid artery. This is important to prevent any leakage of cerebral spinal fluid. Along the same lines, in patients who undergo a pterional craniotomy with a more median extension, the frontal sinus may be opened. In such cases, it is important to cranialize the sinus by stripping the mucosa of the sinus and then obliterating the sinus either with bone wax, if the window to the sinus is small, or with subcutaneous adipose tissue, if the opening in the sinus is wide. The closure is usually reinforced by reflecting and rotating a pericranial flap over the obliterated opening.

FIGURE 10.11
Shows a left-sided Sylvian fissure and a M4 branch leading to the depth of the Sylvian fissure and the region of the M1 segment of the middle cerebral artery. (TL, temporal lobe; FL, frontal lobe.)

FIGURE 10.12
Shows the extent of the exposure achieved by adding the intradural dissections with a transcavernous route to the right pterional approach. Notice the wide exposure of the depth of the surgical field in the region of the interpeduncular fossa. (III, oculomotor nerves; An, aneurysm; P1, posterior segment of the posterior cerebral artery on the right side.)

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and the orbital rim is drilled flat with the orbital roof and after removing the sphenoid ridge. The combination of reconstructing this defect and preservation of the integrity of the temporalis muscle leads to an excellent cosmetic result (Fig. 10.13).

Following this step, the temporalis muscle is sutured back to the superior temporal line from where it was detached as described earlier. This is followed by good approximation of the galea and subcutaneous tissue to establish good hemostasis. For this reason, I do not use any subcutaneous drains in our patients.

The skin is closed with either staples or 3-0 nylon sutures. The sutures are usually removed two weeks from the day of the surgery, and the incision is kept dry during this period of time.

POSTOPERATIVE MANAGEMENT

In the postoperative period, patients are kept for one or two nights in the intensive care unit to monitor their neurologic status, fluid input/output balance, and vital signs. Antibiotics are started an hour before surgery and continued for 24 hours when the surgical procedure is shorter than 4 hours and 48 hours if it is longer than 4 hours. The antibiotics of choice should include coverage for Gram-positive cocci. Nafcillin is one choice in patients who have no penicillin allergy; otherwise, vancomycin is used. For patients in whom the skull base air sinuses are violated, ceftazidime is added for broader spectrum coverage. In the majority of patients, periorbital edema is commonly seen. It is usually treated with cold compresses and by elevating the head of the bed.

On the first postoperative day, patients are moved to a chair, and their Foley catheter is discontinued unless closer monitoring of urine output is indicated. Patients are started on PO diets and advanced as tolerated. Early ambulation is encouraged, and the majority of patients are transferred out of the intensive care unit to a regular room on the second day after surgery.

COMPLICATIONS

The pterional approach and its variants have been well established, and when properly done with minimal trauma to the tissues and attention to preservation of the blood supply to the tissue, they are approaches with a very low complication rate. When proper dissection of the subcutaneous layer is performed, the frontalis branch of the facial nerve achieves full recovery even if a temporary weakness occurs from stretching the nerve or postoperative edema. When significant drilling of the sphenoid wing region is indicated and done, inadequate reconstruction of the pterional bony defect can lead to a postoperative disfiguring depression at the site of the craniotomy. This may be further exaggerated if atrophy of the temporalis muscle occurs due to poor handling of its blood supply. Complications related to vascular, parenchymal, or cranial nerve injuries are in general avoidable using the proper microsurgical technique and an in-depth understanding of both normal anatomy and distorted pathologic anatomy. Obviously, the chance of complications varies with the complexity of the lesions involved.

The reconstruction of the skull base is of utmost importance in avoiding complications such as cerebrospinal fluid leaks leading to rhinorrhea or otorrhea. This is best avoided by in-depth knowledge of the bony anatomy of the skull base and the region of the anterior clinoidal process and its variations especially as it relates to the air sinuses. Adequate reconstruction of the defects in the skull base is best achieved by obliterating the windows leading to the air sinuses as mentioned earlier. This is best done either using subcutaneous adipose tissue harvested from the abdomen or, for a small defect, using a small piece of temporalis muscle and/or fascia.
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RESULTS

An in-depth understanding of the pterional approach and its variations is essential for every neurosurgeon performing cranial procedures. It provides access to a wide intracranial region that harbors a long list of pathologic processes. Mastering this approach and understanding the variations of the bony, vascular, and neural anatomy involved with this approach are essential for the safe and effective treatment of these pathologies.

The results of pterional and orbitopterional craniotomy for many cranial lesions have been well described in the literature. These approaches represent the most commonly performed techniques for clipping all anterior circulation and many aneurysms of the posterior circulation. This has created the standard against which all other results are measured, including endovascular treatment. Sphenoid wing meningiomas, suprasellar tumors, and lesions of the cavernous sinus and interpeduncular cistern have all been approached with ease and success via these approaches with little approach-related morbidity.

PEARLS

- The pterional craniotomy may be modified with different frontal or temporal exposure as needed, depending on the location of the pathology.
- The anterior clinoid can be exposed with careful interdural dissection deep to the meningo-orbital artery.
- The anterior clinoid process should be disconnected from the medial sphenoid wing, optic roof, and optic strut. Copious irrigation should be employed during drilling.
- The Sylvian fissure should be split from the inside to outside, identifying proximal MCA and ICA branches before separating the operculae.

PITFALLS

- During subcutaneous dissection, the adipose tissue pad superficial to the temporalis fascia should be separated from the underlying fascia or the fascia brought up with it in order to avoid injury to the frontalis branch of the facial nerve, which runs superficial to it.
- Drilling of the optic strut carries the risk of injury to the internal carotid artery and the optic nerve and should be done slowly and carefully.

INSTRUMENTS TO HAVE AVAILABLE

- Standard craniotomy instruments
- Variable length bipolar forceps
- Variable-sized suction tips
- Microdissectors
- Microknives
- Microscissors
- Microforceps

SUGGESTED READING

INTRODUCTION

The traditional approach to tumors of the frontal sinus has been an osteoplastic flap with excision of the tumor and either obliteration of the sinus or attempted opening of the sinus into the nasal cavity. This approach resulted in two problems. First, the sinus cavity could not be surveyed endoscopically, and therefore, the only method of assessing recurrence was imaging (either computed tomography [CT] or magnetic resonance imaging [MRI]). Second, if the sinus was opened into the nose and the ethmoid complex was not opened fully at the time, there was a high risk of stenosis and subsequent obstruction of the frontal sinus. These problems have been overcome with the endoscopic modified Lothrop (also termed the Draf 3 or frontal drill-out) procedure. This allows for a wide opening of the frontal sinus for access to the tumor and removal and also allows for postoperative endoscopic surveillance of the frontal sinus so that any recurrence of tumor can be seen immediately.

HISTORY

Patients with lesions of the frontal sinus present with headache, frontal pain, and pressure and, if a mucocele is present, may present with proptosis, limitation of eye movement, diplopia, or loss of vision. If the mucocele becomes infected, then orbital cellulitis or abscess formation may also occur. If the tumor involves the nasal cavity, the patient may have associated nasal obstruction with blood-stained rhinorrhea.

PHYSICAL EXAMINATION

The nasal and ENT examination may be normal in patients in whom the tumor is located entirely within the frontal sinus. A mass, often vascular and friable, may be seen in patients in whom the tumor involves the nasal cavity. CT scan (Figs. 11.1 and 11.2) and MRI scans (Fig. 11.3) are always done to assess the nature of the lesion and whether there is extension into the anterior cranial fossa or orbit. If the tumor extends into the nose, then biopsy is indicated. However, most tumors of the frontal sinus are assessed radiologically, and only if there is doubt about the diagnosis will a frozen section be done at the time of surgery.

INDICATIONS

Benign nasal tumors are the most common to be addressed by this technique. These include frontal sinus inverting papillomas (Figs. 11.1 to 11.3), osteomas, fibrous dysplasia, meningoceles, and meningoencephaloceles. Malignant tumors isolated to the frontal sinuses are uncommon and may be metastatic, usually from the lung or breast, and, unless small and accessible, would not be approached with this technique. Malignant tumors
PART II Anterior Cranial Fossa

FIGURE 11.1
In this coronal scan, opacification of the left frontal sinus is seen.

FIGURE 11.2
In the parasagittal CT scan, the opacification can be seen extending into the frontal recess.

FIGURE 11.3
The coronal T2-weighted MRI scan allows the distinction to be made between tumor and mucus in the opacified regions of the CT scans. The tumor can be seen filling the frontal recess and frontal sinus.
extending into the frontal sinuses will have this approach as part of the resection, but consideration needs to be given as to where else the tumor extends and the involvement of surrounding structures.

**CONTRAINDICATIONS**

Although most areas of the frontal sinus can be accessed through the endoscopic modified Lothrop approach, osteomas involving the entire frontal sinus and following the contours of the sinus are easier to access through an osteoplastic approach. In general, osteomas that do not extend past the midpupillary line are approached in this way, and tumors extending beyond the midpupillary line are dealt with via an osteoplastic flap approach. While I prefer to deal with all inverting papillomas via the endoscopic modified Lothrop approach, even those extending to the far lateral regions of the frontal sinus, it may be easier to remove these very large and extensive tumors via an osteoplastic flap approach. Fibrous dysplasia and meningoencephaloceles that extend to or present lateral to the midpupillary line are also best removed via an osteoplastic approach.

**PREOPERATIVE PLANNING**

All patients have an image guidance CT scan performed prior to surgery. If there is no other sinus disease present, then surgery should start with an uncinectomy and clearance of the anterior ethmoids up to the frontal ostium. If, however, there is sinus disease present, then this is dealt with before the frontal sinuses are approached. In most cases, we would plan to do bilateral frontal sinus minitrephines as part of the surgery. This allows fluorescein-stained saline to be injected into the frontal sinus, and the passage of this fluorescein through the frontal sinus ostium marks the skull base; the skull base should remain safe if the surgeon stays anterior to the fluorescein.

**SURGICAL TECHNIQUE**

The first step is to complete any sinus surgery that is indicated. All patients will have an uncinectomy and maxillary antrostomy, but only those with disease in the posterior ethmoid and sphenoid will undergo a complete sphenoidethmoidectomy. Next, the septal window is created. The landmarks for the septal window are consistent and should be followed in every case. The posterior limit of the septal window is the anterior end of the middle turbinate. The septal window is lowered until a straight instrument can be passed from one side through the septal window and under the middle turbinate axilla on the opposite side (Fig. 11.4). The anterior edge of the septal window is brought further anteriorly until the straight drill can access the bone of the frontal process of the maxilla anterior to the middle turbinate. The superior edge of the window is created by taking the window up onto the nasal vault. Leaving 3 to 4 mm of septal bone here will impair the dissection as one works from the one side across the septum onto the opposite frontal sinus. It is important that throughout this early part of the surgery that both scope and drill are placed from the one side through the septal window and drilling occurs on the opposite frontal sinus. This improves the angle and allows drilling to occur laterally under direct visualization. Attempting

![FIGURE 11.4](image-url)
The minitrephines are placed through the medial ends of the eyebrows with the incision placed through the hairs to camouflage the 2-mm incision. Fluorescein-stained saline is injected through the minitrephines, and this allows accurate identification of the frontal ostia, and as long as surgery is anterior and lateral to the fluorescein, the skull base should be safe.

Once the other sinus surgery is complete, surgery on the frontal sinuses can begin. Our first step is to place bilateral minitrephines into the frontal sinuses to allow for fluorescein-stained saline to be flushed through the sinuses (Fig. 11.5). This is not done if there is a malignant tumor in the frontal sinuses as this would create a risk of seeding the tumor into the skin. This flushing of fluorescein through the frontal ostium allows accurate identification of the natural ostium. The fluorescein can then be followed into the frontal sinuses. If the surgeon stays anterior to the fluorescein, then the drill should be anterior of the skull base. The first landmark that the surgeon should identify is the skin of the nasal bridge or the superior aspect of the lacrimal sac. Drilling proceeds using a 0-degree endoscope and a 3-mm straight cutting burr. Bone is removed superolaterally until the white of the periosteum is seen. The skin is depressed, and this periosteum moves with this maneuver indicating that the lateral extent of the bone removal has been reached. This is done as the first step on both sides. Bone removal continues until the floor of the frontal sinus is opened (Fig. 11.6). However, until the olfactory neurons are visualized, the drill should not be used on the medial aspect of the frontal ostium. Once the bone removal extends above the olfactory neurons, drilling can be continued medially and the two frontal sinuses connected in the midline by taking down the intersinus septum (Fig. 11.4). The next step is to positively identify the skull base. This is done in two ways so that there can be no mistake as to the location of the olfactory fibers as they pass through the very anterior cribiform plate (Fig. 11.7). Firstly, the suction is used to develop the plane between mucosa and bone in the vault just anterior to the skull base where the middle turbinate articulates with the skull base. The mucosa is pushed posteriorly until the first olfactory fiber comes into view. This is repeated.
on the opposite side. This olfactory fiber indicates the level of the skull base. This level is confirmed with image guidance. The image guidance probe is moved from the posterior wall of the frontal sinus inferiorly passing the level of the olfactory neurons. The axial scan is watched on the image guidance, and the forward projection of the skull base is identified. The bone of the frontal T (T is formed by the two middle turbinates and septum) can be lowered to the first olfactory fiber. Once this is completed, the endoscope is changed from a 0-degree to a 30- or 45-degree and the burr changed from a straight 3-mm round cutting burr to a 40-degree-angled cutting burr, and the anterior bone of the frontal beak is removed until the anterior wall of the frontal sinus runs smoothly out into the nose with no lip or ridge present. This maximizes the anterior–posterior diameter of the new frontal ostium.

The frontal sinuses should be completely accessible through this maximally enlarged new frontal ostium. Angled blades and burrs can now reach even the furthest extent of the frontal sinuses including the lateral recess (Fig. 11.8). Tumor removal now commences with either a blade or burr depending upon the consistency of the tumor. In the case of inverting papilloma, all the mucosa from the region of the tumor is removed and the underlying bone drilled with a coarse diamond burr (Fig. 11.9). The burr is run lightly over the bone making certain that any new bone formation or small holes where tumor can reside are removed. Osteomas are best removed with high-speed skull base burrs that run at 60,000 RPM. These burrs have significantly increased cutting power and remove ivory hard osteomas more effectively. Because they do not have inbuilt suction, a second surgeon may be required to provide constant suction to keep the surgical field clear and visible at all times.

**FIGURE 11.7**
The mucosa in the olfactory fossa is pushed inferiorly until the first olfactory fiber (arrow) is identified. This indicates the anterior projection of the skull base. Once this landmark is identified, drilling can proceed medially above these neurons with joining of the two sides. (S, nasal septum; MT, middle turbinate.)

**FIGURE 11.8**
The frontal sinus is exposed, and the inverting papilloma can be clearly seen in the left frontal sinus. This is completely removed and the underlying bone lightly drilled with a diamond burr to remove any residual fragments of mucosa in the bone.
FIGURE 11.9
The bone of the frontal recess and frontal sinus on the left has been drilled with a diamond burr to ensure complete removal of the inverting papilloma from this region.

POSTOPERATIVE MANAGEMENT

The patient can go home the same day or the following morning. Postoperative care includes oral amoxicillin/clavulanic acid for 2 to 3 weeks, analgesia, and a 3-week tapering course of oral prednisolone in all patients who had nasal polyposis. The following day, the patients begin to use saline nasal washes four to six times a day to help remove blood clots and improve healing.

COMPLICATIONS

Major complications are CSF leak and injury to the orbit. The incidence of these complications is less than 1% and similar to those seen in standard endoscopic sinus surgery. CSF leaks should be addressed at the time of the complication, and closure is done with a bath plug of adipose tissue, or if the defect is larger than 1 cm, a multilayer closure usually with a pedicled septal flap. Injury to the orbit can occur if the lamina papyracea is removed during tumor removal. This may result in prolapse of orbital adipose tissue, which is best left alone, but if the periosteal injury occurs in the floor of the frontal sinus, it may involve the trochlea of the superior oblique muscle. If this is damaged or if fibrosis develops in the trochlea postoperatively, then the patient may develop Brown syndrome, which is a limitation of upward and outward gaze in that eye. In most cases, it is not treatable, but early recognition and involvement of oculoplastic surgery may improve the outcome.

RESULTS

Endoscopic frontal sinus surgery is very effective for the treatment of inflammatory disease and has largely supplanted external approaches for the treatment of uncomplicated disease. Even patients who have failed osteoplastic obliteration of the frontal sinus can often be salvaged with endoscopic drainage of mucoceles and mucopyoceles. Patency of the neo-ostium is maintained in 80% to 90% of cases. Patients with aggressive nasal polyposis, especially those with asthma or aspirin intolerance, have a lower recurrence rate of disease (and need for revision surgery) with a Draf 3 drill-out procedure compared to standard endoscopic frontal sinusotomy.

There are multiple reports in the medical literature demonstrating the effectiveness of endoscopic techniques for the treatment of osteomas and inverted papillomas involving the frontal sinus. Recurrence rates are comparable to open approaches with few complications and minimal side effects.

PEARLS

- CT and, in some cases, MRI scans are needed for preoperative planning.
- If both CT and MRI have been performed, then these should be merged on the image guidance to allow appreciation of how the bone of the skull base and soft tissue of the tumor relate.
- Closure should be planned preoperatively including a decision as to whether a septal flap will be used.
- The first landmark for the drill-out is to find the skin under the frontal process of the maxilla, thereby identifying the lateral landmark.
The drill-out is usually performed with a 0-degree scope.

- The olfactory neurons mark the anterior extension of the cribiform plate, and they should be identified.
- The anterior wall on the neo-frontal ostium should be drilled away until the anterior wall of the frontal sinus runs smoothly out of the sinus into the nose without any bony ridge.

**PITFALLS**

- Failure to develop a septal window sufficient for an instrument to be passed from the one side of the nose across the septum and under the axilla of the middle turbinate on the opposite side will not provide adequate exposure. The anterior edge of the septal window should allow an instrument to be passed from one side onto the frontal process of the maxilla on the opposite side. The posterior margin of the window should be the anterior edge of the middle turbinates.
- Failure to extend the window onto the nasal vault will restrict the access for the final stages of opening of the frontal sinus.
- A unilateral approach limits lateral access. Both the scope and instrument should go from one side across the septum to the opposite side to achieve the best and safest angle for dissection.

**INSTRUMENTS TO HAVE AVAILABLE**

- Standard endoscopic sinus surgery instruments
- Image guidance
- Powered endoscopic drill with irrigation and suction
- Straight and angled burrs for the drill
- Frontal sinus minitrephine kit

**SUGGESTED READING**

INTRODUCTION

Guiot first proposed using the endoscope for transsphenoidal procedures in 1957, and Apuzzo reported this approach in 1977. However, it was not until 1984 that Griffith and Veerappen used the pure endonasal technique to resect a pituitary adenoma of the sella. Jho, a neurosurgeon, began to define this purely endoscopic technique in 1997 by working with the otolaryngologists Carrau and Snyderman. However, it was not until 2001 that Jho reported the first endoscopic, endonasal resection of an intracranial meningioma compressing the optic nerve. Other neurosurgeons, such as DeDivittis and Cappabianca, have adopted and refined these techniques, widening their acceptance. Kelly, in 2004, reported on three patients in whom the endoscopic endonasal approach was used to resect suprasellar meningiomas with good short-term results, in this case using an endoscopic-assisted approach.

There remains controversy about the use of the endoscopic technique for suprasellar meningiomas because of concern for vascular involvement or adherence. However, all of these approaches, starting with the transsphenoidal approach to the sella, are based on the simple anatomic relationship of the tumor and its region of origin with the sinus(es) used for access. A natural extension of this concept is using the ethmoid sinuses as a corridor to access the entire anterior cranial fossa.

Yuen, also in 1997, described an endoscopic-assisted craniofacial resection applying the principles and instruments developed for inflammatory endoscopic sinus surgery to surgically address a malignant neoplasm. Stammberger described a completely endoscopic resection of an esthesioneuroblastoma (ENB) in 1999. Since then, multiple case series have documented good results following endoscopic resection of ENBs and other neoplasms of the skull base. These surgeons and others began working regularly as surgical teams of otolaryngologists and neurosurgeons to advance the field and refine these approaches. Not only were tumors of sinus origin such as ENBs being addressed, but tumors with even more significant intracranial extension and origin involving the anterior cranial base, such as meningiomas, were increasingly being shown to be safely accessible.

Adoption of the transcribriform approach has lagged behind that of extended transsphenoidal approaches, possibly due to the lack of adequate transnasal access to the area using a microscope, due to the difficulties with reconstruction, and partly due to the need for a surgical team composed of an otolaryngologist and neurosurgeon. The addition of an endoscope and its application by otolaryngologists and neurosurgeons working together to cross areas of anatomic understanding has allowed some surgical teams to resect most tumors involving the anterior cranial base.

HISTORY

Patients with tumors of the anterior cranial base can present with varying signs and symptoms, depending on the origin and extension of the tumor. Meningiomas can have subtle presentations with gradual loss of cognitive function and inhibition and are often mistaken as dementia. Personality changes and memory difficulties
are often the most identifiable symptoms, even though they often go unrecognized by the patient. As a result, it is important to try to discuss these symptoms with family members or friends who may have noticed subtle changes that can only be identified retrospectively. Patients may become increasingly short tempered, impatient, or disinhibited. Alternatively, abulia may be the overriding presentation and often goes completely unnoticed.

Vision changes (blurred or double vision or loss of vision), headache, loss of taste or smell, and epistaxis are more objective symptoms that can help guide diagnosis and treatment. The period of onset and rapidity of progression also provide important clues and suggest malignancy, though indolent tumors such as meningiomas can reach a critical mass where they rapidly create more noticeable symptoms.

**PHYSICAL EXAMINATION**

A full neurologic examination is critical to look for other signs of involvement. Many more aggressive sinonasal tumors can have occult cranial nerve involvement that is not readily apparent radiographically. Very large tumors or those with significant associated edema can cause papilledema and associated vision loss. This is classically described in Foster Kennedy syndrome, where direct compression causes optic atrophy on one side with a central scotoma, while mass effect and edema result in papilledema on the other. It is also associated with anosmia and cognitive deficits. Full neuro-ophthalmologic evaluation is important to assess for papilledema as early cerebrospinal fluid (CSF) diversion or tumor treatment can prevent long-term loss of vision. In addition, until the increased intracranial pressure is resolved, the risk of postoperative complications associated with failure of reconstruction (such as CSF leak) is increased. Careful examination can also detect signs of orbital involvement such as proptosis.

Sinonasal tumors are more likely to cause anosmia than are meningiomas, but any tumor that involves the cribiform plate can affect smell and taste. These can be tested in the office with coffee or nonnoxious items. The degree of olfactory loss can be quantified with a “scratch and sniff” olfactory test (Sensonics, Inc., Haddon Heights, NJ). Nasal endoscopy for sinonasal tumors can add valuable information about involvement of nasal structures or the presence of associated infection that can affect the route of approach or timing of surgery.

**INDICATIONS**

The indications for surgical treatment depend upon multiple factors, including the diagnosis and biologic behavior of the neoplasm, stage of disease, patient comorbidities, patient preference, and prior treatment. Often, biopsy of sinonasal tumors can be done preoperatively by an otolaryngologist under endoscopic guidance in the office. Imaging is recommended prior to biopsy, though, to ensure that overly vascular tumors are not biopsied in a setting in which they cannot be controlled or appropriately managed. With the aid of a skilled skull base radiologist, the differential diagnosis can usually be narrowed enough to guide management in combination with intraoperative pathologic examination/confirmation. Generally, low-grade malignant tumors and high-grade neoplasms that are early stage are initially treated with surgical excision followed by adjuvant radiotherapy if indicated. Unresectable malignant tumors, high-grade tumors, or those with distant metastases are treated initially with radiation therapy ± chemotherapy. Alternatively, aggressive extradural debulking of the tumor can be performed at the time of the biopsy to relieve symptoms and decrease symptoms from nasal obstruction, orbital compression, or neural involvement or to provide decreased tumor burden prior to radiation and/or chemotherapy (though this is of unproven benefit).

The majority of midline tumors of the anterior cranial base can be addressed endonasally depending upon their extension and neurovascular involvement/relationships. Complete removal with negative margins is the goal for the treatment of malignant sinonasal tumors. This can generally be accomplished equally well endonasally as with open or combined approaches. No approach provides true “en bloc” removal, and the confirmation of histologically negative margins is critical. There are no long-term data available addressing purely endonasal resection of ENBs, but there is growing experience suggesting equivalence for tumor control. It is important to have a surgical team capable of combining an open approach for tumor extension beyond the reach of an endonasal approach, such as superiorly behind the frontal sinus or laterally past the midorbit. The approach should not limit the ability to achieve clear surgical margins.

Tumors such as olfactory groove meningiomas are generally best treated with resection if they are symptomatic from mass effect on either the frontal lobes or optic nerves. In addition, if there is radiographic evidence of frontal lobe or optic compression, resection is indicated as the primary treatment, even if the patient is minimally symptomatic, unless their comorbidities dictate otherwise. If tumors appear benign and are small and incidental, radiosurgery could be considered as the initial treatment, though a period of observation is usually warranted for these tumors in reliable patients given their typically indolent growth curve.

Complete resection of olfactory meningiomas can often be achieved via an endonasal approach, depending upon lateral extension and vascular involvement. If there is tumor extension beyond the meridian of the midorbit, consideration should be given to an open approach to ensure complete removal. In older patients with significant comorbidities, it is often reasonable to achieve subtotal or near-total resection. In these cases, symptom relief by removing mass effect rather than cure becomes the primary goal.
CONTRAINDICATIONS

Other than an active sinus infection, there are few absolute contraindications to an endoscopic endonasal approach. The infection can usually be treated with antibiotics with minor delay of surgery. Sometimes, however, surgical treatment of sinus disease is required for adequate drainage. At other times, infection is associated with tumor involvement and obstruction of natural drainage pathways. In these cases, partial tumor resection to allow drainage may be necessary with judgment required to determine delay of intradural tumor resection, depending on the urgency of patient symptomatology, tumor growth, or need for other treatment.

Preservation of olfaction is rarely possible with tumors that extensively involve the anterior cranial base. Indeed, resection of ENBs with skull base involvement includes both olfactory tracts and bulbs, thereby destroying all olfaction. Small, early-stage tumors can sometimes be removed endonasally with preservation of olfaction on the contralateral side, but oncologic margins should never be compromised to preserve olfaction. Small, unilateral planum or olfactory meningiomas likely carry greater risk of olfactory compromise when approached endonasally. This risk should be clarified with patients as part of the discussion of resection options and compared with the potential complications associated with frontal lobe retraction or manipulation associated with open, transcranial approaches.

Dense fibrous tumor tissue and vascularity are NOT contraindications to an endonasal resection. In fact, most of the same instruments and devices available for tumor debulking and coagulation that are available with open approaches are also available with extended shafts, pistol grips, or thin tips for endonasal use. The wide exposures provided with expanded approaches allow the use of these instruments in the same fashion as an open approach.

Encasement of the anterior cerebral vasculature is a relative contraindication and source of controversy. Certainly, if a tumor has contact with or encasement of arteries, resection becomes more difficult and requires a team that is more advanced in their learning curve. Microdissection techniques can be applied endonasally in the same way they are from an open approach. Arterial repair with suture is not an option via an endonasal approach, but, given the caliber of the vessels involved, it is unlikely that salvage of an injured vessel with suture is likely regardless of approach. Microclips and bipolar partial coagulation remain good strategies to employ in this situation. Nevertheless, this group of tumors should be approached in the way that the surgical team feels most comfortable.

The true advantage of the endonasal approach is the displacement of neurovascular structures to the outside of the tumor, minimizing or completely avoiding all manipulation of these structures. The only limitations are tumor extension beyond these, such as lateral to the bifurcation of the ICA. Most tumors of the anterior skull base do not extend past the optic chiasm but rather elevate it. Therefore, the only limitations are, anterosuperiorly, into the upper frontal sinuses and associated dura or, laterally, past the meridian of the orbit. By removing the lamina papyracea, the periorbita can be safely retracted laterally to allow access to tumor or involved dura extending over the orbit. The limitation becomes the vertical plane of the optic nerve (the midorbit). Most importantly, oncologic principles, especially that of negative margins, must not be compromised by the approach. This may require combining an endonasal approach with an open approach, especially if the tumor or resection margin extends beyond the midorbit or into the frontal sinus or associated dura.

PREOPERATIVE PLANNING

Tumors of the anterior skull base should be thoroughly evaluated with both MRI and CT angiography (CTA). MRI is helpful to determine the degree of involvement of the skull base and sinuses as well as demonstrating associated frontal lobe edema. CTA is often more valuable, though, as it demonstrates osseous changes in the anterior skull base, involvement and erosion of the skull base and orbit (lamina papyracea), and vascular relationships with the tumor (Fig. 12.1). These studies can also be used intraoperatively with image guidance.

FIGURE 12.1
Sagittal CT (computed tomography) angiogram showing the relationship of the anterior cerebral arteries (arrow) with a large olfactory groove meningioma. Notice also the hyperostosis (dashed arrow) of the planum.

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Preoperative embolization is not necessary for most tumors of the anterior skull base when the tumor is approached endonasally. The main blood supply is usually the anterior and/or posterior ethmoid arteries. These are easily accessed during an endoscopic endonasal approach, providing good control and early devascularization.

If the patient has significant papilledema, especially when associated with ventriculomegaly, ventriculoperitoneal shunt placement should be considered to allow for maximum decompression and preservation of vision while awaiting resolution of cerebral edema and also to assist with healing of the resultant skull base defect following tumor removal.

**SURGICAL TECHNIQUE (VIDEO 12.1)**

Positioning is critical for an endoscopic approach to the cribriform area. The patient’s head must be adequately extended to allow access to the anterior-most aspect of the anterior cranial base without the operator’s hands and instruments colliding with the patient’s chest. This will also help the flap or reconstruction graft to stay in place with gravity as an aid during placement.

The major advantage of an endonasal approach to the anterior skull base is based on the fact that the tumor originates from, involves, or is in contact with the skull base directly adjacent to the ethmoid sinuses. Therefore, the approach is via a tailored ethmoidectomy. This can range from sphenoethmoidectomy and posterior ethmoidectomy for access to the planum sphenoidale to full anterior and posterior ethmoidectomies with frontal sinusotomy. Lateral extension can be accessed by adding maxillary antrostomies and removal of the laminae papyraceae. When in doubt, wider exposure and access is always valuable as it improves the visualization, orientation, and working room. If a tumor extends close to the posterior table of the frontal sinus, a frontal sinusotomy (Lothrop or Draf 3) should be performed. This significantly improves orientation by providing a clear anterior border/landmark and may prevent postoperative obstruction of the frontal sinus.

The technique for reconstruction must be planned prior to the surgery. With aggressive malignancies such as many cancers of the sinonasal tract, a nasal septal flap is not a good option due to possible tumor involvement. However, in select ENBs, if there is a radiographic, gross endoscopic, and histopathologically negative margin on a contralateral septal flap, it can be used. If the flap is inadequate for complete coverage, it can be supplemented by a nonvascularized autograft such as fascia lata or allograft-like cadaveric dermis (Alloderm) covering the entire defect with the vascularized flap overlying (superficial to) a portion of this graft. The vascularized flap seems to greatly improve healing of the nonvascularized portion. Otherwise, an extracranial pericranial flap should be planned and used without hesitation (Fig. 12.2). This flap can be placed “extracranially” without a craniotomy by passing it through an opening at the level of the nasion below the plane of the skull base (in contrast to a traditional pericranial flap that is technically intracranial).

Once tailored sphenoethmoidectomies have been performed, the overlying skull base can be removed. The first step in this is to locate, control, and ligate the ethmoid arteries (Fig. 12.3). This also serves to devascularize the tumor as these vessels typically supply the vast majority of any cribriform tumor. The posterior ethmoid artery can be found approximately one-half centimeter anterior to the optic nerve, and it runs slightly posteriorly as it passes from lateral to medial. The anterior ethmoid artery (AEA) (which runs obliquely anteriorly as it passes from lateral to medial) can also be located by removing adjacent lamina papyracea and ligating the artery at its exiting foramen. Care should be taken to completely coagulate the stump of the ethmoid arteries to avoid postoperative retrobulbar hematoma. Once the arteries are controlled, osteotomies can be performed bilaterally with a high-speed drill and coarse diamond burr just medial to the orbit (Fig. 12.4). These are connected posteriorly across the planum sphenoidale or tuberculum sellae as needed. Finally, anterior osteotomies are made just behind the posterior wall of the frontal sinus, extending to the crista galli. Once complete, these will allow bilateral anterior cranial plates, separated by the cribriform plate, to be dissected free from the overlying dura and removed. The planum sphenoidale and tuberculum sellae may be removed separately.

Removal of bone laterally can be extended with a 45-degree Kerrison rongeur to the midorbit if the lamina papyracea has been removed. This will allow complete exposure of all involved dura in most cases, thereby

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**FIGURE 12.2**

Intraoperative photographs showing a vascularized pericranial flap (PF) after harvest (A) and after tunneling through a nasion osteotomy (B). Arrow points to edge of osteotomy.
obviating the need for an open approach. The dura and bulky tumor can now be coagulated with pistol-grip bipolar electrocautery to maximize hemostasis and tumor devascularization. Finally, the crista galli can be dissected free and then removed with either a drill and dissectors or Kerrison rongeur, depending upon the height. Ideally, the dura will be dissected free before the crista galli is detached, as this dissection becomes much more difficult once it is free floating.

Dura is opened just medial to the lamina papyracea (lateral to the olfactory nerve in an anterior craniofacial resection and in the middle of one side of an olfactory groove meningioma). For meningiomas, this should be done bilaterally up to the falx for maximal debulking and then coagulated and cut. Care should be taken not to expose the anterior frontal lobes until late in the operation, as they can sag downward obscuring the view. During an anterior craniofacial resection (e.g., ENB), the dura is opened from lateral to medial up to the falx at the level of the crista galli before the incision is extended posterior to the planum. The falx will then need to be coagulated and transected, angling posteriorly in order to avoid following it up the posterior wall of the frontal sinus.

Extracapsular dissection of the tumor is now performed. With ENBs and other sinonasal malignancies, the olfactory nerves and tracts should be resected with the dura, carefully dissected free from the overlying frontal lobe vasculature. They are transected posteriorly at the level of the planum along with the dura (Fig. 12.5).

Surgical margins of the dura are then examined histologically to ensure complete, microscopic resection. When excising olfactory groove meningiomas, the tumor is carefully rolled inward, using a Cottonoid patty, dissector, or gentle suction to develop a plane between the tumor and the overlying, compressed, gliotic cortex. Laterally, an angled endoscope improves visualization and can help avoid unnecessary venous bleeding. As the dissection proceeds posteriorly, the anterior cerebral arteries (ACAs) become a concern, and proximal control should be gained by dissecting the planum/tuberculum portion of the tumor until these arteries are identified. Further extracapsular dissection can then take place with care and knowledge of their location. If necessary, a small amount of tumor capsule can be left on the anterior communicating complex to avoid injury to the small but critical perforators such as the artery of Huebner.

Reconstruction begins with the placement of an inlay Duragen graft, often draped slightly over the remaining falx. The patient’s head must be in adequate extension so that gravity will hold each layer in place. The entire defect is then covered with a vascularized flap or a free graft; the flap must be in contact with either bone or soft tissue edge circumferentially to heal. Care should be taken to ensure that the pedicle of the flap is in contact with the lateral nasal wall or sinus along its entire course to prevent contraction. Often, turning the flap so that the pedicle runs up the ipsilateral lateral nasal wall provides the best option, with the flap lying obliquely. If an extracranial pericranial flap is used (see Video 12.2), it should be tucked between the orbits and overlying dura for separation. Surgicel and tissue glue are placed along the edges followed by Gelfoam and usually Merocel tampons. A Foley balloon often does not fit well in this rectangular defect.
POSTOPERATIVE MANAGEMENT

Nasal packing (either Foley balloon or Merocel tampons, depending on the size or shape of the defect) is removed approximately 7 days postoperatively following intradural surgery. One to two days of intravenous broad-spectrum antibiotics is recommended, but patients should be maintained on appropriate antibiotics (generally oral cephalosporins or equivalent antibiotic to cover nasal flora) as long as the packing is in place to avoid toxic shock or other associated infection. Once the packing is removed, endoscopy is performed in the outpatient setting to look for an overt CSF leak or defect. The flap should be pulsatile, and, generally, little debridement is performed at this time.

Repeat endoscopy is then performed 3 weeks postoperatively, at the same time that the Silastic nasal splints are removed. More vigorous debridement can be performed at this point to remove any remaining foreign substances such as residual tissue glue or Gelfoam. Crusts are generally allowed to heal without disturbance.

Thromboembolic complications are common, and patients should be routinely monitored for venous thrombosis in an attempt to avoid pulmonary embolus. Subcutaneous heparin can be started safely as early as 24 hours postoperatively in high-risk patients (immobilized or known hypercoagulable states).

COMPLICATIONS

Intraoperative arterial injury is perhaps the most dreaded endoscopic endonasal complication. This is most likely to occur when tumors of the anterior cranial base involve or encase the anterior cerebral arteries. Avoidance of injury is best achieved by strict maintenance of standard microsurgical dissection technique. Significant debulking and sequential extracapsular dissection are performed prior to dissecting the tumor from the arteries.

CSF leak is the best known complication of skull base resection, especially endonasal surgery. Vascularized reconstruction is key to rapid healing and maintaining a low rate of postoperative CSF leak. In many cases, a large nasal septal flap can be raised, but when this is not available, an extracranial pericranial flap provides a good alternative. If a CSF leak or pneumocephalus occurs (typically after packing is removed), it should be re-explored immediately to prevent further complication. With an obvious leak or increase in pneumocephalus, CSF diversion alone is not advisable as it is unlikely to resolve the fistula and may exacerbate the problem by entraining air. Removal of remaining absorbable packing such as tissue glues and Gelfoam will allow thorough inspection to locate the site of the leak. Often, a simple adjustment of the position of the flap is all that is needed, but augmentation with an adipose tissue graft or suture/clip may be needed if there is a pinhole defect in the flap itself. If the flap is inadequate due to retraction or septal perforation, Alloderm or other allograft material can be placed to cover the entire defect before replacing the vascularized flap over it.

Close collaboration between the otolaryngologist and the neurosurgeon remains critical in the postoperative period to remain vigilant for complications. Infectious complications such as sinusitis should be treated promptly to avoid meningitis. Epistaxis is a rare but known complication. Intracranial arterial dissection during tumor removal should be kept in mind as a possible source for postoperative epistaxis. Other hemorrhagic complications include retrobulbar hematoma from avulsion of the ethmoid artery or inadequate coagulation/ligation. Treatment of this should prompt an ophthalmology consultation and may require a canthal release to relieve pressure.

The usual postoperative complications can and do occur following endonasal skull base surgery as happens with traditional approaches. Patients can be safely anticoagulated as early as the first postoperative day in the event of thromboembolism. Obviously, this should be done with care without boluses and with slightly lower levels of anticoagulation. Seizures seem to occur at a lower rate than with traditional approaches, though this has never been thoroughly studied. Anticonvulsant therapy can often be avoided altogether in patients undergoing endoscopic anterior craniofacial resection for meningioma or sinonasal malignancy without significant cerebral edema.

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RESULTS

We recently performed a preliminary review of 35 patients who underwent endoscopic endonasal resection of ENB at the University of Pittsburgh Medical Center (UPMC) over a period of 9 years. The Kadish classification, reconstruction, postoperative complications, adjuvant treatment, and outcomes were analyzed.

The mean age at the time of the surgery was 48 years (16–79), and 60% were male. The majority of patients were Kadish C (63%); 34% were Kadish B, 3% Kadish A, and 0% Kadish D. Two patients required a combined open and endoscopic approach to achieve negative dural margins. The majority of reconstructions were done with a septal flap (57%) and/or pericranial flap (17%). In 14%, no reconstruction was done as dural resection was not needed. Lumbar drainage was used in only five patients (14%). Postoperative complications occurred in 21% of the patients including diplopia (6%), CSF leak/meningitis (3%), epistaxis (3%), intracranial hematoma (3%), orbital emphysema (3%), and cosmetic deformity from a pericranial flap (3%). Postoperatively, 63% received radiation therapy, and 14% received chemotherapy. Negative margins were achieved in 94% of patients. Local/regional recurrence occurred in one patient (3%) and regional recurrence in one patient (3%). The mean follow-up period was 35 months (1–110), and 100% are currently disease-free after surgical salvage. This represents a preliminary review with short follow-up that will need to be peer-reviewed.

Devaiah and Andreoli performed a meta-analysis of available literature to compare EES with open surgery and found that there were greater published survival rates with endoscopic surgery in 361 patients ($p = 0.0019$).

EES was similarly evaluated for the removal of 44 olfactory groove meningiomas between November 2002 and February 2012 at the UPMC. Gross total resection (GTR) was achieved in 24 (54.5%) patients (Fig. 12.6), and 7 more (15.9%) were near total. The remaining 13 patients (29.5%) had a subtotal resection. The majority of these were intentional subtotal removals in elderly patients, but one was due to vascular injury and one due

**FIGURE 12.6**

Preoperative coronal postcontrast, T1-weighted MRI (A) and sagittal CT angiogram (B) showing a medium-sized olfactory groove meningioma. Postoperative coronal (C) and sagittal (D), postcontrast, T1-weighted MRI showing complete resection of the olfactory groove meningioma. Note the enhancing nasoseptal flap (arrow).
to poor visualization from venous bleeding very early in our experience. Tumors were removed in 2 stages in 16
(36.4%) patients. The GTR rates increased over time, from 48% to 69%, demonstrating a learning curve with
this approach.

The most common complication was a CSF leak, occurring in 17 patients (39%), but this has decreased
significantly in recent years with the use of the vascularized nasal septal flap. Three patients subsequently
developed meningitis and one a frontal abscess from superinfection of a Teflon granuloma. All were treated
without further neurologic sequelae. There were two major complications: one intraoperative anterior cerebral
injury, which suffered a rupture of a delayed pseudoaneurysm requiring craniotomy and endovascular
treatment, and the second an octogenarian patient with a large planum/olfactory meningiomas who developed
apparent vasospasm and multiple, distant vascular territory infarcts.

PEARLS

- Perform a full frontal sinusotomy (Draf 3 or Lothrop) for any tumor with extension close to the frontal sinus
as this provides a reliable anterior anatomic landmark.
- Coagulation and ligation of the ethmoid arteries provides early devascularization of any tumor of the anterior
cranial base.
- Vascularized reconstruction, such as a nasal septal flap, extracranial pericranial flap, or a combination,
should be used whenever possible.
- Removal of the lamina papyracea provides additional lateral access out to the coronal level of the midorbit
by retraction of the periorbita.
- The removal of large, benign tumors can often be staged to decrease single anesthesia time, blood loss, and
surgeon fatigue.

PITFALLS

- Tumors with intracranial vascular involvement should be approached with caution since intracranial dissec-
tion requires a surgical team with significant experience with endonasal dissection.
- Endoscopic anterior craniofacial resection should not limit the margins of resection and should be used in
combination with open approaches whenever necessary for oncologic purposes.

INSTRUMENTS TO HAVE AVAILABLE

- A full set of sinus instruments
- High-speed drill
- Zero- and 45-degree endoscopes
- A microdebrider
- Fine and angled tip, pistol-grip bilars (Storz) are critical for extra- and intradural hemostasis.
- Extendable tip neurodissectors (KLS Martin)
- Fine, pistol-grip microscissors (Storz)
- CUSA (Integra) and Sonopet (Stryker) ultrasonic aspirators, both with extended tips

SUGGESTED READING

INTRODUCTION

The transsphenoidal approach to the ventral midline skull base was first proposed more than a century ago. However, only recently, following the introduction and development of rigid endoscopes, appropriate micro-bayonetted instrumentation, and the development of the extended transsphenoidal approaches has the transsphenoidal approach become an accepted standard method of reaching the suprasellar cistern and adjacent intracranial spaces. Several other key developments have led to the widespread acceptance of extended transsphenoidal approaches. The use of neuronavigation has been critical to allow the surgeon real-time updated anatomic information about the location of key anatomic structures. Likewise, the development of techniques to close large openings in the midline skull base endonasally, such as the gasket seal, the button, and the nasoseptal flap, has been critical in keeping the complication rate acceptably low.

Several pioneering groups have published anatomical cadaver studies, case series, and conceptual articles illustrating the possibilities with a purely endonasal endoscopic approach to remove a variety of lesions throughout the cranial base, third ventricle, and subarachnoid cisterns. The endoscopic approaches were heralded for being minimally invasive and enabling the surgeon to approach ventrally located lesions from a ventral trajectory. These approaches avoided the inherent risks of transcranial surgery mainly related to brain retraction and manipulation of neurovascular structures. The endoscopic endonasal transplanum and transtuberculum approach to the suprasellar cistern is the most direct route to the region that avoids manipulation of the optic nerves and carotid artery. The key to the success of this “minimal access” but maximally aggressive approach is in careful case selection. If appropriate cases are selected, then outcomes can be excellent. Likewise, the appreciation, anticipation, and understanding of possible complications and pitfalls ensure the safety of the procedure. We will try to outline these critical factors in this chapter.

HISTORY

A careful history must be performed. Key points to cover include the possibility of visual loss or compromise indicating compression of the chiasm. In addition, limited mobility of the eyes and diplopia may indicate cavernous sinus involvement. Numbness or pain in the face in V1, V2, or V3 distribution may be a key indicator of fifth nerve involvement. Endocrine function should be evaluated as well such as polyuria, polydipsia, enlargement of the hands or feet, temperature intolerance, weight gain and weight loss, or short stature. Headaches can also be important for certain suprasellar lesions such as the Rathke cleft cysts and may indicate pressure within the sella or even early hydrocephalus if the headaches are worse in the morning.
PHYSICAL EXAMINATION

A detailed physical examination should include an examination of the cranial nerves, ophthalmologic evaluation along with visual field testing, assessment of cognitive function, and endoscopic examination of the nasal cavity.

INDICATIONS

- Pituitary adenomas with a significant suprasellar extension. Tumors that extend above the planum sphenoidale (PS) more than 1 cm or have any anterior extension over the planum and in front of the tuberculum may benefit from removal of the tuberculum sellae and a part of the PS. This will allow an extracapsular dissection of the tumor and ensure a complete resection.
- Craniopharyngiomas arise from the stalk and generally lie retrochiasmal in the third ventricle. Some craniopharyngiomas are sellar, and others can extend laterally. For tumors located in the midline and which do not have cysts lateral to the carotid arteries, the extended transplanum approach can afford an excellent corridor for their removal. Often, very little of the planum needs to be removed. The approach will be between the optic chiasm and the normal pituitary gland.
- Rathke cleft cysts also arise from the stalk and are located above the sella. Although some will descend into the sella, others will remain above.
- Chordomas arise in the clivus but may have significant suprasellar extension, which may require a transplanum approach to supplement the transclival approach.
- Meningiomas of the PS and tuberculum sellae and even some small meningiomas of the olfactory groove are amenable to endoscopic, endonasal transplanum resection. It is important to choose these cases carefully. Tumors that extend lateral to the carotid artery may not be suitable.
- Large tumors that cannot be completely resected using an endonasal approach are not always a contraindication. Depending on the age of the patient and the surgical goals, internal decompression or staged resection with an additional transcranial or cranoendoscopic approach may be appropriate.

CONTRAINDICATIONS

- Careful case selection is critical to the success of this minimal access approach. Pathology that extends laterally over the orbits or lateral to or behind the carotid arteries is difficult to remove using even extended endonasal transplanum approaches.
- Invasion of the cavernous sinus is not an absolute contraindication but requires careful preoperative evaluation of surgical goals. The surgeon may elect to enter the cavernous sinus to resect the tumor using a medial approach, understanding the additional risks to the neurovascular contents. Alternatively, the surgeon may opt for an intentional subtotal resection with planned stereotactic radiotherapy postoperatively, depending upon the pathology. Availability of an interventional neuroradiologist is critical in preparation for surgery around the carotid artery.
- Vascular encasement of the A2 branches of the anterior cerebral artery is not an absolute contraindication depending on the goals of the surgery. If microdissection can be performed to remove the tumor from the A2 branches, then surgery can proceed. Leaving residual tumor adherent to vessels may be appropriate.
- Edema within the brain or floor of the third ventricle is not an absolute contraindication. Careful dissection of the posterior margin of the tumor, which may invade the brain, may be required. Likewise, leaving tumor invading into the hypothalamus (craniopharyngioma) may be appropriate to preserve function.
- The differential diagnosis of large macroadenomas may include suprasellar lesions such as hypothalamic hamartomas, large intracranial aneurysms, and germ cell tumors, which may not be suitable for this approach. Such lesions require a very different workup and approach, and meticulous evaluation should be undertaken in appropriate patients to rule out such lesions preoperatively.

PREOPERATIVE PLANNING

- Patients with any visual symptoms or compression of the optic apparatus are referred to a neuroophthalmologist for complete neuro-ophthalmologic examination with visual field testing. Comprehensive endocrinologic testing is often indicated to establish baseline hormone production capability and deficiencies. An endocrinology referral may be indicated to establish a relationship for postoperative follow-up and
to determine whether an adequate stress response can be produced by the pituitary gland or whether cortisol replacement will be likely.

- Careful examination of the preoperative imaging is essential. Both CT and MRI can provide information. The location of the sphenoid sinus septations and their relative position with respect to the midline and the carotid arteries should be determined. The pneumatization of the sphenoid sinus should be understood, and the expected bony landmarks such as the carotid and optic protuberances can often be established from the preoperative imaging studies. The extent of the opening such as the amount of the ethmoid sinuses and planum that will have to be removed to adequately expose the entire base of the tumor should be determined. Septal perforations and spurs should be identified to establish whether a nasoseptal flap can be raised and from which sides of the septum or whether another type of flap will be required for closure. Invasion of the brain and vascular encasement can be determined from MRI scans.

**SURGICAL TECHNIQUE**

- Positioning and preparation (Fig. 13.1): Under general anesthesia with the patient in the supine position, antibiotics (2 g Ancef or 1 g vancomycin) and steroids (10 mg dexamethasone) are given. Steroids are held in the case of Cushing’s disease. For some large extended intracranial cases, we administer triple antibiotics, for example, vancomycin, a second-generation cephalosporin, and Flagyl. After placement of a urinary catheter and arterial line, a lumbar puncture is typically performed during which 10 mL of cerebrospinal fluid (CSF) is removed steriley, mixed with 0.2 mL of 10% fluorescein, and reinjected into the CSF. We find the use of intrathecal fluorescein useful in identifying CSF leaks, although this practice is optional and we pretreat with antihistamines prior to administration. In cases of extended skull base approaches for large lesions, a lumbar drain may be left in place to drain CSF postoperatively in order to prevent a CSF leak. For the limited endoscopic transsphenoidal approach, postoperative lumbar drainage is not routine. Cottonoids with 4 mL of 4% cocaine are placed in the nares to vasoconstrict the nasal mucosa. The patient is placed in a Mayfield head holder and pins, with the head elevated above the heart, slightly extended (approximately 10 to 15 degrees), and turned toward the patient’s right (approximately 5 degrees) (Fig. 13.2). The Mayfield head holder is used in order to maintain accurate neuronavigation during the case and to steady the head for microdissection in extended skull base procedures.

![FIGURE 13.1 OR setup. Operating room organization. Ergonomic setup of the equipment is essential as endoscopic procedures require nondirect tools for visualization (i.e., viewing screens and neuronavigation). The patient's head is positioned in the center of the operating room, angled slightly away from anesthesia. We use two projection screens to allow direct visualization by both the main operator and the assistant who stand on either side of the bed from each other. This is essential for extended endoscopic cases to avoid the need for either operator to continuously turn their head to see the projection screen. For a right-handed surgeon, the primary surgeon usually stands on the patient's right side. The navigation system is placed at the head of the bed so both surgeons can view the screen simultaneously.](image-url)
Alternatively, the head may be placed on a horseshoe with a headset or tripod-fixed reference marker for neuronavigation.

- Neuronavigation: Neuronavigation is not required but is highly recommended in endoscopic endonasal surgery. Navigation provides real-time information about the angle of approach through the endonasal corridor and allows the surgeon to tailor the approach to maximize visualization of pathology while minimizing required exposure and manipulation of vital neurovascular structures.
- For extended approaches in which a large skull base defect is anticipated, we prepare the thigh to harvest fascia lata. If only adipose tissue is required, such as for repairing a CSF leak after resection of an intrasellar lesion, the abdomen is prepared. We also prepare for harvesting a nasoseptal flap if a large skull base defect is anticipated.

Under 0-degree endoscopic view, the inferior, middle, and superior turbinates as well as the sphenoid ostia are identified bilaterally. The middle and superior turbinates are most often retracted laterally; however, in some patients, the middle turbinate is removed to optimize the exposure. A nasoseptal flap is elevated before the posterior septectomy is performed and covers an area extending from the floor of the nasal cavity under the middle turbinate superiorly to the septum adjacent to the nasal roof (Fig. 13.3). The flap is pedicled on the posterior nasal septal artery and is placed out of the way in the nasopharynx until it is needed for the closure.

The ostium of the sphenoid sinus is then enlarged to expose the sphenoid sinus, and the posterior third of the nasal septum adjacent to the vomer and maxillary crest is resected with a tissue shaver. The sphenoid sinus rostrum is fully exposed, and the floor and lateral wall of the sphenoid sinus are drilled down to facilitate placement of the nasoseptal flap at the end of the operation. The keel of the sphenoid is completely removed. All sphenoid septa are removed with a drill, and the mucosa of the sphenoid sinus is completely removed. Bleeding is stopped with either warm saline irrigation or Gelfoam. At this point, a 0-degree, 30-cm rigid 4-mm endoscope is introduced through the left nostril and held in place with a flexible scope holder. The carotid protuberance, optic protuberance, and medial and lateral opticocarotid recesses (LOCRs) are identified. The anterior and lateral extent of the sphenoidotomy is verified using intraoperative neuronavigation ensuring that optimal exposure is obtained in all dimensions before proceeding with progressively deeper exposure. Bilateral posterior ethmoidectomies are performed to adequately visualize the most anterior portion of the PS.

The bone over the tuberculum sellae is initially thinned with a high-speed diamond drill under constant irrigation. The opening extends between the medial opticocarotid recesses (MOCRs), and the inferior extent of the exposure can extend down to the clival recess. The opening is extended anteriorly above the level of the diaphragma sellae, and the PS is removed, the anterior extent of which is determined by using image guidance (Fig. 13.4). If necessary, the bone overlying the medial opticocarotid recess is then drilled using a diamond drill and copious irrigation to thin and remove the bone overlying the optic nerve dural sheaths. The optic nerve dura is unroofed bilaterally, and the bone overlying the carotid prominences is thinned with a drill and removed with Kerrison rongeurs (Fig. 13.4). The location of the carotid arteries is verified using a Doppler ultrasound probe. The dura above and below the superior intercavernous sinus is opened, and the sinus is coagulated and cut just medial to the cavernous sinus bilaterally. The diaphragma sellae is then incised and removed with microscissors. This maneuver is performed during the approach for craniopharyngiomas and macroadenomas. For tuberculum meningiomas, the diaphragm, which is often the site of origin of the tumor, is removed at the end of the operation to ensure a complete resection.

Large pituitary tumors, meningiomas, and craniopharyngiomas are immediately visualized once the dura is opened. Internal decompression is performed either with two upwardly curved suction or, if the tumor is firm, with an ultrasonic surgical aspirator, radiofrequency monopolar or ring cautery, or miniaturized microdebrider.
device as well as with microscissors. Visualization is enhanced with a 30-degree, 30-cm rigid 4-mm endoscope (Karl Storz). Once decompressed, the tumor capsule can be mobilized, and the anterior communicating artery complex and perforators are dissected sharply off of the tumor capsule. Care must be taken to preserve the recurrent artery of Heubner and the subchiasmatic perforating and hypophyseal vessels. The optic nerves and pituitary stalk are identified and dissected off the tumor capsule with preservation of the arachnoid membrane when possible. Avoidance of coagulation and “pulling” are critical to the preservation of vital neurovascular
structures while the remaining capsule is removed. The resection bed is examined with a 45-degree, 18-cm rigid 4-mm endoscope to ensure the absence of any residual tumor. Curved suctioners, angled microsurgical rongeurs, and dissectors can be used to reach residual pieces of tumor.

Tumor extensions behind the chiasm that extend into the third ventricle are dissected with the view provided by a 0-degree, 30-cm rigid 4-mm endoscope. The solid components are carefully dissected free from the optic chiasm and stalk. Internal decompression facilitates mobilization of the capsule for sharp dissection from the walls of the hypothalamus. It is important to visualize and preserve critical neurovascular structures such as the carotid arteries and hypothalamic and chiasmatic perforators. Once the tumor is partially removed, the location of the stalk may become apparent if it was previously obscured by tumor, and one can safely work on either side of the stalk if the gland is not mobilized. If invasion of the walls of the third ventricle is noted, it may be prudent to leave some wall of the capsule to prevent hypothalamic injury. Once the tumor and cyst wall are completely removed, the resection bed is examined with a 45-degree, 18-cm rigid 4-mm endoscope to ensure the absence of residual tumor. In most cases, the third ventricle ependyma including the foramen of Monro and aqueduct of Sylvius is clearly seen, and contents of the interpeduncular cistern are also apparent (Figs. 13.5 to 13.8).

**Multilayered Skull Base Closure**

The technique for reconstruction of the skull base starts with an inlay of an adipose tissue graft to fill any dead space and decrease the pooling of CSF. The next step is to create a “gasket-seal” closure. A piece of fascia lata, cut to be larger than the defect by about 1 cm circumferentially, is placed as an onlay, and then, a piece of Medpor, cut to be the same size as the defect, is countersunk into the fascia lata to hold it in place as a rigid buttress. The fascia lata should stick out circumferentially beyond the Medpor. This is then covered with a vascularized nasoseptal flap directly over the gasket-seal construct followed by a final layer of Duraseal to hold everything in place and ensure a watertight closure. No Duraseal is placed between the flap and the gasket-seal construct since it would prevent fibrosis and vascularization of the skull base. If a large sellar opening is performed as would be done to resect a giant macroadenoma, we do not use the gasket-seal technique since the curvature from the bottom of the sella to the front of the planum does not lend itself to a rigid buttress inlay. In this situation, we place adipose tissue in the sella, buttress it with Medpor, and cover it with a nasoseptal flap and Duraseal (Fig. 13.9). We then fill the nasal cavity with Floeseal (Baxter, Deerfield, IL) for hemostasis.

A small piece of Telfa is finally placed in each nostril overnight to absorb any drainage and is removed in 1 to 2 days. If a lumbar drain is placed intraoperatively, it is typically drained at approximately 5 mL per hour for 24 hours and then clamped and removed in the evening so the patient will lie flat after its removal during the night as they sleep to decrease the risk of spinal headache.

**POSTOPERATIVE MANAGEMENT**

- Patients are closely monitored in the ICU for the first 24 hours.
- Disorders of water balance and anterior pituitary endocrinopathies are by far the most common perioperative events, and their management is the most important aspect of the perioperative care of patients undergoing endonasal, endoscopic transsphenoidal neurosurgery.
- Urine output is monitored, and output greater than 250 mL per hour for 2 consecutive hours with specific gravity less than 1.005 should raise suspicion for diabetes insipidus (DI) and may require treatment with supplemental DDAVP.
- Elevated serum sodium indicates a free water deficit and requires fluid replacement, particularly in patients who are not able to drink to keep up with their fluid needs.
- DVT prophylaxis is important for patients who are immobile.
- Severe headache or mental status change should prompt a CT scan to rule out pneumocephalus.
- Salty taste in the back of the mouth or clear fluid running out of nose when the patient is sitting forward may indicate a CSF leak that requires treatment.
- Spiking fever and neck stiffness may indicate meningitis, which should be diagnosed with a lumbar puncture.
- Fasting AM cortisol off steroids prior to discharge will indicate the need for long-term steroid replacement.

**COMPLICATIONS**

- Complications can be divided into endocrine (hypopituitarism, DI), vascular (stroke, hemorrhage), CSF leak, infectious (meningitis, abscess), neurologic (visual loss, hemiparesis), nasal (crusting, sinusitis), and medical (DVT, PE, pneumonia, MI).
FIGURE 13.5 Surgery to remove a solid craniopharyngioma. A. The preoperative sagittal MRI scan with contrast shows an enhancing mass superior to the pituitary gland. B. After removing the bone and opening the dura, the mass is dissected free circumferentially from surrounding vasculature such as the superior hypophyseal artery. C. The tumor is attached to the bottom of the chiasm. D. Small remnant of tumor seen below chiasm in front of stalk. The basilar artery and posterior cerebral branches can be seen in the distance. E. The tumor has been removed from the undersurface of the chiasm. F. Close-up view of the stalk to the left with the basilar artery, posterior cerebral arteries, superior cerebellar arteries, and third nerves emerging between the two. The mammillary bodies can be seen just above the basilar apex. G. The defect in the skull base with the chiasm behind it. H. Gasket-seal closure of the skull base defect. Note the Medpor buttressing the fascia lata graft.
Meticulous surgical dissection to preserve the pituitary stalk and supporting vasculature is important to prevent postoperative DI.

Careful study of neurovascular anatomy on preoperative imaging studies is imperative to prevent intraoperative catastrophic neurovascular injuries.

Characteristics of the defect, type of tumor pathology, and volume of CSF leak influence the type of skull base reconstruction.

**FIGURE 13.6** Surgery to remove a suprasellar epidermoid. **A.** The preoperative sagittal MRI scan with contrast shows a mass above the pituitary gland. **B.** Transtuberculum, transplanum bone opening exposes the intact dura between the optic nerve canals. **C.** The dura is opened, and edges are cauterized. The green fluorescein–stained CSF is visualized as well as the white tumor. **D.** The pituitary stalk pushed laterally is seen below the optic nerve with adjacent small bits of tumor remnant. **E.** Tumor remnants medial to optic nerve. The adjacent carotid artery and A1 segments are easily seen. **F.** A Comm and both A2 branches are seen emerging from above the chiasm. **G.** The interhemispheric fissure and adjacent optic nerve. **H.** Gasket-seal closure of skull base.
● Intrathecal fluorescein can identify subtle CSF leaks and help improve skull base reconstruction, thereby preventing postoperative morbidity.
● Lumbar drainage, bed rest, and stool softeners can successfully treat the majority of postoperative small CSF leaks in the absence of pneumocephalus, assuming a meticulous multilayer closure of the skull base has been performed.
● Infectious complications are rare in endoscopic skull base surgery in the absence of a postoperative CSF leak. These may be reduced with 24 to 48 hours of antibiotics delivered in the perioperative period.
● Mucosal sparing surgery followed by routine and frequent postoperative care (topical nasal therapy, postoperative debridement) can significantly decrease sinonasal complications after endoscopic pituitary and skull base surgery.

RESULTS

The field of endoscopic endonasal skull base surgery has rapidly evolved because of technologic innovations and the development of operative techniques by several innovative groups to reach almost the entire ventral skull base. The endonasal transplanum transtuberculum approach extends the exposure beyond the sella by removing the tuberculum sellae and a portion of the PS to enable surgical access to the suprasellar cistern. As with any new approach, there is a learning curve that must be surmounted to achieve optimal results, and continuing evaluation of new ideas and technology must occur at periodic intervals as these results evolve. In this retrospective series, we have demonstrated, as others have previously, that suprasellar tumors can be safely and completely removed using the endoscopic transplanum/transtuberculum approach. In our series of patients,
we have reported low overall complication rates, the evolution of a negligible CSF leak rate (<5%), improved neurologic outcomes, a high extent of resection, and minimal trauma to the surrounding brain parenchyma. The low complication rates represent a substantial improvement compared to the high rates of CSF leaks that were reported early on in the endoscopic skull base experience for suprasellar tumors and justify an important role for the endonasal, endoscopic approach in the management of these tumors.

**FIGURE 13.8** Surgery to remove a suprasellar solid and cystic giant craniopharyngioma. *A.* The preoperative sagittal MRI scan with contrast shows an enhancing mass above the pituitary gland extending along the PS and down the clivus in front of the pons. *B.* The view up into the third ventricle shows the tela choroidea above with residual tumor adherent to the walls of the third ventricle and hypothalamus. *C.* View up into the roof of the third ventricle shows the foramina of Monro, fornices, and choroid plexus with residual tumor attached to walls of third ventricle. *D.* Looking through the foramina of Monro into the lateral ventricles from below. The choroid plexus and fornices are more clearly seen.

*FIGURE 13.9* Placement of the nasoseptal flap. *A.* The gasket-seal closure in place. *B.* The nasoseptal flap is placed over the gasket seal. *C.* Duraseal is used to cover the flap and keep it in place.
The direct approach to ventrally located tumors afforded by endoscopic techniques overcomes the difficulties and blind spots of transcranial skull base approaches that expose the tumor from an anterolateral to medial trajectory and inevitably require brain retraction, manipulation of a compressed optic apparatus, and carotid artery dissection to gain access to a tumor. In addition, the endonasal approach is excellent for visualizing and removing tumor extending into the medial optic canal (OC) such as commonly occurs with tuberculum sellae meningiomas. Improved ventral exposure, however, is achieved at the expense of surgical access superior and lateral to the optic nerve and carotid artery, thereby substituting one set of exposure-related operative difficulties with another. Ultimately, the predominant tumor growth pattern and suprasellar/parasellar extension in relation to the optic nerves and carotid arteries dictate the optimal approach or combination of approaches. Appropriate patient selection with careful review of preoperative neurovascular imaging is critical to optimize outcome. In general, tumors with significant lateral extension beyond the carotid bifurcation are difficult to access through an endonasal approach.

**PEACE**

- When opening the sphenoid ostium, avoid straying inferolaterally, as this may result in injury to the sphenopalatine artery along its course.
- For very large tumors and for extended approaches, the middle turbinate may be removed to provide additional visualization.
- The micro-Doppler should be used to identify the location of the carotid artery prior to opening the dura.
- Carefully examine the preoperative CT and CTA or MRI to understand the relationship between the septations in the sphenoid sinus and the carotid artery. CTA navigation can be useful intraoperatively.
- Use a diamond rather than a cutting burr to remove bone over the dura and carotid artery.
- For extended approaches, it is important not to make the opening in the bone too small. Once you are confident in your ability to close large skull base defects, larger openings in the bone are possible. Navigation is useful to determine the required size of the opening to expose the extent of the tumor.
- Frequent internal decompression and extracapsular dissection permit the surgeon to avoid blindly pulling the tumor into the surgical field.
- For extended transsphenoidal approaches where there is significant risk of CSF leak, more elaborate methods of closure are necessary. We recommend either the “gasket-seal” closure using a fascia lata/vomeric bone or rigid buttress with a vascularized nasoseptal flap. Intradural fat can decrease the dead space but can make postoperative imaging of residual tumor challenging requiring the use of fat saturation imaging.
- Visual identification of the pituitary and stalk is important, as accidental injury to these structures must be avoided. Devascularization of the stalk can cause hypopituitarism, and the superior hypophyseal arteries should be identified and preserved if possible.
- Hemostasis of venous bleeding is most effectively performed with hemostatic agents and gentle pressure.

**PITFALLS**

- If the bone opening is too small, the surgeon is forced to pull the pathology into the field of view, which risks injury to vessels attached to the posterior aspect of the tumor.
- The venous plexus in the clival dura can be extensive. Slow and meticulous opening with careful hemostasis is imperative to ensure the success of this approach.
- If injury to the carotid artery occurs, the sphenoid sinus should be packed quickly and a Foley catheter inflated to maintain pressure. The patient should be taken intubated for emergent endovascular assessment and treatment.
- If reoperation is undertaken to close a CSF leak, it is useful to identify the source of the leak prior to surgery. This can be done with intrathecal iohexol and a CT or intraoperatively with intrathecal fluorescein.

**INSTRUMENTS TO HAVE AVAILABLE**

- Endoscopic endonasal surgery is best performed with a set of instruments completely different from those used for standard transcranial microsurgical approaches.
- Whereas bayoneted instruments are necessary in microsurgical techniques to maintain the surgeon’s hands outside the view of the microscope, long straight instruments and pistol grips are better for endoscopic approaches. Specially designed bayoneted instruments can be used.
- While monopolar cautery is favored during the approach for mucosal bleeding, as with open transcranial surgery, bipolar coagulation is used on the dura and intracranial structures.
- A tissue shaver or microdebrider is useful for resection of intranasal pathology, whereas intracranial pathology requires more precision such as an ultrasonic aspirator, radiofrequency device, or gentle bimanual suction.
A micro-Doppler probe is particularly useful in identifying vascular structures. A range of endoscopes including 18’ and 30’ scopes with 0-, 30-, and 45-degree lenses should be available. It is also important to ensure that all endoscopic visualization equipment is working prior to the case. High-definition cameras and wide screen large displays substantially help the surgeon visualize the normal and abnormal sellar and suprasellar structures. A sheath around the scope can be used to irrigate and clean the lens during the operation to minimize the need for repeated removal and introduction of the scope. Finally, a scope holder is often useful to maintain a fixed, steady field of view during aspects of the case in which mobile visualization is not required.

**SUGGESTED READING**


INTRODUCTION

Masses, both benign and malignant, arising from the sinonasal tract are uncommon and provide a substantial challenge to head and neck surgical oncologists. Often, these tumors erode or infiltrate the adjacent orbit and anterior cranial fossa. A complete history, physical examination, and imaging studies provide important information for surgical planning. Although a diagnosis can readily be made with nasal endoscopy, the open, transfacial approaches have provided the access for traditional surgical resection. Recent advances in the understanding of nasal endoscopic anatomy and technical advances in surgical instrumentation have allowed for the removal of these lesions via a purely endoscopic approach.

HISTORY

Both benign and malignant tumors of the sinonasal tract are listed in Table 14.1. Malignant tumors of the sinonasal tract make up about 3% of tumors in the head and neck. Exposure to nickel refining, wood dust, industrial fumes, and leather tanning has been implicated in the etiology of sinonasal malignancies. Industrial exposures such as radium dial paints, soldering and welding, lacquer paint, isopropyl oils, chromium, and mineral oils have also been implicated. There is also a higher incidence of malignancies in smokers as compared to non-smokers. Benign vascular tumors are found in teenage males.

Tumors arising in the nasal cavity and sinuses often present as large lesions involving one or more sinuses. This is due to the relatively large intranasal space allowing growth prior to the onset of symptoms. Early symptoms include nasal obstruction, headache, nasal discharge, epistaxis, and anosmia. Patients with large tumors present with exophthalmos, diplopia, chemosis, supraorbital swelling, and edema of the eyelid. The absence of pain with ophthalmologic symptoms does not rule out malignancy, though deep-seated facial pain and facial paresthesia raise the index of suspicion for malignant tumors. The presence of epiphora suggests obstruction or destruction of the nasolacrimal duct. Loose-fitting dentures or loss of teeth suggests invasion of the floor of the maxilla. As tumors progress and invade the anterior cranial fossa and frontal lobe, subtle changes such as reduced speech, reduced verbal fluency, and altered expressive language may occur. The patient may begin to show signs of impaired insight and judgment while maintaining cognitive ability and memory.

PHYSICAL EXAMINATION

The physical examination should include careful examination of the sinonasal region, orbit, cranial nerves, middle ear, and neck and should include bilateral nasal endoscopy. Examination begins with an otomicroscopic examination; fluid in the middle ear suggests compression, invasion, or blockade of the eustachian tube in the nasopharynx, posterior to the pterygopalatine fossa, or the infratemporal fossa. Eye findings will suggest compression and/or invasion of orbital contents. Examination using a nasal speculum may reveal the physical
nature of the tumor and suggest the vascularity of the neoplasm. Evaluation of the oral cavity, particularly of the upper alveolar ridge and teeth, will suggest the effect of the neoplasm on the floor of the maxillary sinus and nasal cavity. Evaluation of the neck is vital since lymphadenopathy would suggest a malignant process. Finally, a complete evaluation of the cranial nerves is performed looking for focal deficits.

**INDICATIONS**

Tumors involving the orbit that do not involve the anterior wall of the maxillary sinus or anterior table of the frontal sinus, the optic nerve, and ophthalmic artery, with little involvement of the superior orbital bone may be accessed through an endonasal approach. Tumors located between the medial and inferior rectus and medial to the ophthalmic artery and optic nerve are readily resectable. In more experienced hands, tumors extending into the medial orbital apex and medial temporal lobe may be resected.

**CONTRAINDICATIONS**

Although there are a few solid contraindications for the transorbital approach, some contraindications may be relative based upon the experience and skill of the surgeon. Removal of the anterior table of the frontal sinus involved by tumor is not achievable by a totally endoscopic approach. Tumors located between the medial and inferior rectus and medial to the ophthalmic artery and optic nerve are readily resectable. In more experienced hands, tumors extending into the medial orbital apex and medial temporal lobe may be resected.

**PREOPERATIVE PLANNING**

**Imaging Studies**

Tumors involving the sinonasal tract require imaging using both computed tomography (CT) and magnetic resonance (MR) imaging with contrast. Contrast allows for an estimate of tumor vascularity. Image-guidance protocols should be performed if endoscopic approaches are entertained. CT imaging provides valuable information as to the integrity of the skull base, orbit, and sinonasal bony skeleton. MR allows for evaluation of

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<th>TABLE 14.1 Tumors Involving the Orbit</th>
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<td>Adenoid cystic carcinoma</td>
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<td>Dermoid</td>
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<td>Glioma</td>
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<td>Lacrimal gland or duct tumors</td>
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<td>Lymphoma</td>
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<td>Rhabdomyosarcoma</td>
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<td>Schwannoma</td>
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<tr>
<td>Sinonasal undifferentiated carcinoma</td>
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<td>Squamous cell carcinoma</td>
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soft tissue invasion, neural invasion, and entrapment of mucus in the sinuses versus tumor. If malignancy is confirmed, a positron emission tomography–CT scan should be performed for staging.

**Nasal Endoscopy with Biopsy**

I do not recommend in-office biopsy of sinonasal tumors, especially vascular tumors when the control of epistaxis can be very difficult to handle in the office setting. Patients are taken to the operating room for bilateral nasal endoscopy with biopsy. Definitive treatment is delayed until permanent pathologic diagnosis is confirmed.

**Ophthalmology Evaluation**

Patients with tumors of the sinonasal tract with ophthalmologic findings on physical examination or imaging undergo a complete eye examination by a neuro-ophthalmologist. Subtle findings such as ophthalmoplegia, visual field deficits, and optic nerve involvement may not be found on routine physical examination and help guide surgical planning. Furthermore, ophthalmologic assistance in tumor removal may be desirable in selected cases.

**Neurosurgical Evaluation**

At our institution, tumors abutting or eroding the skull base or involving or invading the brain undergo a full neurosurgical evaluation. It is my opinion that these tumors should be removed using a team approach.

**Tumor Board**

Once all of the preoperative evaluations, imaging, and pathology are complete, the case is presented at a multidisciplinary skull base tumor board for treatment planning. The tumor board consists of individuals from neurosurgery, otolaryngology, ophthalmology, medical oncology, radiation oncology, radiology, and nurse practitioners. Treatment planning is then finalized and presented to the patient.

**SURGICAL TECHNIQUE**

**Transconjunctival Approach**

Although not a requirement, some institutions prefer to have an ophthalmologist perform a transconjunctival approach in concert with an endoscopic transorbital approach to improve orbital retraction and allow retraction on the middle and inferior rectus muscles. As this is not uniformly established, the details of this approach are not described in this chapter (see Suggested Readings).

**Transnasal Approach**

The patient is placed in a supine position on the operating room table. The septum, middle turbinate, uncinate process, and anterior wall of the sphenoid sinus are injected with 1% lidocaine with 1:100,000 epinephrine bilaterally. Afrin- or cocaine-soaked pledgets are placed in the middle meatus and nasal cavity. While the decongestion process is taking place, the image-guidance system preferred by the surgeon is loaded and calibrated. The patient is then draped with clear tape over the eyes to protect the cornea. The eyes should be easily seen throughout the procedure for early recognition in the event of proptosis secondary to an orbital hematoma.

A wide maxillary antrostomy and total ethmoidectomy are performed on the side of the lesion. If the lesion extends to the sphenoethmoid recess, a sphenoidotomy is performed (Fig. 14.1). The middle turbinate is resected using a pair of endoscopic scissors with special attention not to violate the cribriform plate and lateral lamella. If a binostril approach is desired or the lesion crosses the midline, an anterior ethmoidectomy is performed on the contralateral side to allow visualization of the frontal recess, and the superior anterior portion of the middle turbinate is removed to prepare for a Draf III frontal sinusotomy. A complete Draf III, which allows for binostril access to the frontal sinus, is performed. If tumor is present in these regions, it is removed up to the frontal sinus and lamina papyracea with frozen section analysis of margins.

Similar to an endoscopic orbital decompression, the lamina papyracea is removed inferiorly to the maxillary antrostomy, posteriorly to the anterior wall of the sphenoid sinus, anteriorly to the nasolacrimal canal, and superiorly to the frontal recess. The nasolacrimal canal can be resected if removal allows for negative margins. A lacrimal stent is placed prior to the completion of the surgery to prevent epiphora. The bone of the lamina papyracea is easily removed with a Cottle elevator and backbiting forceps. Thicker bone is thinned with a high-speed diamond drill with continuous irrigation and then removed as above. The anterior and posterior ethmoid arteries are either clipped with endoscopic clip appliers or cauterized with pistol-grip bipolar electrocautery and cut. Thin bone of the superior orbital roof is then removed with rongeurs or a high-speed
FIGURE 14.1 Cadaveric dissection demonstrating a unilateral, endonasal transorbital approach to the anterior cranial fossa. All images are 0-degree endoscopy unless otherwise noted. A. Right anterior ethmoidectomy and middle turbinate resection (arrow) have been performed showing the right frontal recess with 0-degree endoscopy (star). B. The middle turbinate has been resected (arrow). A Draf II frontal sinus exploration has been completed revealing the right frontal sinus with 0-degree endoscopy (star). C. View into the right frontal sinus showing the far lateral wall of the sinus (star) using 30-degree endoscopy. The posterior table of the frontal sinus is fully visualized (arrow). D. Straight Frazier suction showing the lateral reach of straight instrumentation into the frontal sinus without the assistance of the transorbital approach. E. The right lamina papyracea has been removed (star), and the anterior ethmoid artery is identified (arrow). F. The periorbita is compressed laterally to show the edge of the orbital roof (arrow). Again not the posterior table of the frontal sinus (star). G. View into the right frontal recess after removal of the lamina papyracea and medial half of the orbital roof. Note increased lateral reach of a straight Frazier suction compared to (D). Posterior table of the frontal sinus (star). H. Removal of the posterior table of the frontal sinus showing the anterior cranial fossa parenchyma (star).
diamond drill with continuous irrigation as the periorbita is retracted. This can be carried posteriorly over the orbit and under the dura of the frontal pole for lateral extension of tumor posteriorly over the orbit. Special attention is directed to not violate the periorbita since it causes dehiscence of adipose tissue into the frontal recess or ethmoid sinuses blocking endoscopic visualization. A small amount of orbital adipose tissue may be shrunk with bipolar cautery. By removing the orbital roof, increased lateral access to the frontal sinus is achieved. Tumor eroding into or through the posterior table can now be removed under direct visualization. Dura may be removed as a posterior margin with endoscopic scissors. The removal of tumor invading the brain parenchyma endoscopically is controversial and beyond the scope of this chapter. Cerebrospinal fluid (CSF) rhinorrhea of the posterior table can be repaired through various endoscopic techniques previously published (see Suggested Readings).

If tumor extends posterior to the globe and involves or erodes the periorbita, the periorbita is removed with endoscopic scissors (Fig. 14.2) with frozen section analysis of margins. The inferior and medial rectus muscles are first identified just under the periorbita. The optic nerve and ophthalmic artery are identified lateral to and between the medial and inferior rectus muscles and preserved in cases of benign disease and removed if involved with malignant disease. Tumor involving the globe requires an open orbital exenteration. If the artery is sacrificed, a clip is placed on the ophthalmic artery posteriorly for hemostasis. Dehiscent adipose tissue posterior to the globe is cauterized with bipolar cautery to maintain a clear field of vision for the surgeon. Further invasion of tumor into the pterygopalatine fossa, infratemporal fossa, temporal lobe, and/or cavernous sinus is beyond the scope of this chapter and is described elsewhere (see Suggested Readings). Reconstruction of the periorbital defect is not necessary for small defects. Larger defects can be reconstructed with a cadaveric dermal graft (Alloderm) held in place with sutures and packing. Packing is not required after endoscopic transorbital approaches to the anterior cranial fossa. Absorbable, hemostatic materials or fibrin glues may be used to reinforce anterior cranial base reconstruction.

POSTOPERATIVE MANAGEMENT

If the dura is not violated, patients are observed overnight and have a new MR or CT prior to discharge. If the dura is violated and repaired during surgery with a vascular flap (i.e., nasoseptal flap), a lumbar drain is not warranted. If a vascular flap does not cover the defect or nonvascular flaps are used for dural repair, I recommend a lumbar drain for 72 hours. Nasal saline sprays are used every 2 hours while awake to prevent crusting of the nasal cavity. Sinonasal rinses are instituted 1 week after surgery until complete healing is obtained.

COMPLICATIONS

CSF Rhinorrhea

The most common morbidity after any endonasal intracranial approach to the anterior cranial fossa is postoperative CSF rhinorrhea. With the advent of pedicled rotation flaps, the occurrence is less than 5% in the literature. Close observation and immediate repair prevents poor outcomes from meningitis and pneumocephalus.
**Epistaxis**

Epistaxis requiring intervention occurs in about 1% of endoscopic, endonasal approaches to the cranial base. Temporary packing of the nasal cavity followed by immediate surgical re-exploration is required to prevent retro-orbital hematoma and intracranial bleeding.

**Enophthalmos**

Enophthalmos is a rare complication if the periorbita is left intact during the procedure. If the periorbita is removed, the dehiscence of adipose tissue into the ethmoid sinuses and middle meatus may lead to enophthalmos. Prompt ophthalmology consultation is warranted.

**Diplopia**

Diplopia may occur after violation of the periorbita with subsequent enophthalmos. Diplopia may also occur if the inferior or medial rectus muscle or motor nerves are violated. Prompt ophthalmology consultation is warranted.

**Visual Loss**

Visual loss is a real but fortunately rare complication if the optic nerve or ophthalmic artery is disrupted during surgery.

**RESULTS**

Unfortunately, peer-reviewed manuscripts analyzing the outcomes of the transorbital approach to the anterior cranial fossa are limited to a few isolated case reports. In my hands, patients have a short hospital stay (2 to 3 days) and little morbidity (temporary diplopia).

**PEARLS**

- A wide maxillary antrostomy provides helpful orientation of the orbital floor to the surgeon.
- A full Draf III approach allows binostril, endoscopic access to the orbit, frontal sinus, and anterior cranial fossa and the use of four-handed surgery.
- A 3-mm, high-speed diamond drill with continuous irrigation helps with the removal of the nasolacrimal canal, thick lamina papyracea, and posterior table.
- Early recognition and ligation of the anterior and posterior ethmoid arteries will allow vascular control and the avoidance of a retro-orbital hematoma.
- Early recognition of the medial and inferior rectus muscles guides the surgeon to the optic nerve and ophthalmic artery.
- Various methods of skull base reconstruction to separate the intracranial contents from the sinonasal tract are described. The surgeon(s) should be competent in several methods of reconstruction.
- A thorough understanding of open skull base approaches allows the conversion of selected cases from endoscopic to open to provide appropriate surgical resection in some cases.
- A multidisciplinary, skull base tumor board is essential to provide the best service to fit the individual needs of the patient.

**PITFALLS**

- Unrecognized injury to the ethmoid arteries can lead to a retro-orbital hematoma and blindness.
- Angled endoscopy and instrumentation limits the ease of surgical dissection and reconstruction and should be avoided except in rare circumstances.
- Injury to the optic nerve or ophthalmic artery will cause permanent visual loss.

**INSTRUMENTS TO HAVE AVAILABLE**

- Standard endoscopic sinus surgery instruments
- Endoscopic bipolar electrocautery
- High-speed endonasal drill with 3 and 4 mm coarse diamond bits
- Silastic lacrimal stent tubing
SUGGESTED READING


INTRODUCTION

Surgical approaches to the skull base have evolved significantly to minimize patient morbidity while allowing effective treatment of the underlying pathology. Technologic advances in optics and materials have mirrored and been critical in enabling this progress. Transnasal endoscopic approaches have been widely expanded and highly refined; concurrently, supraorbital “keyhole” approaches have been described that provide excellent access to the anterior cranial fossa (ACF) through the frontal bone. More recently, transorbital approaches have been described that access the anterior and middle cranial fossae through the thin bone of the orbit, using transcuteous (upper blepharoplasty/superior lid crease [SLC]) or transconjunctival (precaruncular [PC], inferior transconjunctival [ITC], or lateral retrocanthal [LRC]) incisions.

The rationale for considering the orbit as a surgical portal was based on the dimension, location, and composition of the bone. The bone of the orbits borders the majority of the ACF and the anterior aspect of the middle cranial fossa (MCF); the roof is also among the thinnest bones in the cranium. In addition, the dimensions of the orbit are relatively wide and shallow. These characteristics offer the potential for excellent access to structures in or adjacent to these regions.

When considering means to reduce the surgical trauma of skull base procedures, it is helpful to divide the procedure into three conceptual components: (1) creation of a surgical pathway, (2) manipulation of the surgical target, and (3) reconstruction of the defect. It is difficult to reduce the morbidity of target manipulation since the therapy may require circumferential access and dissection, as well as tissue ablation. Typically, reconstruction of the defect does not create a significant amount of trauma per se, unless a donor site is created. Furthermore, depending on the location of the pathology, reconstruction may not be required if an endoscopic approach is used. Creation of the surgical pathway, however, is often a source of significant morbidity, especially when open surgical techniques are used. Since the approach is merely the means of accessing the pathology, any trauma caused in its creation is, in theory, “collateral” damage. Thus, creation of the surgical path is perhaps the component of the procedure that provides the greatest opportunity to reduce surgical morbidity, and every effort should be made to reduce this trauma to insignificance.

In order to minimize pathway trauma and optimize surgical efficacy, the approach should be short and direct. It should provide ample access for instrumentation and an unobstructed view of the lesion but avoid trauma to critical neurovascular structures. At times, two or more pathways may be required to optimize visualization and facilitate endoscopic instrumentation angles for pathology abutting critical structures. Addition of another pathway can improve visualization around critical structures and bring the line of sight out of the obstructing vector of instrumentation. Combining two or more pathways, referred to as multiportal surgery, allows four- to six-handed surgery with freedom for each hand to maneuver without collisions (Fig. 15.1). Multiportal surgery can also help to overcome the geometrically limiting funnel effect that can occur when attempting to place instruments, suction, and an endoscope through a monoportal pathway.

The decision on the pathway(s) to use should be based on the location and characteristics of the target pathology, preferably without preexisting bias for a given approach. By performing preoperative pathway analysis using
navigation software, the spectrum of approaches (monoportal or multiportal) offered by various surgical trajectories can be analyzed and optimized for each patient’s individual pathology. A combination of approaches can be selected that will avoid endangering critical structures and optimize the surgeon’s ability to visualize and access challenging lesions using minimally disruptive technique. Virtual endoscopy can then be performed before surgery to confirm the appropriateness of the approaches and visualize the critical structures that will be encountered.

The techniques that we use for these approaches are *transorbital*, not *transpalpebral*. The term *transorbital* refers to approach vectors that access or traverse the orbit without removing bone of the orbital rim or adjacent structures. The term *transpalpebral* refers to approaches that employ incisions that partly or completely transect an eyelid. Thus, supraorbital craniotomies can be performed with a transpalpebral incision, though the approach is not transorbital. The SLC incision described herein is a transpalpebral incision, but the approach is strictly transorbital. We have found that removing the bone of the orbital rim and adjacent structures requires more extensive incisions, creates more morbidity, and prolongs the recovery period. Furthermore, we have found from computer analysis, cadaver studies, and clinical experience that the surgical approach vector is typically not improved by excising more bone.

This chapter describes our system of transorbital approaches to the ACF and suggests ways of combining these and other approaches in multiportal technique to maximize the surgeon’s ability to visualize and instrument these complex surgical targets with minimal disruption. Our transorbital approaches to the MCF are described in Chapter 34 of this book.

**HISTORY**

The history of patients presenting with ACF lesions is highly dependent on the type of pathology. When the orbit is involved, pain, diplopia, diminished visual acuity, proptosis, and ptosis are common presenting symptoms. A prior history of ophthalmologic problems and treatment should be noted. If the pathology involves the nasal cavity or sinuses, drainage, epistaxis, and loss of olfaction are common. Headache is a common nonspecific symptom, while decreased facial sensation may indicate involvement of the trigeminal nerve by tumor. Trismus may signify spread of tumor into the pterygomaxillary space or infratemporal fossa.

**PHYSICAL EXAMINATION**

A complete head and neck and neurologic examination is mandatory, with special attention to the cranial nerves. Regional lymph nodes should be examined for signs of metastatic cancer. For pathology that might encroach on the nasopharynx or nasal cavity, fiberoptic nasopharyngoscopy should be undertaken. The globes and orbits should be examined, and visual acuity should be checked. Asymmetry of orbital volume, position of the globe, size and reactivity of the pupils, and position of the eyelid should be noted. Normal extraocular muscle function should be confirmed. Strong consideration should be given to preoperative evaluation by an ophthalmologist to search for subclinical disease or other contraindications before transorbital surgery is undertaken.

**INDICATIONS**

Transorbital endoscopic surgery may be indicated for the treatment of pathology involving structures within or adjacent to the orbit. It can also be used as a pathway to more distant structures when it lies in the vector between the pathway entry point and the surgical target. It can be used as a single approach or combined with transnasal, transmaxillary, or supraorbital portals. It may also be used as an adjunct to a traditional craniotomy or subfrontal

![Figure 15.1](image-url)
craniectomy. As part of a multiportal approach, the transorbital pathway can be used for visualization (endoscopy), instrumentation, or both to provide the best possible means of safely manipulating the surgical target.

A more recent application of the transorbital approaches is the surgical treatment of orbital, frontal, sinus, and intracranial manifestations of sinogenic infections such as epidural abscesses (see Suggested Readings). The indications of these procedures are expanding with further work in the laboratory and improvements in surgical technology.

**CONTRAINDICATIONS**

The two absolute contraindications to transorbital endoscopic surgery are found in trauma patients: a ruptured globe or hyphema (blood in the anterior chamber of the eye). Relative contraindications to undertaking these approaches are noted below, and these patients should be managed in consultation with an ophthalmologist.

- Intraocular surgery within the last 6 months (e.g., cataract, retinal, glaucoma, or corneal transplantation surgery); consult with the ophthalmic surgeon before proceeding.
- Orbital infection (risk of posterior spread of the infection).
- Severe orbital inflammation or congestion (decreased space for retraction within the orbit may lead to increased pressure on the globe and optic nerve).
- Patients with diminished corneal sensation from previous laser corneal surgery or other cause may be at increased risk for postoperative complications.
- Other orbital pathology that creates a mass effect or alters anatomy in a manner that could obstruct endoscopic access.

Glaucoma and dry eye do not appear to be contraindications to transorbital pathways, though increased care should be given to lubrication of the ocular surface during and after surgery. Consultation with the ophthalmologist is an important aspect in the care of patients with these conditions.

**PREOPERATIVE PLANNING**

Full radiographic imaging should be obtained to completely evaluate and characterize the pathology in question including its exact location, extent, and vascularity when indicated. Imaging for intraoperative surgical navigation should be undertaken and should include computed tomography (CT) and magnetic resonance imaging (MRI) so that fusion guidance can be obtained as needed. Preoperative analysis of the navigation images on a computer planning station is helpful to investigate the ideal surgical approach or approaches to the target. Depending on the software, this may include highlighting the pathology, analyzing the target three-dimensionally, and performing a vector analysis of the possible approaches with virtual endoscopy.

Among the factors to consider in choosing a surgical approach are the following:

- Critical structures involved with or adjacent to the pathology.
- Adequacy of exposure for passage of instruments.
- Ability to visualize the pathology from the approach angle.
- Absence of impediments to visualization or manipulation of the target.
- Ability to instrument the target from the approach angle.
- Morbidity caused by creation of the pathway.
- Ability to reconstruct defects created by the pathway or target manipulation.
- The pathway should not cross critical neurovascular structures in a manner that can expose them to pressure or other trauma.
- A shorter pathway may allow increased ease of target visualization and manipulation.
- Adequacy of exposure for four- to six-handed (four to six function) surgery as needed.
- Experience of the surgical team.
- Patient preference.

For planning surgical approaches, we consider the number of surgical functions that will be required. These functions typically involve illumination/visualization (endoscopy), aspiration, irrigation, ablation, retraction, and manipulation. The literature on skull base surgery typically describes the need for “four-handed” surgery, that is, the ability for two surgeons to work together during the procedure. While this is a critical concept, there are times when more than four “hands” may be desirable to carry out a task. To address this, developments in surgical technology have provided instruments that can carry out multiple tasks. Thus, a single instrument such as a microdebrider may provide aspiration, irrigation, and tissue ablation, providing three functions in one “hand.” There are times when by using a multifunctional instrument, a single surgeon can perform five or more functions using two hands (illumination and visualization in one hand, with irrigation, bone aspiration, and suction in the other). We emphasize, therefore, the number of surgical functions required when planning the surgical pathway.
When possible, an approach that is coplanar with the target is beneficial (Fig. 15.2). A coplanar approach consists of an entry portal, dissection pathway, and surgical target that all lie within a single axial, sagittal, or coronal plane, such as one that might be visualized on a single CT image. For example, if a lesion is located immediately superior to the planum sphenoidale, a surgical approach that allows dissection along the ACF through a PC portal will simplify the procedure by allowing for the creation of an epidural pathway along the bone of the ACF without the need to use angled endoscopy or instrumentation.

Our choice of surgical portal is based on a division of the orbit into four quadrants, each of which has a specific entry portal (Fig. 15.3A). These are the superior, medial, inferior, and lateral quadrants. The approach is chosen based on the quadrant that is directly involved with the pathology or is transgressed by the optimal pathway to the surgical target (Fig. 15.3C). A schematic of the surgical portals and skull base regions of access is demonstrated in Figure 15.4. The approaches to the lateral and inferior quadrants are used primarily for access to the MCF and adjacent structures—these are described in Chapter 34 on transorbital approaches to the MCF.

The superior quadrant is bounded laterally by the superior orbital fissure and its anterior extension to the orbital rim and medially by the anterior and posterior ethmoid arteries (Fig. 15.3B and C). The entry portal is created through a transcutaneous superior lid crease approach. The trochlea is typically the medial extent and the lacrimal gland the lateral extent of this portal, though the trochlea and the periosteum to which it attaches can be lifted from the bone of the orbit to extend the approach if needed. Extension of this transcutaneous approach into a lateral transconjunctival approach requires a lateral canthotomy and superior cantholysis, though this is rarely necessary.

The medial quadrant is bounded superiorly by the anterior and posterior ethmoid arteries at the skull base and ends inferiorly at the orbital floor (Fig. 15.3B and C). The portal of entry is through a precaruncular transconjunctival incision. The superior limit of this incision is the medial horn of the levator aponeurosis and muscle. There is no inferior anatomic limit as it can be continued inferolaterally into a pre-septal or ITC incision through the lower eyelid conjunctiva.

The surgical approach is chosen by orbital quadrant as noted above. In addition, the surgeon must decide whether an extracranial (subcranial) or intracranial approach will be used. If an intracranial pathway is to be used, an extradural or intradural dissection or combination thereof must be chosen. In addition, the plan must include whether the target will be manipulated by monoportal or multiportal technique and whether the approach will be ipsilateral or contralateral. Options for reconstruction should be planned before the operation begins.

The patient should be engaged in the choice of surgical pathway(s). The various possible surgical approaches should be thoroughly discussed, and detailed informed consent should be obtained. It is also important during preoperative planning to consider any adjuvant therapies such as tumor embolization that should be coordinated with other members of the team. Anticoagulant medications should be stopped as indicated.
FIGURE 15.3
A. The four quadrants of the orbit. The surgical approach is chosen by the quadrant of the orbit that is most involved by the underlying pathology. The superior quadrant is accessed by the superior lid approach (SLC) approach; the medial quadrant is entered through a precaruncular (PC) incision. The inferior quadrant approach is made through an inferior transconjunctival (ITC) dissection, and the lateral quadrant is reached through a lateral retrocanthal (LRC) gateway; these are discussed in Chapter 37. B. Surgical anatomy of the orbit. The optic nerve is located in the medial orbital wall, medial and slightly superior to the junction of the superior and inferior fissures. Note that the anterior and posterior ethmoid arteries are coplanar with the optic nerve and demonstrate the level of the skull base. Dotted lines/arrows demonstrate approximate borders between the superior lid crease (SLC), precaruncular (PC), and inferior transconjunctival (ITC) approaches. 1, medial wall; 2, orbital roof; 3, lateral wall; 4, floor. C. Left. Green lines demonstrate approximate region that is accessed in SLC approach. Right. Approximate region that is accessed in PC approach (note the level of the ACF that is visible through the dehiscent lamina). Part or all of this bone can be removed as a pathway to adjacent targets.
The procedure begins with the administration of a general anesthetic. If indicated, a lumbar drain is placed. If intrathecal fluorescein is going to be used for localization of a cerebrospinal fluid (CSF) leak, this should be given as early as possible to allow diffusion of the dye. The table is then rotated 180 degrees, with the anesthesia equipment and anesthesiologist at the foot of the table as demonstrated in Figure 15.5. The patient’s head is placed in pins or on a circular gel headrest as preferred by the surgical team—fixation prevents alteration of the angulation of the head; changing this position may be beneficial at different stages of the operation. The head is placed in 15 degrees of retroflexion to allow the frontal lobes to relax away from the ACF if dissection is planned in this region. Less than 1 mL of 1% lidocaine with epinephrine 1:100,000 is then injected into the periorbital operative site. If a multiportal approach with transnasal portals is used, local anesthetic is infiltrated intranasally as well. The operating table is inclined 10 to 15 degrees to aid in hemostasis.

The navigation mask is placed, and the system is registered and registration accuracy confirmed. The surgical pathway vector from the planned portal to target is then analyzed on the patient using the navigation system, and the final choice of entry portal(s) is made (Fig. 15.6). The patient’s face is prepared and draped in the sterile environment.
fashion preferred by the surgical team. Ophthalmic Betadine should be used instead of regular Betadine to avoid irritation of the eye. Alcohol products and other caustic prepping agents should not be used around the eyes.

There are four primary transorbital endoscopic approaches (superior, medial, inferior, and lateral). The lateral and inferior approaches are used primarily to access the MCF and are described in Chapter 37. The approaches we use most commonly to the ACF are the superior and medial, as described below.

**Medial Quadrant: Precaruncular Approach**

The PC approach through the medial quadrant provides effective access above and/or below the ACF to structures in the central corridor and medial orbit roof. This includes the cavernous sinus, cavernous carotid arteries, and optic nerve (Figs. 15.7 and 15.8).

The approach is begun by placing a lubricated protector over the cornea. Probes are then placed in the lacrimal canaliculi to prevent inadvertent damage. These may be taped to the adjacent skin to aid in retraction.

![FIGURE 15.6 Preoperative surgical planning, PC approach. A. Navigation to right lateral cavernous sinus. B. Enlarged navigation planning image demonstrating pathway.](c) 2015 Wolters Kluwer. All Rights Reserved.
An incision is then made with a small scissors through the conjunctiva at the apex of the medial canthus, between the caruncle and skin. The incision is extended superiorly and inferiorly in the conjunctiva. The avascular plane is entered deep to the posterior limb of the medial canthal tendon, and that tendon is followed to the posterior lacrimal crest. The periorbita is incised vertically posterior to this structure and lifted.
laterally off the bone of the medial orbit (lamina papyracea). Dissection is continued posteriorly (using a suction elevator under visualization with a 4-mm 0-degree endoscope) between the periorbita and medial orbital wall. A malleable brain retractor is used to gently displace the orbital contents during the dissection. The anterior and posterior ethmoid arteries are cauterized with a bipolar cautery before sharply transecting them. Before cauterizing the posterior ethmoid artery, navigation is used to confirm that a safe distance is maintained from the optic nerve. The optic nerve is then visualized at the orbital apex; the nerve is located in the most posterior portion of the medial orbital wall, at the approximate level of the ethmoid arteries. The skull base lies immediately superior to the ethmoid arteries and can be seen as more dense, opaque bone than that of the lamina papyracea. At this point, the dissection proceeds along the trajectory of the planned pathway toward the target.

If the dissection is to proceed intracranially, the craniectomy is created in the superior medial orbit and medial roof. The appropriate site is confirmed with navigation. The bone can be removed with a diamond burr or an ultrasonic bone aspirator. We prefer the latter, as the instrument does not skip off the bone and appears to cause less damage to the adjacent dura if the dura is contacted. Furthermore, the bone aspirator both irrigates and aspirates through a single instrument, simplifying the maneuver.

Intracranial dissection can then proceed intra- or extradurally until the target is reached in accordance with the surgical plan.

If the optic nerve is to be decompressed, we prefer to do this by infracturing the medial and inferior aspects of the bone canal away from the nerve, using a fine periosteal elevator. This avoids the heat transmission and risk of injury that can occur from using a drill. If the bone of the canal is to be infractured, an ultrasonic bone aspirator or drill with a diamond burr may be used. The decompression is undertaken over the entire canal to the dura anterior and to the optic chiasm. The intracranial course of the nerve can be followed to the chiasm as needed. Figure 15.6 demonstrates a typical surgical navigation image of this approach.

**Medial Quadrant: Preocular Approach to Contralateral ACF**

At times, a contralateral approach to the target may be beneficial (Fig. 15.9). Pathology on the lateral wall of the sphenoid sinus/medial wall of the MCF can be difficult to visualize from an anterior approach without heavily angled endoscopy, and instrumentation under these conditions can be challenging. Occasionally, there may be unrelated pathology that blocks an ipsilateral transorbital or transnasal approach that can be circumscribed by a contralateral approach. An example of this is shown in Figure 15.10, a patient referred with a persistent right ACF CSF leak after craniectomy and resection of a meningioma. The patient also had a massive osteoma of the right orbital roof and wall, which he declined to have resected. A contralateral (left) PC approach to the right supraorbital skull base was undertaken to repair the dura and skull base.

The contralateral PC approach is undertaken with the same technique as an ipsilateral PC approach. For a subcranial target, the vector from the portal to target dictates the region of the lamina papyracea that is removed. The posterior ethmoid cells are removed on the side of the approach using a microdebrider. The midline is then crossed through the perpendicular plate of the ethmoid and sphenoid rostrum. The posterior ethmoid and sphenoid sinuses are opened on the side of the pathology as dictated by the approach vector. For an intracranial target, the initial dissection is undertaken with a subcranial or intracranial dissection as directed by the approach vector. The craniectomy is created in the indicated region of the skull base, and intracranial dissection is then continued to the target zone.

**FIGURE 15.9**

Schematic, ipsilateral (yellow) versus contralateral (green) PC approach to lateral aspect right MCF/sphenoid. This navigation analysis demonstrates the improved angulation to the lateral opticocarotid recess achieved by a contralateral PC approach.
Superior Quadrant: Superior Eyelid Crease Approach

Pathology involving the superior orbit, frontal sinus, supraorbital ACF, and posterior central ACF can be accessed through an SLC approach (Fig. 15.11). This approach can also be used for access to the olfactory region of the anterior interorbital skull base if, for example, the surgeon plans to resect the olfactory bulb and nerve en bloc.
with an esthesioneuroblastoma from an intradural approach. The incision is identical to an upper blepharoplasty, though it may be made in a more superior crease. The incision is tailored to the location of the portal as determined by preoperative path-to-target analysis. As this is a transcutaneous approach, a corneal protector is not used; a temporary tarsorrhaphy suture is placed instead. The incision is made through the skin and preseptal orbicularis oculi muscle. Deep to this, the orbital septum is identified, through which the prelevator fat can be seen. The septum and adipose tissue are not disturbed. Dissection is continued immediately posterior to the orbicularis muscle toward the superior orbital rim. When the orbital rim is identified, the periorbitum is incised along its anterior border, sparing the supratrochlear and supraorbital neurovascular pedicles. A plane is created between the periorbitum and the roof of the orbit using a periosteal elevator. The periorbitum is dissected away from the roof of the orbit under endoscopic and navigation guidance in the manner described above. The optic nerve is identified posteriorly as indicated, and the ethmoid arteries can be visualized medially. The dissection proceeds as far laterally as necessary. The craniectomy is then performed at the point where the portal-to-target pathway meets the skull base, using an ultrasonic bone aspirator or diamond burr. The dura is then lifted off the skull base, and the intracranial dissection is continued as appropriate. A navigation image of the approach is demonstrated in Figure 15.12.
The SLC approach can also be used to access the frontal sinus (Fig. 15.13). This is an excellent pathway for pathology in the lateral sinus that may be difficult to reach transnasally (e.g., obstructing osteoma). It is also applicable for treatment of orbital abscesses that stem from frontal sinusitis and which can extend to create epidural abscesses. The intersinus septum can be opened with this technique, allowing frontal sinus drainage through the contralateral frontal recess. By using an SLC approach, the orbital abscess can be drained, the frontal sinus abscess can be treated, and the epidural space can be reached for exploration or drainage of purulence. The frontal sinus is entered after the SLC approach has been completed. Navigation is used to choose the appropriate vector to the target, and the region for opening into the floor of the sinus is marked. The bone is then removed as described above. A 0-degree endoscope is used. To inspect the frontal recess from its superior aspect looking inferiorly, a 30-degree endoscope will be beneficial.

**Reconstruction**

Reconstruction is performed as needed, in a manner tailored to the pathology and type of craniectomy. Reconstruction of the medial wall is not necessary if the defect is small, there is no enophthalmos, and the periorbita is intact so that the medial rectus muscle will not catch on bone edges. If reconstruction is indicated, this is performed by placing a thin orbital fracture implant across the defect, sandwiched between the periorbita and bone superior and inferior to the defect. The navigation probe is then scanned across the reconstruction to assure that it conforms to the position of the normal medial orbital bone visible on the preoperative CT scan.

The same principles hold true for reconstruction of the bone of the roof of the orbit. If a dural defect is present, it should be repaired. Typically, the superior craniectomy does not need reconstruction. If none is performed, the globe may be noted to pulsate somewhat with the heartbeat for 1 to 2 weeks postoperatively. This generally resolves spontaneously. If reconstruction of the bone is deemed necessary, it can be performed with the technique used for the medial orbit. A short screw can be placed posterior to the orbital rim to hold the implant in place.

The SLC incision is loosely closed with 5-0 absorbing sutures through the orbicularis and 6-0 sutures placed through the skin so that fluid can drain, but the skin is approximated. We do not generally close the conjunctival incisions.

**POSTOPERATIVE MANAGEMENT**

The postoperative management for patients who have undergone transorbital endoscopic procedures is dictated by the target pathology being treated. The morbidity occurring from creation and reconstruction of the pathway is similar to or less than that experienced by a patient undergoing a repair of a single-wall orbital fracture. At times, patients are overly eager to be discharged since they awaken from surgery without having had a bifrontal craniotomy or procedure with a large incision and extensive bone resection. They may have to be reminded they have undergone treatment of a major ACF or MCF lesion. For those who have had a significant component of intracranial surgery and for all who have had intradural surgery, a postoperative noncontrast CT scan is obtained, and the patient is maintained in the intensive care unit overnight.

If a lumbar drain was indicated for treatment of the target pathology, this is maintained postoperatively as it would for other approaches. Pain is usually managed with oral medications. No dressings are applied; for transconjunctival incisions, oculair lubricants are used liberally for 1 week after surgery, and antibiotic ointment is applied to cutaneous incisions for 48 hours. Patients are given oral antibiotics for 5 to 7 days. The patient is seen as an outpatient in clinic at postoperative day 7, 14, and 28 and then followed as indicated for the underlying pathology. For patients who travel long distances for their surgery, postoperative care is turned over to their local surgeon after day 14. If a patient was seen by an ophthalmologist preoperatively, a postoperative visit is requested approximately 1 month after surgery, unless there is an indication for earlier evaluation.
CHAPTER 15  Transorbital Endoscopic Approaches to the Anterior Cranial Fossa

COMPLICATIONS
To date, we have had no significant complications from the SLC or PC approaches to the ACF. The absence of large incisions used with typical craniotomies and subcranial approaches should not lead the patient or surgeon to think that these are minor procedures, however. Patients must be counseled on the risks inherent with operating on or near the eyes and critical neurovascular structures. Great care must be taken to protect the cornea and globe from injury, and the nursing staff should be informed of the significant extent of these surgical procedures to aid in appropriate postoperative monitoring.

RESULTS
We have published evaluations of our outcomes and experience using this system of transorbital approaches to orbital and skull base lesions (see Suggested Reading). We have found these techniques to be highly effective, with an excellent safety record. A primary concern with transorbital approaches is the potential exertion of pressure on the globe and optic nerve during procedures that may last 4 hours or more. While we have not had any known cases of diminished visual acuity after a transorbital endoscopic approach, we take great care to protect the ocular surface during surgery and regularly check the pupils for enlargement or irregularity that might suggest elevated intraocular pressure. If this occurs, instruments are removed from the orbit until the pupil returns to normal. The safety of these procedures was demonstrated in our evaluation of over 100 cases in which no significant complications occurred.

Patients have been pleased with these procedures. The pain has tended to be less than they expected, the recovery period is brief, and there have been no visible scars or cosmetic complaints.

PEARLS
- Obtain complete imaging preoperatively including an MRI and CT scan under the navigation protocol. Consider angiography with embolization for vascular lesions. Consult and collaborate with an ophthalmologist, especially for patients with underlying ocular pathology.
- Study the lesion preoperatively including 360-degree analysis of adjacent anatomy. Evaluate all possible angles of approach to the target, and consider multiple pathways as needed. Individualize the approach for each target, optimizing the ability to visualize and instrument the lesion.
- Work in a team consisting of a neurosurgeon and otolaryngologist, with close collaboration of specialists in other disciplines including ophthalmology, radiation oncology, and neuroradiology.

PITFALLS
- Failure to perform cadaver dissections may make it especially challenging when trying to translate these surgical concepts to patients.
- Performing these procedures without surgical navigation is potentially dangerous, particularly when performing surgery on or near the optic nerve or intracranially. If you wander in this region, the consequences are often neurologically serious.
- Check the size and shape of the pupil every 20 to 30 minutes. If the pupil begins to dilate, remove instruments from the orbit for a short time to allow the pupil to return to normal.
- Protect and hydrate the cornea to prevent abrasions or drying.
- Careful selection of the patient is essential. If you cannot reach the pathology with navigation, it is best to terminate the procedure and attempt an open approach.

INSTRUMENTS TO HAVE AVAILABLE
- Complete endoscopic skull base instrument set
- Oculoplastic set with retractors, corneal protectors, lacrimal dilator, and probes
- High-quality endoscopes (0 and 30 degree) with high-resolution monitors, preferably suspended from ceiling in ergonomic positions
- Endoscope irrigation system
- Endoscopic microdebrider
- Drill with diamond burr or, preferably, ultrasonic bone aspirator (Sonopet)
- Radiofrequency soft tissue aspirator (Coblator)
- Surgical navigation system with vector analysis and lesion highlighting (segmentation) software
- Intraoperative CT scanner (useful but not critical)
SUGGESTED READING


INTRODUCTION

The supraorbital approach is a minimally invasive keyhole technique in which a small anterolateral craniotomy is used to reach a wide range of anterior and midline skull base pathologies. This technique provides effective surgical access to the anterior fossa floor, the parasellar region, the proximal Sylvian fissure, the circle of Willis, the basal frontal lobe, and the ventral brainstem. The versatility of the supraorbital keyhole makes it a frequently used approach for providing access to lesions in these anatomic sites. The supraorbital keyhole technique is a classic example of a minimally invasive, maximally effective approach; when practiced correctly, it offers excellent exposure with a small cosmetically acceptable incision and minimal bone drilling. These features make it one of the most efficient and practical approaches in neurosurgery.

HISTORY

It is important to obtain a history of previous surgery in this area. Recurrent tumors have poorly defined planes and may require more extensive cranial access. With tumors involving the cribriform plate, obtaining a history of olfaction is mandatory if one is attempting to preserve the sense of smell.

PHYSICAL EXAMINATION

The width of the eyebrow will determine how good the result will be cosmetically. The presence of frontal protuberances occasionally offers assistance in determining the location of the adjacent frontal sinuses. Also, in the elderly, the skin creases in the forehead may be prominent enough to “hide” a scar. If so, the eyebrow incision may be replaced with a forehead skin crease incision. Physical examination may reveal scarring in the area of the operative site, which may change the plan of management.

INDICATIONS

Indications for the supraorbital approach include the presence of a surgical lesion involving the floor of the anterior cranial fossa, the suprasellar or parasellar regions, the ipsilateral circle of Willis, the basal frontal lobe, or the interpeduncular cistern. Supplementing this approach with neuroendoscopy augments the exposure to include the contralateral circle of Willis, the sella, the anterior third ventricle, the anterior interhemispheric fissure, the midline anterior portion of the anterior cranial fossa, the superior third of the clivus and interpeduncular cistern, and a portion of the ipsilateral middle cranial fossa. In many cases, the supraorbital approach is an effective less-invasive alternative to the standard pterional or orbitozygomatic craniotomies in providing access to these anatomic regions.
When selecting a keyhole supraorbital approach, care must be taken in reviewing pertinent imaging and in assessing the anticipated surgical trajectory. Although selection of the surgical technique must be individualized to the unique features of each case, in general, the supraorbital approach provides effective access to the following lesions:

- Aneurysms of the anterior communicating artery
- Aneurysms of the ipsilateral internal carotid artery
- Aneurysms of the ipsilateral middle cerebral artery
- Aneurysms of the ipsilateral posterior communicating artery
- Anterior clinoid meningioma
- Anterior cranial fossa cerebrospinal fluid (CSF) leaks
- Basal frontal gliomas
- Cranioopharyngioma
- Intraorbital lesions approaching the roof of the orbit
- Intraorbital lesions that are superolateral to the optic nerve
- Olfactory groove meningioma (see Contraindications)
- Pituitary adenoma
- Tuberculum sellae meningioma
- Tumors of the ventral midbrain

CONTRAINDICATIONS

The primary contraindications to the supraorbital approach refer to the limits of its anatomic access. Because the supraorbital approach provides a flat trajectory along the roof of the orbit, it provides poor access to the lateral cavernous sinus and middle cranial fossa. In addition, although it can be enhanced by a supplemental orbitotomy, the supraorbital approach provides limited cephalad trajectory. Lesions with significant superolateral extension or those involving a substantial portion of the middle cranial fossa are better approached using a standard pterional craniotomy, with or without removal of the orbital rim. Midline lesions with a significant superior component may be better approached using the endonasal transsphenoidal corridor. In addition, because the craniotomy of the supraorbital approach is small, broad-based superficial lesions, such as a frontal meningioma with a wide dural tail, may require a more extensive craniotomy for adequate exposure.

The common anatomic contraindications to the supraorbital approach include the following:

- Substantial middle fossa extension of the lesion of interest
- Significant superior or lateral extension of the lesion of interest
- Superficial extension (e.g., dural tail) beyond the limits of the craniotomy
- Lesions confined to the anterior olfactory groove (especially with underlying bone involvement such as meningiomas)

Because the supraorbital craniotomy adheres to the keyhole principle, whereby a small cranial opening provides wider access to deeper structures, the allowable position of the craniotomy and the trajectory it provides must be carefully considered. One important concern in planning a supraorbital craniotomy is the position and size of the frontal sinus. A large frontal sinus requires a more lateral craniotomy that may further limit the surgical working area and alter the achievable surgical trajectory. The use of image-based frameless stereotaxy is helpful in assessing the operative trajectory in each case. Furthermore, knowledge of alternative approaches, such as a traditional pterional or orbitozygomatic craniotomy, is important if the exposure provided by the supraorbital approach proves to be inadequate.

PREOPERATIVE PLANNING

Careful preoperative review of a recent MRI is critical prior to planning a supraorbital craniotomy, both in assessing involvement of surrounding neurovascular structures and in determining the surgical accessibility of the lesion of interest (Fig. 16.1). Close examination of axial sequences will demonstrate the lateral and posterior extent of the lesion in relation to the sella, the carotid arteries, and the sphenoid ridge. Coronal sequences will also provide important details regarding the lateral extent of the lesion into the adjacent middle cranial fossa, involvement of the cavernous and supraclinoid carotid arteries, and the position of the optic nerves and chiasm. A careful examination of sagittal sequences will demonstrate potential intrasellar extension, the position of the infundibulum and optic apparatus, and the cephalad extent of the lesion. A thoughtful assessment of the radiographic features of the lesion is crucial before one selects the supraorbital approach.

Before surgery, patients for whom a supraorbital approach is selected should be counseled regarding the risk of numbness of the forehead, frontalis palsy, and nasal CSF leak although the rates of these complications...
FIGURE 16.1 A–F. Preoperative (A, C, E) and postoperative (B, D, F) MRIs of a tubercular meningioma resected via a right supraorbital keyhole approach. The large size of the lesion and involvement of neurovascular structures were not contraindications to this keyhole approach. The postoperative MRI demonstrates a gross total resection.
are very low in experienced hands. In our series of over 450 cases, our CSF leak rate is negligible, and only two patients experienced permanent frontalis palsy.

**SURGICAL TECHNIQUE**

After intubation under general endotracheal anesthesia, the patient is placed in the supine position. The head is fixed in a 3-point rigid head holder. The table is placed in approximately 20 degrees of reverse Trendelenburg to optimize venous drainage. After pinning, the head is gently extended to bring it above the level of the heart, and 20 degrees of neck extension is applied to facilitate the natural “retraction” of the frontal lobe by gravity. This maneuver is crucial in opening the subfrontal corridor through which microsurgery will proceed and in avoiding the use of retractors. The head is then rotated slightly to the contralateral side to bring the malar eminence to the uppermost position. The degree of contralateral rotation may depend on the site of the surgical pathology, with 15 to 30 degrees used to address ipsilateral lesions and up to 45 to 60 degrees of rotation required to approach contralateral lesions. The ipsilateral eye is lubricated and closed with a temporary nylon tarsorrhaphy suture to prevent surgical prep solution from contacting the cornea.

Following positioning, the image-based frameless stereotaxic system is registered. Use of image guidance prior to incision is helpful to assess the position of the frontal sinus and to ensure an optimal trajectory to the lesion of interest. The lateral margin of the frontal sinus is marked, and the supraorbital notch is palpated. The supraorbital notch represents the medial limit of the skin incision. When the supraorbital notch is lateral to the frontal sinus, it also marks the medial limit of the craniotomy. In cases where a large frontal sinus extends lateral to the supraorbital notch, the lateral margin of the frontal sinus marks the medial limit of the craniotomy.

After prepping and draping, a skin incision is made within the eyebrow in its superior half (Fig. 16.2), extending from the supraorbital notch medially to the lateral aspect of the brow. The subgaleal layer is undermined, and the soft tissue is retracted superiorly with fishhooks. A U-shaped pericranial flap is fashioned by incising the pericranium as superiorly as possible and reflecting it inferiorly to the orbital rim. This pericranial flap is held inferiorly with sutures to the drapes. Laterally, the superior portion of the temporalis muscle is dissected to allow placement of a burr hole below the superior temporal line in the keyhole region. Any further temporalis dissection is unnecessary and should be avoided. A craniotomy is fashioned as low on the frontal floor as possible. The supraorbital craniotomy is typically 2 to 3 cm wide and 1.5 to 2 cm high (Fig. 16.3). While a small craniotomy can provide versatile access, the opening in the bone must be wide enough to accommodate a fully spread bipolar instrument. Particular lesions, such as those with a wide superficial component, may require a wider opening. Care is taken to preserve the supraorbital nerve medial to the craniotomy and to avoid violation of the frontal sinus. If the frontal sinus is breached, it can be packed with Betadine-soaked Gelfoam and sealed with bone wax, or repaired with the pericranial flap.

**FIGURE 16.2**
Proper positioning for the supraorbital craniotomy with eyebrow skin incision. The right eyelid temporary suture and skin incision, extended from the supraorbital notch to the lateral aspect of the brow (yellow line), are demonstrated in this photograph. The patient's head is extended to allow the frontal lobe to fall away. The degree of head rotation may vary, depending on the size and location of the lesion of interest. In this case, minimal contralateral rotation was used. Rotation of the operating table during surgery, however, allows for the angle to be tailored during the course of the procedure.
The dura is dissected off the roof of the orbit prior to opening the dura. Protuberances of the orbital roof are drilled flat, as is the inner table of the inferior ledge of the craniotomy; this maneuver is critical in maximizing visualization of the skull base. The dura is then opened in a U-shaped fashion with the base of the flap at the inferior aspect near the orbital rim. Immediately after opening the dura, a small arachnoid incision is made to initiate CSF drainage, while the surgical microscope is brought into position.

Without retractors, the subfrontal corridor is dissected under microscopic visualization. The ipsilateral optic nerve and carotid artery are identified. The arachnoid of the interchiasmatic, opticocarotid, and carotid–oculomotor cisterns, as well as the proximal Sylvian fissure, may be opened. With dissection of arachnoid adhesions and CSF egress, the frontal lobe falls away to further aid in the surgical approach. The pathology is identified and treated using the appropriate lesion-specific microsurgical techniques (Fig. 16.4B–D). Care is taken in assessing involvement and/or displacement of the optic nerves, the optic chiasm, the ipsilateral and contralateral carotid arteries, the anterior cerebral arteries and anterior communicating artery (ACOM), and the pituitary stalk. Neuroendoscopy with a 30-degree endoscope may augment visualization of the sella, interpeduncular cistern, interhemispheric cistern, contralateral circle of Willis, and middle cranial fossa, if necessary.

After the lesion of interest has been addressed, meticulous hemostasis is established. The dura is closed in a watertight fashion and sutured to the lower rim of the craniotomy. Adequate repair of a breached frontal sinus is confirmed. A noncompressive layer of Surgicel is placed in the epidural space, and the bone is replaced with low-profile titanium plates. Care is taken to minimize the gap between the skull and bone flap at the more cosmetically noticeable superior margin. Surgicel is placed in the remaining craniotomy line. The pericranium, frontalis muscle, and galea are closed in layers. The skin of the eyebrow is reapproximated with a subcuticular nylon suture with no knots.

Proper placement of this final skin suture is essential in obtaining a cosmetically acceptable result. The skin must be approximated under slight tension to ensure healing by primary intention. Prior to tying of the suture, its free ends are flossed back and forth to ensure that it can be freely removed in 5 to 7 days. The free ends of this suture are tied so that the skin edges are reapproximated under gentle tension. A nonabsorbable dressing is placed under the tied ends of the extradermal portion of the suture to prevent it from burrowing into the incision. Immediately after the skin is closed, gentle continuous pressure is held over the incision until the

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**FIGURE 16.3**  A. A skin incision is made within the eyebrow in its superior half, extending from the supraorbital notch medially to the lateral aspect of the brow. B. After the subgaleal layer is undermined and the soft tissue is retracted superiorly with fishhooks, a U-shaped pericranial flap is fashioned by incising the pericranium as superiorly as possible and reflecting it inferiorly to the orbital rim. C. The superior portion of the temporalis muscle is dissected and retracted laterally to allow placement of a burr hole below the superior temporal line in the keyhole region. Two osteotomies are made with a craniotome, both starting from the burr hole and meeting medially just lateral to the supraorbital notch. The inferior osteotomy is fashioned as low on the frontal floor as possible, flush with the orbital roof. D. After the inner cortex of the supraorbital bone is drilled, a U-shaped dural opening is made and reflected inferiorly to give access to the intradural space.
The patient is extubated and breathing comfortably. This maneuver prevents formation of a pseudomeningocele that could be promoted by coughing or straining as the patient emerges from anesthesia. The skin suture is removed 5 to 7 days postoperatively.

Video 16.1 demonstrates the surgical nuances of the case depicted in Figures 16.2 and 16.4. The right supraorbital craniotomy is drilled flush with the orbital roof. The subfrontal corridor is dissected without the use of retractors. The arachnoid of the ipsilateral opticocarotid cistern is opened with an 11 blade, and the surgeon patiently allows egress of CSF to occur. This step is critical in achieving adequate brain relaxation. The tumor extending from the tuberculum sellae along the planum sphenoidale is addressed. The lesion is devascularized along its base with bipolar electrocautery and resected with a combination of suction and sharp dissection. The involvement of the anterior cerebral arteries, ACOM complex, and both optic nerves is appreciated. Once the tumor is freed from these surrounding structures, a large portion is removed en bloc. Following complete removal, both optic nerves and the pituitary stalk are clearly visible. This final photograph allows one to appreciate the anatomic reach of the supraorbital approach.

**FIGURE 16.4 A–D.** Intraoperative photographs of the case depicted in Figure 16.2. Following craniotomy and dural opening, the base of the frontal lobe is exposed (A). Identification of the ipsilateral optic nerve is a crucial first step as tubercular meningiomas tend to push the optic nerve superiorly (B). The involvement of the anterior cerebral arteries and ACOM complex are clearly demonstrated (C). Following tumor removal, both optic nerves and the pituitary stalk are clearly visible (R A1 = right proximal anterior cerebral artery) (D). This final photograph allows one to appreciate the anatomic reach of the supraorbital approach.

**POSTOPERATIVE MANAGEMENT**

The supraorbital keyhole approach is usually associated with minimal discomfort and a short hospital stay. In most cases, patients are discharged home on the 1st postoperative day. Some degree of periorbital edema is to be expected if the periorbita is violated during pericranial dissection or placement of the craniotomy. This generally resolves within 5 days. All patients should be assessed clinically for possible CSF leaks and, in cases of involvement of the pituitary stalk, endocrinopathies.
COMPLICATIONS

Aside from general surgical complications, the following complications are specific to the supraorbital approach:

- Numbness of the forehead (caused by injury to the supraorbital nerve)
- Frontalis palsy (caused by injury to the frontalis branch of the facial nerve)
- Nasal CSF leak (caused by violation of the frontal sinus and inadequate repair)
- Poor cosmetic appearance. This may be the result of poor skin closure, partial or full thickness burns from the surgical microscope set at greater than 75% intensity for any length of time, infection, or persistent pseudomeningocele.

Overall, because the supraorbital approach requires only a small skin incision with minimal temporalis dissection, scalp pain, swelling, and difficulty with mastication are observed with less frequency than with standard pterional or orbitozygomatic approaches.

RESULTS

I have operated on over 450 patients using the supraorbital keyhole approach in over 450 cases. This includes more than 430 tumors, eight aneurysms, and three cases of trauma to the anterior skull base. In no case was conversion to a larger craniotomy required. The frequency with which I use this approach is a testament to its versatility. My 0% incidence of conversion to a larger craniotomy demonstrates that, with proper selection and execution, the supraorbital keyhole does not compromise necessary anatomic access.

PEARLS

- Carefully assess preoperative imaging. Close inspection of the preoperative MRI is the most important step in properly selecting the supraorbital approach and ensuring that the lesion of interest can be reached.
- Extend the head to allow the frontal lobe to fall away. This simple positioning maneuver makes gravity work in the surgeon’s favor. Mild extension of the head allows the frontal lobe to fall away, naturally opening the subfrontal corridor and obviating the need for retractors.
- Avoid the frontal sinus. The frontal sinus can be easily avoided with image-based frameless stereotaxis. Successful avoidance of entrance into the sinus eliminates the risk of nasal CSF leak.
- Position the craniotomy flush with the orbital roof. Because the supraorbital craniotomy is a keyhole approach, each millimeter of bone left superficially above the orbital roof disproportionately limits the surgical trajectory to deeper targets. The goal is to achieve a low anterior-to-posterior working trajectory along the base of the frontal lobe, directly along the roof of the orbit.
- Drill the roof of the orbit flat to achieve a flat trajectory along the orbital roof.
- Patiently allow CSF egress to relax the brain.
- In experienced hands, the anatomic limits can be pushed with the use of angled endoscopes, and a 30-degree endoscope may provide access to the sella, the contralateral circle of Willis, the interhemispheric fissure, and a portion of the middle cranial fossa.
- A watertight closure minimizes the risk of pseudomeningocele and offers additional protection against a nasal CSF leak.
- A cosmetic closure is of utmost importance. The following steps are key in performing an optimal cosmetic closure:
  > Close with a subcuticular suture with no buried knots.
  > Floss the skin stitch.
  > Tie the loose ends under gentle tension.
  > Place a nonabsorbable dressing under the tied ends.
  > Hold pressure until the patient is extubated.

PITFALLS

- Inadequate review of the preoperative imaging or an incomplete understanding of the anatomic limits of the supraorbital approach may lead to inadequate surgical access.
- Breach of the frontal sinus can be avoided by identifying the lateral edge of the frontal sinus with image guidance prior to performing the craniotomy.
- Generally, the supraorbital nerve may be preserved by palpating the supraorbital notch to identify the medial limit of the skin incision.
- The risk of injury to the frontalis branch of the facial nerve is reduced by limiting the extent of the lateral incision and minimizing lateral dissection of the subcutaneous tissue.
- Pseudomeningocele may be avoided with a watertight closure of the dura and by holding pressure on the closed incision until after extubation.

**INSTRUMENTS TO HAVE AVAILABLE**

- “Matchstick” drill for leveling the orbital roof
- 30-degree endoscope to expand the field of view
- Angled instruments for endoscopic-assisted surgery

**SUGGESTED READING**

INTRODUCTION

Although en bloc craniofacial resection is the traditional teaching in oncologic surgery of the anterior cranial base, there has been a growing acceptance of alternative minimally invasive transnasal endoscopic techniques. In select patients, the endoscopic approach for resection of the anterior skull base, when compared to the historical “gold standard” of external craniofacial resection, has been shown to be oncologically sound. This approach is not only less invasive and cosmetically appealing, obviating the need for a lateral rhinotomy or sublabial incision, but also more cost-effective in select patients.

HISTORY

The traditional anterior skull base resection involves removal of the entire anterior skull base bilaterally (Fig. 17.1A and B). In very select patients, a “hemi” anterior skull base resection, sparing one olfactory nerve and cribriform plate, has been performed (Fig. 17.1C). However, the latter is more controversial.

The anterior skull base is limited laterally, by the medial orbital walls; by the planum or roof of the sphenoid bone, posteriorly; and by the posterior table of the frontal sinus, anteriorly. The midline structures of the anterior skull base include the crista galli and cribriform plates, which are lined intranasally by olfactory neuroepithelium that perforates the cribriform plate, allowing for the transmission of olfactory nerve fibers to the nasal cavity. Lateral to the cribriform plate lies the roof of the ethmoid sinus or fovea ethmoidalis.

Depending on the stage and location of the neoplasm, resection of the anterior skull base may be required to obtain negative superior margins in the surgical management of many sinonasal malignancies (Tables 17.1 and 17.2). However, it is not necessarily the pathology but rather the extent of disease that determines the appropriateness for a purely endoscopic approach versus a craniofacial resection.

When confined to the nose, the most common early symptoms are unilateral nasal obstruction and/or epistaxis. These symptoms are nonspecific and usually confused with chronic rhinosinusitis. One must exercise a high index of suspicion in these patients. Depending on the type of pathology and/or the aggressiveness of the neoplasm, additional orbital or neurologic symptoms may ensue. These include proptosis, facial swelling, cranial neuropathy, ophthalmoplegia, visual loss, and/or mental status changes.

PHYSICAL EXAMINATION

Nasal endoscopy, and a complete examination of the head and neck, including cranial nerve assessment, should be performed on all patients. Physical examination may reveal proptosis; extraocular muscle impairment; mass effect of the cheek, gingiva, or gingivobuccal sulcus (e.g., ill-fitting dentures); and/or loose dentition. Numbness of the skin of the cheek or upper lip, or hypesthesia of the infraorbital (V3) branch of the maxillary nerve, strongly
FIGURE 17.1
Coronal (A) and sagittal (B) images illustrating the anatomical limits of a more traditional anterior skull base resection. In select cases, a “hemi” (C) anterior skull base resection may be more appropriate, in order to spare an olfactory bulb.

TABLE 17.1 Common Sinonasal Malignancies

<table>
<thead>
<tr>
<th>Epithelial</th>
<th>Nonepithelial</th>
<th>Lymphoreticular</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Adenoid cystic carcinoma</td>
<td>• Angiosarcoma</td>
<td>• Giant cell tumor</td>
</tr>
<tr>
<td>• Melanoma</td>
<td>• Chondrosarcoma</td>
<td>• Lymphoma</td>
</tr>
<tr>
<td>• Metastatic carcinoma</td>
<td>• Connective tissue sarcoma</td>
<td>• Plasmacytoma</td>
</tr>
<tr>
<td>• Olfactory neuroblastoma (esthesioneuroblastoma)</td>
<td>• Fibrosarcoma</td>
<td></td>
</tr>
<tr>
<td>• Sinonasal undifferentiated carcinoma</td>
<td>• Hemangiopericytoma</td>
<td></td>
</tr>
<tr>
<td>• Squamous cell carcinoma</td>
<td>• Leiomyosarcoma</td>
<td></td>
</tr>
<tr>
<td>• Transitional cell carcinoma</td>
<td>• Liposarcoma</td>
<td></td>
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<tr>
<td></td>
<td>• Myxosarcoma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Osteosarcoma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Rhabdomyosarcoma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Soft tissue sarcoma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Synovial sarcoma</td>
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</tbody>
</table>
suggests malignant invasion of the nerves. Transnasal endoscopic biopsy of the lesion is commonly performed in the office under topical or local anesthesia, when possible. Alternatively, the sampling can be performed in the more controlled environment of an operating room when a deep biopsy is required, when the lesion is difficult to access due to its location (i.e., dependent sinus or skull base), or if profuse bleeding is anticipated.

**INDICATIONS**

Most benign and malignant neoplasms originating in the nose and paranasal sinuses, which are determined to be free of extensive orbital, intracranial, lateral maxillary, or palatal invasion, may be considered candidates for endoscopic anterior skull base resection as a stand-alone procedure. A combined external/endoscopic approach is otherwise indicated, during the same setting, or staged for a later date. Therefore, patients should be appropriately counseled and provided informed consent.

**CONTRAINDICATIONS**

Not all lesions are amenable to this technique, due to the extent of supraorbital, orbital, lateral maxillary, or palatal involvement. In such cases, the endoscopic-assisted external approach or more traditional craniofacial resection still affords many of the benefits of a purely endoscopic resection. Tumors in these locations may necessitate an orbital exenteration, a palatectomy, and/or a radical maxillectomy, respectively.

**PREOPERATIVE PLANNING**

Computed tomography (CT) scan and magnetic resonance imaging (MRI) are considered complementary to each other for the evaluation of neoplastic disease of the paranasal sinuses and adjacent skull base and orbit (Fig. 17.2). CT scan is superior for the evaluation of the bony architecture, assessing for bony erosion or remodeling in critical areas of the skull base and orbit. The use of contrast also reveals tumor vascularity and its relationship to the carotid artery. Disadvantages of CT include its inability to differentiate tumor borders from the surrounding soft tissue and exposure to ionizing radiation. MRI is the best modality for defining soft tissue detail. It can differentiate adjacent tumor from soft tissue (e.g., gadolinium enhances tumor diffusely to an intermediate degree, whereas inflamed mucosa enhances more intensely in a peripheral fashion), differentiate tumor from secretions in an opacified sinus, demonstrate perineural spread (especially adenoid cystic carcinoma), and demonstrate invasion of the dura, orbit, or brain parenchyma. Additional testing, to evaluate or embolize vascular structures (i.e., MRA or angiography), or to evaluate for metastatic disease (i.e., PET/CT), may be necessary in select cases.

Intrathecal fluorescein is not routinely used for elective skull base resections but may be instilled prior to taking the patient back to the operating room to assist the surgeon with skull base reconstruction. The absence of fluorescein along the margins of the reconstructed dural defect denotes absence of cerebrospinal fluid (CSF)

<table>
<thead>
<tr>
<th>American Joint Committee on Cancer (AJCC) for Ethmoid Carcinomas</th>
<th>Olfactory Neuroblastoma Staging Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX: Primary tumor cannot be assessed</td>
<td>Kadish staging system</td>
</tr>
<tr>
<td>T0: No evidence of primary tumor</td>
<td>Stage A tumors are confined to the nasal cavity.</td>
</tr>
<tr>
<td>Tis: Carcinoma in situ</td>
<td>Stage B tumors in the nasal cavity show extension into the paranasal sinuses.</td>
</tr>
<tr>
<td>T1: Tumor restricted to any one subsite, with or without bony invasion</td>
<td>Stage C tumors extend into the orbit, base of the skull, or cranial cavity or present with cervical or distant metastasis.</td>
</tr>
<tr>
<td>T2: Tumor invading two subites in a single region or extending to involve an adjacent region within the nasoethmoidal complex, with or without bony invasion</td>
<td>UCLA staging system</td>
</tr>
<tr>
<td>T3: Tumor extends to invade the medial wall or floor of the orbit, maxillary sinus, palate, or cribriform plate</td>
<td>Stage 1 tumors involve the nasal cavity, paranasal sinuses, or both (excluding sphenoid), sparing the most superior ethmoidal air cells.</td>
</tr>
<tr>
<td>T4a: Tumor involves any of the following: anterior orbital contents, skin of the nose or cheek, minimal extension to anterior cranial fossa, pterygoid plates, sphenoid, or frontal sinuses</td>
<td>Stage 2 tumors involve the nasal cavity, paranasal sinuses, or both (including the sphenoid), with extension to or erosion of the cribriform plate.</td>
</tr>
<tr>
<td>T4b: Tumor involves any of the following: orbital apex, dura, brain, middle cranial fossa, cranial nerves other than (V3), nasopharynx, or clivus</td>
<td>Stage 3 tumors extend into the orbit or protrude into the anterior cranial fossa.</td>
</tr>
<tr>
<td>T4c: Tumor involves the brain.</td>
<td>Stage 4 tumors involve the brain.</td>
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leak. Also, intraoperative computer-assisted navigation is not used routinely for anterior skull base resections. However, it may be useful when resection margins are extended posteriorly around the carotid artery and adjacent neurovascular structures. If used, the patient would have placement of fiducials preoperatively and registration performed once the patient is intubated, prior to prepping.

SURGICAL TECHNIQUE (VIDEO 17.1)

Intraoperative Patient Positioning and Prepping

The patient is placed in the supine position on the operating table. Following intubation, the endotracheal tube is secured to the left side of the oral cavity. As with all endonasal procedures, a right-handed surgeon typically stands on the right side of the patient’s head. When a four-handed technique is required, typically during the anterior skull base resection portion of the procedure, the assistant stands to the left of the operating surgeon. Both have simultaneous visualization of the video monitor(s). Ointment is placed in each eye, and each eyelid is secured in the closed position with a transparent dressing, in order to detect the presence of an expanding orbital hematoma. Oxymetazoline-soaked, one-half-by-three-inch, neurosurgical Cottonoids are placed in both nasal cavities. The head of the bed is then rotated 180 degrees. Placing the bed in reverse Trendelenburg helps to decrease venous congestion and intracranial pressure throughout the procedure, if necessary. The patient is prepped with Betadine paint and draped in a sterile fashion, including the nose and both eyes in the surgical field.

After removal of the oxymetazoline-soaked Cottonoids, a 30-degree rigid nasal endoscope is used for visualization and exchanged for a 70-degree rigid nasal endoscope when needed during the course of the procedure. A 70-degree endoscope is useful when inspecting the nasoseptal angle and anterolateral frontal and maxillary sinus margins. One percent lidocaine with 1:100,000 epinephrine is used to inject the septal mucosa, the attachment of the middle turbinate, and the area adjacent to the sphenopalatine foramen when exposure permits. However, depending on the size and extent of the lesion, endoscopic debulking of intranasal tumor may first be required.

Intranasal Tumor Debulking and Determination of the Tumor Epicenter

The surgery begins on the ipsilateral side of the tumor. A microdebrider is used to resect the intranasal portion of the mass, taking care to identify and preserve the point(s) of mucosal attachment and the tumor’s “epicenter.” Although noncutting forceps can be used as an alternative, the microdebrider system has the added benefit of specimen collection into a filtration sock placed on the suction apparatus. Once the mass is adequately debulked, the contents can then be sent for confirmatory pathologic evaluation. The sock is changed as often as needed and labeled appropriately, based on anatomic site. It is not uncommon for the middle and superior turbinates to be involved in the disease process and therefore are removed during debulking. Even if the structure is grossly uninvolved, turbinate resection is performed in order to improve visualization of the anterior skull base. However, it is still sent as a separate specimen for permanent sections.
CHAPTER 17 Endonasal Resection of the Anterior Cranial Base

Tumor Mapping and Clearance of Sinonasal Margins

Once the site of origin or epicenter of the tumor is identified, a complete resection of all involved structures of the nose and paranasal sinuses is performed in a stepwise manner, sending separate surgical specimens for permanent section for the purpose of postoperative tumor mapping. This helps to differentiate which cavities or structures are involved with tumor versus inflammation. In most endoscopic anterior skull base resections, this typically involves sending 15 to 20 separate specimens for permanent section, each specifying a different and detailed anatomical area, bilaterally. During this portion of the procedure, close endoscopic inspection and frozen sections from critical areas, known to necessitate further external procedures, such as deep involvement of the periorbita, lateral involvement of the maxillary sinus bone, palatal involvement, pterygomaxillary space involvement, or extensive nasopharyngeal involvement, are determined. Prior to proceeding with the anterior skull base resection, the surgeon needs to decide during this portion of the procedure whether to proceed endoscopically, stage the procedure for a future date (endoscopic and/or external approach), or proceed with a combined external approach at this time.

Once the nasal patency is reestablished, a wide maxillary antrostomy is performed. The posterior fontanelle is entered posteriorly with a frontal curette and removed, along with the remaining soft tissue and bone of the middle meatus, all the way anteriorly to the convexity of the nasolacrimal duct. Conversely, if the uncinate process is detectable, then a standard antrostomy is created anteroposteriorly in the standard fashion, starting at the maxillary natural ostium. Any areas suspicious for neoplastic involvement are sent for frozen section. In the absence of lateral involvement of the maxillary sinus mucosa and bone, the procedure begins with a total radical sphenoidectomy with exenteration of all mucosal elements. When the inferior turbinate or medial wall of the maxillary sinus appears to be involved with tumor, then an endoscopic medial maxillectomy is performed, including resection of the nasolacrimal duct. Once the total ethmoidectomy is completed, the sphenoid sinus is entered and the anterior wall removed, incorporating the sphenoid cavity into the total ethmoid cavity. A Kerrison rongeur is used to widen the osteotomy, initially in the medial and inferior directions, until the underlying pneumatized sinus is visualized. Mucosal elements are exenterated and sent for frozen section. The roof of the sphenoid sinus, or planum sphenoidale, indicates the vertical level of the anterior skull base at its most posterior aspect and is closely inspected. Following along the continuation of the skull base in a posterior-to-anterior fashion, the roof of the ethmoid or fovea ethmoidalis is carefully inspected as well. Any residual bony ethmoid septations not destroyed by the disease process are then resected flush to the medial wall of the orbit and ethmoid fovea. Abnormal pitting of bone, bone erosion, or abnormal looking dura is noted throughout this endoscopic skull base exposure part of the procedure.

With a curved ostium seeker or probe, the infundibulum of the frontal sinus is identified, and the septations of the agger nasi cell are then fractured anteroinferiorly and removed. The lateral wall of the nose over the nasolacrimal sac is inspected at this point and if suspicious, removed for frozen section. Before proceeding with the extended frontal and sphenoid sinusotomies described below, a contralateral sphenoidectomy and frontal sinusotomy are performed, thereby creating a pathologic map of the contralateral side.

Medial and anterior enlargement of the frontal sinus ostium is then undertaken using bone curettes and angled cutting burs, and a Draf III (modified Lothrop procedure) is performed, demarcating the anterior margin of resection (Fig. 17.3). Additional burring of the nasal side of the nasal bone is performed, if tumor extends close to this area. The lateral margin of resection on each side can be extended to include the lamina papyracea and/or periorbita, as dictated by the extent of the lesion. A superior septectomy (including bone and cartilage) is performed as far inferiorly as necessary to clear the margins. This may include extending the septectomy to

![FIGURE 17.3](https://example.com/fig173.png)

Completed modified Lothrop (Draf type III frontal sinusotomy), delineating the anterior margin of an anterior skull base resection. Left (LF) and right (RF) frontal sinus cavities are examined. Small arrows denote the remnant of the frontal intersinus septum.
the nasal floor. A caudal and dorsal strut of septal cartilage can usually be preserved, minimizing the chance of dorsal nasal collapse and subsequent saddle nose deformity.

An extended sphenoid sinusotomy is performed (Fig. 17.4). This includes removal of the sphenoid rostrum, intersinus septum, and exposure of the anterior planum or roof of the sphenoid sinus in the midline. The nasopharyngeal and sphenopalatine mucosal margins are sampled at this point and sent for frozen section. This completes the exposure of the anterior skull base. As mentioned previously, up to this point, the procedure can be staged for a later date without the need for reconstruction or proceed with the anterior skull base resection part of the procedure below. Regardless, all sinonasal and septal margins must be cleared pathologically prior to proceeding with the anterior skull base resection of the procedure below.

**Anterior Skull Base Resection**

Although neurosurgical support should be available from this point on, neurosurgical involvement for most anterior skull base cases is rarely used, unless extensive dural or parenchymal invasion is encountered. An ultrasonic bone curette or aggressive diamond burr is used to thin the bony margins of the anterior skull base (i.e., fovea ethmoidalis, anterior planum, and posteroinferior frontal sinus posterior table). Once eggshell thin, any remaining bone is gently mobilized from the overlying dura, removed, and sent for permanent pathologic evaluation. In order to facilitate reconstructive efforts and further dural resection (if necessary), the dura overlying the orbits is gently elevated at this time with a neurosurgical Cottonoid. After cautering the anterior and posterior ethmoidal arteries with a monopolar suction cautery at 10 W of energy, the dura is incised with a sickle knife and resected in a four-hand technique with careful suction traction using endoscopic scissors, starting as far laterally as possible, but leaving a cuff of dura for frozen section, circumferentially. Alternatively, a small tru-cut forceps may be used to resect and sample the dura simultaneously, therefore assuring clear margins on frozen sections, while the resection continues below. Dural incisions are begun over the fovea first and then connected anteriorly over the posterior wall of the frontal sinus. As the incisions are created, the specimen is retracted inferoposteriorly into the nasopharynx, allowing visualization of the overlying intracranial vasculature and brain parenchyma. Any bleeding intracranially from dural vessels is controlled with bipolar cautery. Venous bleeding may also be controlled with gentle pressure for a minute or two minutes using a neurosurgical Cottonoid and powdered Gelfoam. Superiorly, the specimen must be separated from the crest of the crista galli and falk cerebri. The crista galli can be thinned with the ultrasonic bone curette, or burr, and down-fractioned as high as possible. The falk cerebri is incised bilaterally, over the crista galli, and the specimen is slowly dissected free in a posterior direction. The final dural cuts over the planum sphenoidale, as well as transection of both olfactory nerves, are performed at this time, allowing the specimen to drop into the nasopharynx. At this point, the anterior skull base specimen is removed en bloc through the nostril (Fig. 17.5). If the olfactory neuroepithelium is involved with the disease process (i.e., esthesioneuroblastoma), the olfactory nerves are sampled and sent for frozen section to be certain that this margin is clear.

**Anterior Skull Base Reconstruction**

Once the dural and intracranial margins are negative, reconstruction of the skull base defect may begin. Inability to adequately clear the intracranial dural margins requires neurosurgical intervention with possible conversion to a combined craniofacial resection. Reconstruction is performed with hydrated acellular dermal graft of approximately 1 mm average thickness (Alloderm, LifeCell Corporation, Branchburg, NJ), placed to span the dural defect of the anterior skull base circumferentially, like a hammock (Fig. 17.6). It is not important whether
the graft is placed epidurally, subdurally, or both. What is more important is that a large enough sheet of graft material is available and placed intracranially as described below. Typically, one can measure the anteroposterior and lateral (superior orbit to orbit) size of the skull base defect and add at least 2 cm circumferentially, for the final graft size. That would be a total of 4 cm on top of the final defect side, for the anteroposterior, as well as the lateral, dimensions. For example, if the final skull base defect ranges from 3 cm orbit to orbit, by 4 cm anteroposteriorly, then a 7 cm × 8 cm sheet of graft material is used. It is critically important that the edges of the graft are infolded onto itself circumferentially, so that an intranasal portion overlies the de-epithelialized orbital, planum, and posterior frontal bony margins (Fig. 17.7). In order to maintain graft position around the periphery and prevent intracranial or intranasal migration, 1 to 2 cm² pieces of moistened compressed gelatin sponge (Gelfoam, Pfizer, New York, NY) are then placed into the pocket created by this infolding, circumferentially, over the orbital roof, planum sphenoidale, and posterior table of the frontal sinus. This step helps to tightly seal the defect, reducing the risk of postoperative CSF leak and pneumocephalus. The Gelfoam is further dehydrated and firmed up by tucking it into the pocket using a curved suction tip over a neurosurgical Cottonoid. The remaining graft spanning the central defect is then overlaid with moistened compressed gelatin sponge and secured with two polyvinyl alcohol–compressed nasal packs (Merocel, Medtronic Xomed, Jacksonville, FL), suspended between the common frontal and sphenoid sinus cavities, to provide counter pressure against brain parenchyma and restored CSF pressure levels in the immediate postoperative period (Fig. 17.8).
FIGURE 17.7
Acellular dermal graft placed into the defect and tucked circumferentially, creating a pocket that is filled with Gelfoam. The free nasal edge of the graft is seen circumferentially over the medial orbital wall, posterior edge of the common frontal sinusotomy, and bony edge of the planum defect. Care is taken not to obstruct the common frontal opening with the graft.

FIGURE 17.8
Merocel nasal tampon placed over the Gelfoam bed overlying the graft, between the common sphenoid and frontal sinus cavities.
POSTOPERATIVE MANAGEMENT

Lumbar drains are not used routinely. The patient is kept in a monitored bed overnight, before being transferred to a regular bed. The presence of CSF leak is checked daily by having the patient sit up in bed and then gently bend forward, without straining. Any clear watery fluid emanating from the nostril(s) is noted. The patient is monitored for any mental status or visual changes, along with routine vital signs. In the absence of fever, CSF leak, mental status change, or visual changes, the patient typically is discharged from the hospital by the 3rd postoperative day. A return clinic appointment is given for approximately 7 days postoperative.

Postoperative prophylactic antibiotics are prescribed until packing removal in the office approximately 1 week after surgery. However, the underlying layer of Gelfoam is left undisturbed and left to fall off over time and with the help of irrigations. Nasal irrigations with isotonic saline are begun at this time. The patient is instructed to refrain from straining, and if indicated, use stool softeners. Pain medication is prescribed as needed.

Prolonged crusting is inversely proportional to the degree and rapidity of mucosalization of the sinonasal and anterior skull base cavities. Mucosalized cavities crust less than do cavities that need to heal by secondary intention and formation of granulation tissue. Prolonged crusting of the reconstructed skull base area may be a slight disadvantage with acellular dermal graft (Alloderm) or lyophilized dura, as compared to mucosalized grafts or flaps. However, the ease of repair, and rapid availability of these grafting materials, along with their consistent results in providing excellent closure of the anterior skull base defect, outweighs this minor issue in our hands. Also, donor site crusting may still occur in cases where pedicled mucosal flaps are used. Periodic endoscopic debridements, daily postoperative irrigations, and culture-directed topical and oral antibiotics, as needed, help mitigate the crusting if it occurs. Radiation therapy, when indicated, may be begun within 4 weeks after surgery. Complete remucosalization may be expected within 6 months (Fig. 17.9).

As with all oncologic patients, postoperative long-term endoscopic and radiologic follow-up is imperative. At a minimum, patients are followed every few months, with a repeat brain MRI at least once per year, or sooner if symptoms warrant (Fig. 17.10). Follow-up CT is used to address any symptomatic obstructive sinus disease. The management of symptomatic chronic sinonasal obstructive disease is identical to that for patients with chronic rhinosinusitis.

COMPLICATIONS

The most common reported complications of endoscopic anterior skull base resection are CSF leak and epistaxis. Sinus obstruction due to fibrosis, crusting, or mucosal thickening may occur at any point and can account for persistent inflammatory disease, discolored mucous, headaches, and crusting. Altered mental status, hypoesthesia, orbital hematoma, diplopia, loss of vision, cellulitis, vestibular stenosis, and deep vein thrombosis have also been documented. However, these are more common in patients undergoing the more traditional craniofacial resection.

RESULTS

The endoscopic approach, when compared to craniofacial resection, has been demonstrated to be both safe and effective with comparable rates of operative complications and overall survival in select patient populations. Endoscopic techniques do not impact one’s ability to obtain negative surgical margins. Decreased overall

FIGURE 17.9
Mucosalized anterior skull base approximately 1 year postoperatively. Common frontal sinus cavity (F) is inspected. Medial orbital walls (O, arrows) are also in view.
morbidity and shorter hospital stays are routine. An added benefit of the technique is the dynamic quality and superior visualization afforded by angled nasal endoscopes, thus improving the accuracy of tumor resection while sparing uninvolved vital structures.

**PEARLS**

- The care of each patient is individualized based on the stage of neoplastic disease and the specific histopathology.
- Intraoperative navigation and intrathecal fluorescein is not used routinely for anterior skull base resection and is usually unnecessary for anterior skull base resections, unless significant resection is extended posteriorly into the middle or posterior cranial fossa, where identification of the carotid artery and adjacent neurovascular structures is critical.
- Meticulous intraoperative mapping and intraoperative frozen sections are imperative, not just to determine the extent of disease and clearance of the resection margins but also to determine close or unresectable margins. This helps guide postoperative adjuvant radiation therapy protocols or allows for further surgical planning at the same sitting or as a staged surgical procedure (endoscopic or external).
- When using Alloderm for reconstruction of the anterior skull base
  - Use 1 mm thickness. Too thin may not give enough support. Too thick is not pliable enough to create the circumferential “pocket” over the orbit, posterior table of the frontal sinus, and planum sphenoidale.
  - The pocket must extend at least 1 cm circumferentially.
  - Make sure to tuck sufficient Gelfoam into the circumferential pocket created by infolding the graft back on itself. This keeps the infolded part firmly against the bone and allows the cranial portion of the graft to move superiorly or inferiorly. The intranasal edge of the pocket must clearly be visible after placement of Gelfoam into this pocket.

**PITFALLS**

- Tucking the graft circumferentially without creation of a pocket risks superior displacement particularly if there is low intracranial pressure, brain atrophy, or CSF levels are slow to reestablish in the immediate postoperative period.
- It is not necessary to use free mucosal grafts or flaps to cover the graft in the majority of the cases. Alloderm becomes quickly replaced with granulations, followed by mucosalization within months. However, this is at the expense of increased crusting in the postoperative period.

**INSTRUMENTS TO HAVE AVAILABLE**

- Standard endoscopic sinus surgery trays
- Powered instrumentation
CHAPTER 17  Endonasal Resection of the Anterior Cranial Base

- Ultrasonic bone emulsifiers
- Long fine endoscopic skull base scissors, forceps, probes, suction tips, tissue dissectors and bipolar grasping forceps

SUGGESTED READING


INTRODUCTION

Neoplasms of the nasal cavity and paranasal sinuses account for only 0.2% to 0.8% of all malignancies and 2% to 3% of all head and neck cancers. The incidence is between 0.3 and 1 case per 100,000 population. Tumors in this location are rare in childhood with the incidence beginning to increase in the fourth decade. The median age of diagnosis is 62 years in men and 72 years in women. There is a slight male predominance.

The majority of tumors of the nasal cavity and paranasal sinuses arise from the mucous membranes lining these air spaces. The most common pathology in North American and Asian society is squamous cell carcinoma with olfactory neuroblastoma, adenocarcinoma, adenoid cystic carcinoma, and sinonasal undifferentiated carcinoma being other pathologies common in larger surgical series (Table 18.1). It is often difficult to determine the exact site of origin of these tumors given that more than 90% of them may have invaded at least one sinus wall and the disease may extend well beyond the original sinus. The maxillary sinus is the most common primary site of origin in 55% of cases. Ten percent of these tumors arise in the ethmoid sinus and only 1% in the sphenoid and frontal sinuses. Thirty-five percent of tumors originate from within the nasal cavity. Epidemiologic studies have identified a variety of environmental hazards that have been associated with the development of sinonasal tumors. A significant association between sinonasal tumors and cigarette smoking has been identified in a large case control analysis of white American males. Various occupational hazards have also been linked to the development of sinonasal tumors. The tumor type, occupational setting, and suspected carcinogens are outlined in Table 18.2.

The transcranial approach for anterior craniofacial resection is a technique used to manage these sinonasal malignancies when the neoplasm extends to or through the base of the skull to involve the parameningeal space, the meninges themselves, or the intradural and intracerebral structures. The technique provides excellent visualization, the ability to manage the orbits safely and completely, and the opportunity for robust dural and cranial base repair.

HISTORY

The most common initial symptoms of malignant sinonasal disease are nasal airway obstruction that is frequently unilateral, chronic nasal discharge, and epistaxis. Unfortunately, these early symptoms of malignant disease are identical to those of benign nasal and paranasal sinus disease. Studies have shown a combined physician and patient delay ranging from 3 to 14 months due to this nonspecific symptom complex. The liberal use of imaging studies and early biopsy has lessened the diagnostic delay and increased the percentage of tumors being diagnosed at an earlier stage.

Tumors of the superior aspect of the nasal cavity and ethmoid sinus may be associated with anosmia and headache. Carcinoma of the frontal sinus may present as an acute frontal sinusitis with pain, swelling, and evidence of bone erosion. Nasal obstruction, epistaxis, and nasal discharge may be absent when the tumor is located in the sphenoid sinus, and patients typically suffer from headache, diplopia, and cranial neuropathy.
A thorough examination of the head and neck, including endoscopic evaluation of the sinonasal and nasopharyngeal regions, is an important part of the evaluation of patients suspected of having a malignancy of the sinonasal tract. Middle ear effusion may indicate tumor involvement of the nasopharynx, eustachian tube, pterygoid plates, or tensor veli palatini muscle. The cranial nerves must be evaluated. A full ophthalmologic examination should be completed. Eye movements should be carefully assessed to identify any restriction of movement consistent with involvement of the orbital tissues or ocular motor nerves. Specific attention should

# TABLE 18.1  Histologic Distribution of 209 Patients with Paranasal Sinus Tumors Treated by Craniofacial Resection at M. D. Anderson Cancer Center, 1992–2008

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squamous cell carcinoma</td>
<td>35</td>
</tr>
<tr>
<td>Olfactory neuroblastoma</td>
<td>28</td>
</tr>
<tr>
<td>Adenocarcinoma</td>
<td>23</td>
</tr>
<tr>
<td>Adenoid cystic carcinoma</td>
<td>21</td>
</tr>
<tr>
<td>Sinonasal undifferentiated carcinoma</td>
<td>13</td>
</tr>
<tr>
<td>Osteosarcoma</td>
<td>11</td>
</tr>
<tr>
<td>Neuroendocrine carcinoma</td>
<td>7</td>
</tr>
<tr>
<td>Angiofibroma</td>
<td>7</td>
</tr>
<tr>
<td>Melanoma</td>
<td>6</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td>6</td>
</tr>
<tr>
<td>Fibrosarcoma</td>
<td>5</td>
</tr>
<tr>
<td>Low-grade unclassified sarcoma</td>
<td>4</td>
</tr>
<tr>
<td>Inverting papilloma</td>
<td>4</td>
</tr>
<tr>
<td>Rhabdomyosarcoma</td>
<td>4</td>
</tr>
<tr>
<td>Nerve sheath tumor</td>
<td>3</td>
</tr>
<tr>
<td>Meningioma</td>
<td>3</td>
</tr>
<tr>
<td>Malignant fibrous histiocytoma</td>
<td>3</td>
</tr>
<tr>
<td>Malignant peripheral nerve sheath tumor</td>
<td>2</td>
</tr>
<tr>
<td>Mucopyocele</td>
<td>2</td>
</tr>
<tr>
<td>Benign fibrous tumor</td>
<td>2</td>
</tr>
<tr>
<td>Metastases</td>
<td>2</td>
</tr>
<tr>
<td>Single pathologies*</td>
<td>15</td>
</tr>
</tbody>
</table>

*Includes mucoepidermoid carcinoma, mesenchymal chondrosarcoma, teratocarcinosarcoma, angiosarcoma, esthesioneuroblastoma, fibrovascular polyp, ameloblastic carcinoma, PNET/Ewing sarcoma, high-grade unclassified sarcoma, malignant solitary fibrous tumor, germ cell tumor, myoepithelial carcinoma, liposarcoma, hemangioma.

# TABLE 18.2  Occupational Hazards Associated with Paranasal Sinus Tumors

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Occupational Setting</th>
<th>Suspected Carcinogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squamous cell carcinoma</td>
<td>Nickel refining</td>
<td>Nickel compounds</td>
</tr>
<tr>
<td></td>
<td>Mustard gas manufacturing</td>
<td>Dichlorodiethyl sulfide</td>
</tr>
<tr>
<td></td>
<td>Isopropyl alcohol manufacturing</td>
<td>Isopropyl alcohol</td>
</tr>
<tr>
<td></td>
<td>Watch painting</td>
<td>Radium</td>
</tr>
<tr>
<td></td>
<td>Woodworking</td>
<td>Hardwood dust</td>
</tr>
<tr>
<td></td>
<td>Chrome pigment manufacturing</td>
<td>Chromium compounds</td>
</tr>
<tr>
<td></td>
<td>Isopropyl alcohol manufacturing</td>
<td>Isopropyl oil</td>
</tr>
<tr>
<td>Adenocarcinoma</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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be paid to examination of the trigeminal nerve. The not infrequent occurrence of perineural extension of malignancy to the branches of the trigeminal nerve may be identified by areas of hypesthesia associated at times with paresthesia. Biopsy of any suspicious lesions should be performed.

**INDICATIONS**

Parameters to consider when planning management for a patient with a malignancy of the paranasal sinuses include tumor pathology and biologic aggressiveness, extent of disease, the availability and potential success rates of adjuvant therapies, and the potential for functional impairment and esthetic deformity with extirpative surgery. Currently, most patients are treated with surgery and radiation therapy as a combined treatment modality, but other adjuvant therapies such as chemotherapy and radiosurgery may be indicated (Table 18.3). Optimal patient outcome is only achieved through multidisciplinary assessment and management.

**CONTRAINDICATIONS**

Patients with comorbidities, such as severe cardiovascular disease; markedly debilitated or demented patients; patients with coagulopathy; or those with end-stage renal or pulmonary disease will probably not benefit by excision of these tumors. Although patients with metastatic disease are usually not candidates for craniofacial resection, those with oligometastatic disease of low- to intermediate-grade tumors are occasionally selected for craniofacial resection for palliation of specific symptoms such as optic neuropathy and pain. I do not recommend craniofacial resection for patients with involvement of the intracranial internal carotid artery by high-grade malignancy.

**PREOPERATIVE PLANNING**

Computed tomography (CT) and magnetic resonance imaging (MRI) are complementary studies and the imaging methods of choice for assessing sinonasal malignancies. CT imaging is particularly useful for assessing

**TABLE 18.3 Management Paradigms and Applicable Malignancies**

<table>
<thead>
<tr>
<th>Chemotherapy and radiation therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ewing sarcoma</td>
</tr>
<tr>
<td>Lymphoma</td>
</tr>
<tr>
<td>Most rhabdomyosarcomas and MPNST</td>
</tr>
<tr>
<td>Neuroendocrine carcinoma</td>
</tr>
<tr>
<td>Some patients with SNUC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemotherapy, radiation therapy, surgical resection, and stereotactic radiosurgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenoid cystic carcinoma</td>
</tr>
<tr>
<td>Squamous cell carcinoma</td>
</tr>
<tr>
<td>High-grade sarcoma</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre- and postoperative chemotherapy, surgical resection, and postoperative radiation therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-grade sarcoma</td>
</tr>
<tr>
<td>High-stage squamous cell carcinoma</td>
</tr>
<tr>
<td>Some patients with SNUC and melanoma</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surgical resection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal cell carcinoma</td>
</tr>
<tr>
<td>Desmoid fibromatosis</td>
</tr>
<tr>
<td>Low-grade chondrosarcoma</td>
</tr>
<tr>
<td>Some other low-grade sarcomas and low-grade adenocarcinomas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surgical resection and postoperative radiation therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenocarcinoma</td>
</tr>
<tr>
<td>Adenoid cystic carcinoma</td>
</tr>
<tr>
<td>Most metastases</td>
</tr>
<tr>
<td>Olfactory neuroblastoma</td>
</tr>
<tr>
<td>Some low-grade sarcomas</td>
</tr>
<tr>
<td>Squamous cell carcinoma</td>
</tr>
</tbody>
</table>

MPNST, malignant peripheral nerve sheath tumor; SNUC, sinonasal undifferentiated carcinoma.
bone changes, especially erosion. Direct coronal CT is best for evaluating the integrity of the anterior skull base including the roof of the orbit, cribriform plate, and planum sphenoidale (Fig. 18.1). The extent of tumor is best assessed with MRI, which can differentiate tumor from inflamed mucosa, blood, or inspissated mucus in most cases (Fig. 18.2). Obliteration of adipose tissue planes in the pterygopalatine fossa, infratemporal fossa, and nasopharynx usually indicates tumor involvement of these regions (Fig. 18.3). Dural thickening and enhancement are usually an indication of tumor invasion (Fig. 18.4). Similarly, thickening and enhancement of cranial nerves indicate perineural spread of the malignancy (Fig. 18.5). The identification by MRI of signal voids within the tumor or proximity of the neoplasm to the internal carotid artery may be an indication for preoperative angiography to assess tumor vascularity and plan surgical treatment. PET–CT along with MRI

**FIGURE 18.1**
Coronal CT with bone window algorithm. The arrow identifies erosion of the cribriform plate in this patient with sinonasal neuroendocrine carcinoma. (All figures are property of the Department of Neurosurgery, The University of Texas M.D. Anderson and are used with permission.)

**FIGURE 18.2**
A. Coronal postcontrast T1-weighted MRI reveals an enhancing tumor of the sinonasal cavity with transcranial extension into the left subfrontal region. (Same patient as in Fig. 18.1) (All figures are property of the Department of Neurosurgery, The University of Texas M.D. Anderson and are used with permission.) B. Axial T2-weighted MRI reveals a tumor of the sinonasal cavity of intermediate signal intensity (arrowhead) and adjacent high T2 signal intensity sinus secretions (arrow) (Same patient as in Fig. 18.1) (All figures are property of the Department of Neurosurgery, The University of Texas M.D. Anderson and are used with permission.)
CHAPTER 18 Transcranial Approach for Anterior Craniofacial Resection

FIGURE 18.3
Axial noncontrast T1-weighted MRI of patient with sinonasal adenoid cystic carcinoma. Note the expansion of the left pterygomaxillary fossa (arrow) with loss of fat hyperintensity. (All figures are property of the Department of Neurosurgery, The University of Texas M.D. Anderson and are used with permission.)

FIGURE 18.4
Sagittal postcontrast T1-weighted MRI identifies dural thickening and nodular enhancement consistent with recurrent sinonasal adenocarcinoma (arrow). (All figures are property of the Department of Neurosurgery, The University of Texas M.D. Anderson and are used with permission.)

FIGURE 18.5
Coronal postcontrast T1-weighted MRI. The arrow highlights the enlarged and contrast-enhancing left maxillary nerve in this patient with adenoid cystic carcinoma of the maxillary sinus. Pathologic confirmation of perineural extension of malignancy was made at the time of surgery. (All figures are property of the Department of Neurosurgery, The University of Texas M.D. Anderson and are used with permission.)
may help to identify lymph node involvement or distant metastasis. This, however, occurs in less than 10% of patients at initial evaluation.

Optimal management plans can only be constructed with accurate pathologic diagnosis of the neoplasm. Endoscopy permits access to most tumors of the sinonasal cavities. Occasionally, deep-seated lesions can be sampled by CT-guided needle biopsy. The importance of evaluation of the biopsy specimen by an experienced pathologist cannot be overemphasized.

**SURGICAL TECHNIQUE**

The goal of surgical management is to achieve a microscopically complete tumor resection with acceptable morbidity. Recent evidence suggests that this may not necessarily need to be done in an en bloc fashion. Certainly neurologic function should not be risked in an attempt to achieve an en bloc resection. In the presence of tumor extension to the cavernous sinus, internal carotid artery, and optic chiasm and in patients with distant metastases, surgery is usually not indicated except in highly select circumstances.

The transcranial approach for anterior craniofacial resection has as its goals the basal exposure of the medial anterior cranial fossa. It can be used as a stand-alone approach in tumors that do not extend lateral to the medial third of the maxillary sinuses, but it is commonly used in concert with nasal endoscopic techniques or occasionally with open transfacial approaches. The size of the craniotomy used depends on individual anatomic variability (especially of the frontal sinuses), tumor size, and extent. The use of intraoperative frameless stereotactic navigation allows for the optimization of the size of the craniotomy and its placement. The contours of the frontal sinus can easily be identified if a direct transfrontal sinus approach is chosen.

The patient is placed supine under general endotracheal anesthesia. The endotracheal tube is placed such that it will not interfere with any endoscopic or transfacial approaches. A tracheostomy is sometimes required. If facial incisions are used, then tarsorrhaphy sutures are placed on the side of the lateral rhinotomy or bilaterally. The head is elevated to allow improved venous drainage and gravitational relaxation of the cerebrum. Lumbar spinal drains are not used. A bicoronal incision extends from just in front of the tragus bilaterally posterior to the patient’s hairline. The incision is deepened down through skin and subcutaneous tissue until the galea aponeurotica is identified. The galea is opened sharply to expose the subgaleal space. Once the incision has been completed, skin hooks or rakes are used to elevate the bifrontal scalp flap. Sharp dissection with the #15 blade is used to dissect the underside of the galea away from the loose connective tissue until the bone is exposed. The galea is opened sharply to expose the subgaleal space. Once the incision has been completed, skin hooks or rakes are used to elevate the bifrontal scalp flap. Sharp dissection with the #15 blade is used to dissect the underside of the galea away from the loose connective tissue layer maximizing the thickness of the combined peristeal and loose connective tissue layer. This separation should not extend below approximately 1 to 1.5 cm above the orbital rims in order to protect the distal branches of the facial nerve supplying the frontalis muscles. The scalp flap is deflected anteriorly over a roll of lap sponges to prevent acute folding of the scalp. The scalp posterior to the incision is then undermined in the same layer to allow for the elevation of a large vascularized pericranial flap. The pericranial flap is then separated from the superior temporal lines bilaterally and posteriorly from beneath the scalp flap and with subperiosteal dissection is reflected forward (Fig. 18.6). Incisions are then made through both superficial and deep layers of the temporalis fascia beginning at the superior temporal line and traveling posteriorly toward the root of the zygoma for approximately 5 cm. This incision should begin approximately 1.5 to 2 cm above the “keyhole” region and travel parallel to the zygomatic arch. Subfascial dissection allows exposure of the anteriormost aspect of the cranial base.

**FIGURE 18.6** Intraoperative photographs of the incisions necessary to elevate the vascularized pericranial flap from the calvarium. Bilateral incisions through both the superficial and deep layers of the temporalis fascia free the flap from the superolateral orbits. The bilateral incisions at the superior temporal lines are connected posteriorly beneath the scalp posterior to the incision line. (All figures are property of the Department of Neurosurgery, The University of Texas M.D. Anderson and are used with permission.)
temporal fossa. The anterior aspect of the temporalis muscle can be dissected from the temporal fossa with periosteal elevators to expose the “keyhole” region bilaterally (Fig. 18.7). Entry holes are placed in both “keyhole” regions to expose the dura of the frontal lobe and the floor of the anterior cranial fossa. One or two entry holes are placed over the midline exposing the posterior most frontal dura lateral to the superior sagittal sinus bilaterally. The dura is then dissected from the underside of the calvarium, and a power osteotome is used to divide the calvarium from the central burr hole down to each entry hole in the “keyhole” regions. The power osteotome is used to create osteotomies superior to the orbital rims bilaterally. These osteotomies are carried to approximately the inner third of the orbits bilaterally. Osteotomies are then placed inferiorly from the medial aspect of these osteotomies to the region of the frontal nasal suture. The bone is then divided at the level of the frontal nasal suture. Usually, this allows for a controlled fracture of the posterior wall of the frontal sinus. If this is not easily accomplished, the use of a fine power osteotome through the previously constructed osteotomies with scoring of the posterior wall of the frontal sinus allows its controlled fracture. The bifrontal bone flap is then elevated. In patients in which the dura is tightly adherent to the calvarium, it may be best to remove the anterior wall of the frontal sinus as a separate osteotomy and then remove the posterior wall of the frontal sinus under direct vision. Cottonoids are used to protect the dural surface, and the dura is dissected from the posterior wall of the frontal sinuses bilaterally to the level of the foramen cecum. Careful epidural hemostasis is achieved. The frontal sinuses are then completely demucosalized and cranialized. With this very basal approach, the dura of the floor of the anterior cranial fossa is dissected and elevated from the floor. This is greatly facilitated by elevation of the patient’s head, by the use of hyperventilation to an arterial PCO₂ of 28 mm Hg, and, if necessary, by the bilateral opening of the frontal dura to allow egress of cerebrospinal fluid (CSF). The dura is elevated to the level of the crista galli and over both orbits. The crista galli is removed with a high-speed drill under magnified vision. The dural sleeves extending through the cribriform plate are cut, and elevation of the dura continues posteriorly to expose the frontal–sphenoid suture. The posterior ethmoidal arteries are identified at the posterolateral aspects of the cribriform plate in line with the frontal–sphenoid suture. After coagulation and division of the posterior ethmoidal arteries, further elevation of the dura is

FIGURE 18.7 Subfrontal approach for transcranial resection of a sinonasal malignancy. The vascularized pericranial flap has been elevated and reflected anteriorly, and the anterior temporalis muscle has been deflected posteriorly. A bifrontal craniotomy has been performed with inferior extension to just above the frontonasal suture. The next step would be to cranialize and demucosalize the frontal sinus and gain the subfrontal exposure by dissection of the dura off of the floor of the anterior cranial fossa.
The dura is then repaired primarily. If a larger defect is present, then a dural replacement graft is inserted and microscopically sutured to achieve a watertight closure. Much more commonly, however, the dura is involved by neoplasm, and in these circumstances, an intradural exposure is necessary. In this situation, bilateral frontal dural incisions are made, and the anteriormost superior sagittal sinus is ligated. Any tumor extending into the brain is removed in a piecemeal fashion. Involved cerebrum is resected using standard neuromicrosurgical techniques. Incisions are then made in the dura of the floor of the anterior cranial fossa circumferentially around the involved dura. The involved dura is allowed to remain fixed to the underlying tumor while the free edges are elevated off the floor. At this point, a dural replacement graft is inserted and microscopically sutured.

With a high-speed drill, osteotomies are made in the floor of the anterior cranial fossa. If the tumor involves the entire ethmoid sinus complex, the osteotomies are placed through the medial aspect of the roof of the orbit to enter the orbits bilaterally lateral to the lamina papyracea (Fig. 18.8). The posterior osteotomy should be at the level of the frontal–sphenoid suture. This suture typically overlies the posterior end of the posterior ethmoid air cells although it may overlie the anterior aspect of a large sphenoidal sinus. The posterior ethmoid arteries are identified, coagulated, and divided. Of note is that the exit of the optic nerve from the optic canal can be found approximately 5 to 7 mm posteromedial to the posterior ethmoid neurovascular bundle. The anterior ethmoid arteries are also identified intraorbitally, coagulated, and divided. From above, the peri-orbita is dissected from the lamina papyracea bilaterally, and a small curved osteotome is placed medial to the orbital tissues (Fig. 18.8). Osteotomies are made at the inferior aspect of the lamina papyracea just where the bone turns to form the floor of the orbit. This osteotomy is placed bilaterally. An osteotomy is then carried out across the lamina papyracea posteriorly with half of the osteotome placed in the orbit and half in the posterior ethmoid sinus. The posterior bony nasal septum is then divided with this curved osteotome. If the posterior osteotomy is through the planum sphenoidale, it enters the sphenoid sinus and needs to be continued through the anterior wall of the sphenoid to the floor of the sinus. Bringing the osteotomy through the floor of the anterior sphenoid sinus separates the face and rostrum of the sphenoid from the cranial base. The anterior osteotomy is performed across the base of the frontal sinuses and enters the nasal cavity (Fig. 18.8). The anterior aspect of the nasal septum is exposed and divided with heavy scissors. This allows removal of the specimen transcranially. Residual air cells are removed, and any involved or
questionable periorbital tissue is resected. Small periorbital defects are well tolerated, but large defects should be repaired with temporalis fascia. I do not use nasal packing but prefer to use bipolar cautery and the judicious use of topical hemostatic agents to achieve complete hemostasis. Small drill holes are then placed through the residual bone of the planum sphenoidale (Fig. 18.9). The pericranial flap is then tailored to the appropriate length and sutured to the drill holes placed in the planum and in the medial orbital roofs if available (Fig. 18.10). The bone flap is then placed in its anatomical position and rigidly fixated taking great care to avoid compression of the pericranial flap between the edges of the bone. The pericranium should be able to move freely between the edges of the bone. The bilateral incisions of the temporalis fascia are closed as is the scalp. The scalp is typically closed in two layers with absorbable suture in the galea and either staples or a nonabsorbable suture in the skin. Drains are not typically placed.
POSTOPERATIVE MANAGEMENT

Following extubation in the operating room, the patient is transferred to the intensive care unit for observation overnight. Hourly neurologic examinations are performed to assess for any changes in neurologic status. Assessment of the amount and nature of any nasal drainage is also important. It should be expressly communicated to all caregivers that nothing should be inserted into the nose. Also, if the orbits were entered during surgery, postoperative evaluations of visual acuity and pupillary function are necessary. Careful electrolyte balance is maintained since hyponatremia is not uncommon. Antibiotic coverage, begun preoperatively, is continued for 24 hours. Postoperative MRI is performed, preferably within 24 to 48 hours following surgery in order to avoid misinterpretation due to surgically induced enhancement of tissues.

COMPLICATIONS

The most concerning potential postoperative complication following craniofacial resection is that of tension pneumocephalus. There seems to be a particular risk for this complication following resection of the cribriform plate when compared with larger degrees of resection of the anterior cranial base. The relatively smaller degree of skull base resection needed for removal of the cribriform plate may contribute to a ball-valve mechanism that predisposes the patient to the accumulation of air under tension. This complication has become almost nonexistent since I stopped using lumbar spinal drainage. If it should occur, treatment consists of percutaneous aspiration of air and, in some cases, intubation. Much more commonly seen as a consequence of lumbar spinal drainage of CSF has been the syndrome of intracranial hypotension. In its mildest form, it consists of severe and occasionally incapacitating postural headache. Management is fluid hydration and slow mobilization. A high-volume (30 mL) epidural blood patch may be required if a lumbar drain has been used. The incidence of complications in the literature is difficult to evaluate because of a lack of uniformity in reporting. Most series report complications in 25% to 40% of patients undergoing craniofacial resection with mortality rates ranging from 0% to 7%. The most commonly identified complications include wound infections, meningitis, CSF leakage, delayed return of neurologic function, and pneumocephalus. Most of these series have spans of many years. In my series, dating back to 1992, in which aggressive antibiotic coverage is used routinely, no cases of osteomyelitis have been identified, and the incidence of meningitis is less than 1%. Similarly, consistent attention toward watertight closure of the dura, the use of vascularized grafts, and the liberal use of free tissue transfer have resulted in a 1% incidence of CSF leakage in my patients undergoing anterior craniofacial resection.

RESULTS

Recent large series of craniofacial resection have reported overall 5-year survival rates of 47% to 70%. The International Collaborative Study noted an overall survival of 48.3% at 5 years, with a 5-year disease-specific survival rate of 53.3% and a 5-year recurrence-free survival rate of 45.8%. Outcome is histology specific. At my institution, the 5-year overall survival rate for mucosal melanoma was found to be 38.7%, while that for olfactory neuroblastoma was 89%. Pathologically positive margins, involvement of the orbit, and invasion of the brain have also been shown to be predictors of local recurrence and a shorter survival time. However, well-selected patients with transdural extension of malignancy can have outcomes similar to those without intradural tumoral spread. In this group of patients, the most important factors affecting overall and progression-free survival were the ability to achieve microscopically negative margins and the lack of direct invasion of the brain. Although advanced age has often been identified as a negative prognostic factor, Hentschel et al. found no difference in oncologic outcome in a population of patients aged 70 years or greater when compared to a younger cohort. The cohort of elderly patients did, however, have a significantly greater incidence of cardiovascular comorbidities and systemic complications. Involvement of the intracranial internal carotid artery by high-grade malignancy remains the major contraindication to surgical excision of these tumors. Surgical resection did not provide a survival advantage in this subgroup of patients with malignancy of the anterolateral skull base.

PEARLS

- The first step in management is obtaining an accurate pathologic diagnosis.
- CT and MRI are complementary studies, both of which contribute to the ability to best plan the surgical removal of a sinonasal malignancy.
- The use of lumbar subarachnoid drains for withdrawal of CSF is unnecessary and is associated with a high rate of complications.
- Sharp dissection immediately below the galea aponeurotica maximizes the thickness of the loose connective tissue layer and thus the pericranial flap.
- The optic canal lies 5 to 7 mm posterior and medial to the posterior ethmoid foramen located at the lateral end of the frontosphenoid suture.
CHAPTER 18 Transcranial Approach for Anterior Craniofacial Resection

PITFALLS

- Failure to completely cranialize and demucosalize the frontal sinus can result in formation of a mucocele.
- Replacement of the frontal craniotomy without leaving adequate space for the pericranial flap can result in necrosis of the flap and an elevated risk of CSF leakage and infection.

INSTRUMENTS TO HAVE AVAILABLE

Standard neuromicrosurgical set, dural replacement graft, and frameless stereotactic navigation for some patients.

SUGGESTED READING


INTRODUCTION

While endoscopic endonasal access to the sphenoid sinus and skull base has dramatically changed the operative approach and patient recovery for many skull base pathologies, there are still many (and perhaps the majority) of neoplastic lesions involving the ventral skull base that require more than the endonasal approach alone. The development of the endoscope for cranial base surgery has made transfacial approaches nearly obsolete, but the concept of open craniotomy access remains viable. While transfacial approaches are still used for tumors that involve superficial structures such as skin, premaxillary adipose tissue, lacrimal sac, and anterior orbit, in our institution they are rarely applied outside of these situations.

The innovative use of traditional and minimal access craniotomy approaches has expanded the breadth of skull base pathologies that are now addressed with combined endoscopic-assisted craniofacial resections. There is no “attempt” to perform craniofacial resections “endoscopically or not”; the surgery is merely predetermined by the pathology, anatomical regions that need to be approached to resect the tumor, and reconstructive considerations. While we consider the endoscope helpful for osteotomy placement from above, with the avoidance of transfacial incisions that can have deleterious side effects apart from cosmesis (Fig. 19.1), the endoscope allows better access to the medial orbital wall to floor transition and still offers, in our opinion, better visualization of pathology in and around the sphenoid sinus. None of these advantages, however, dictate the application of endoscopic-assisted craniofacial surgery. We combine the endoscopic and open craniotomy approaches based on sensible anatomical guides that offer a practical approach to endoscopic-assisted craniofacial surgery, whether the combination is for access, reconstruction, or vascular control.

The majority of the tumors of the cranial base managed with endoscopic-assisted resections are malignant tumors or high-grade meningiomas, and as with other malignancy, the presentation may be related to local, regional, or distant disease. Defining the histology of the tumor and its stage is the key goal of investigations. Finally, treatment is generally multimodal with a combination of surgery and radiotherapy as the mainstay for most lesions. The proximity of critical structures, specifically the orbit, brain, and cranial nerves, dictate the morbidity from curative interventions.

HISTORY

The most important element in accurate diagnosis of sinonasal malignancy is clinical suspicion. The insidious onset of unilateral symptoms, the lack of previous inflammatory sinus disease or rhinitis, and the relative age of the patient (>50 years for tumors compared to <50 years for inflammatory disease) should be key features that prompt exclusion of neoplasia as a cause for a patient’s symptoms. Although the presentation can be with regional symptoms (mass in the neck, orbital changes, diplopia, epiphora or cranial nerve dysfunction) and/or distant metastasis, this is relatively uncommon for most tumors, and the more common presenting symptoms
(nasal obstruction, bleeding, discharge, and hyposmia) are local. These symptoms share common presenting complaints of patients with inflammatory sinonasal disease, which again highlights the importance of initial clinical suspicion. Unilateral eustachian tube dysfunction can also occur. Gross macroscopic changes to the mucosa of the hard palate or the skin are uncommon in developed countries. True involvement of the cavernous sinus by malignancy is generally a contraindication to surgery and curative treatment. Involvement of the proximal trigeminal nerves or the other upper cranial nerves should be evaluated. Numbness of the palate and midface dysesthesia are the signs of involvement in the pterygopalatine fossa and V2 involvement in the orbital floor or the roof of the maxillary sinus. Along with asking about orbital symptoms (visual acuity changes, diplopia, and displacement of globe), the inclusion of epiphora is important as this is an anterior limit often missed and needs to be addressed via a transfacial approach.

General health, nutrition, smoking status, bleeding risks, and prior nasal/sinus and cranial procedures should also be noted.

**PHYSICAL EXAMINATION**

The evaluation of a patient with skull base neoplasia should include the limits of the tumor. Superiorly, the involvement of the dura and brain parenchyma is a radiologic assessment in most patients. Inferiorly, the palate should be evaluated to see whether a total maxillectomy is necessary. Anteriorly, the lacrimal sac and premaxillary tissue should be evaluated bimanually via the gingival buccal sulcus. Laterally, above the orbital floor, signs of restricted ocular movements, conjunctival congestion, and orbital displacement are signs of involvement of a space-occupying tumor. The presence of trismus is an important sign that the masticator space/pterygoid muscles are involved.

Endoscopic examination reveals a mass within the nasal cavity (Fig. 19.2). Preoperative endoscopic examination can be useful to inspect for uninvolved areas of the paranasal sinuses. Many lesions appear extensive...
on imaging, but they are predominantly exophytic lesions with only a small area of invasion. If the lesion is unilateral, then assessment of the contralateral septum and sphenoid recess can greatly assist surgical planning. Look for evidence of prior surgery on the septum, sinus, or turbinates. The local reconstructive options available should be noted on examination. Examination of the neck for cervical lymph node metastases is important as these are not always accurately assessed on imaging and may provide an easy route for tissue diagnosis.

**INDICATIONS**

Skull base pathologies requiring endoscopic-assisted surgery are neoplasms: primarily malignant tumors of the paranasal sinuses (Fig. 19.3A). Some intracranial lesions such as atypical/aggressive meningioma are also addressed (Fig. 19.3B). The general principle of surgical access is important here. If the surgical approach crosses the axis of critical neural or vascular structures, then an alternate route should be considered.

Classic absolute indications to combined endoscopic and open cranial resection:

1. Involvement of the dura beyond the midorbital roof and intraorbital extension
2. Involvement of the anterior table or lateral recess of the frontal sinus
3. Significant involvement of the posterior table of the frontal sinus, where preservation of the sinus is not practical and cranialization should be performed
4. Tumor superior or lateral to the optic nerve canal
5. Tumor lateral to the carotid artery or involvement around bifurcations
6. Extension into facial or orbital soft tissues (usually transfacial approaches apply)

Relative indications:

1. Gross involvement of brain parenchyma
2. Lateral extension of tumor to the lateral wall of the maxillary sinus and infratemporal fossa

**CONTRAINDICATIONS**

Tumors that are situated entirely medial to the cavernous internal carotid artery (ICA) are most accessible using an endonasal approach and do not need an open approach. Where bacterial colonization is associated with the pathology, preoperative antibiotic therapy should be given. Severe local mucosal involvement from concomitant inflammatory conditions should warrant consideration of an alternate route.

**PREOPERATIVE PLANNING**

**Radiologic Evaluation**

Imaging should always be focused on what is trying to be achieved, namely tumor staging. Accurate information on local tissue involvement is critical for “T” staging. Most patients will undergo both computed tomography (CT) and magnetic resonance imaging (MRI) for several reasons. The T2 MRI will highlight edematous...
mucus and retained secretions compared to the tumor as defined on T1 post–contrast imaging (Fig. 19.4A). The involvement of the periorbita is determined by bone loss on CT and enhancement of adipose tissue on MRI. Thirdly, involvement of the dura (and brain parenchyma) is defined by bone loss on CT and dural enhancement on MRI (Fig. 19.4). Perineural involvement of cranial nerves is usually defined using fine-slice adipose tissue–saturated T1 post–contrast MRI. Finally, the relationship of the tumor to the intracranial course of the ICA and its branches is defined by either CT or MR angiography. Formal angiography of the ICA should be considered when there is tumor involvement or ectasia. The merits of preoperative balloon occlusion testing

FIGURE 19.4
The T1 (A) and T2 post–contrast (B) MRI characteristics of an invasive right sphenoethmoid SCC. The differentiation of tumor, mucus, and mucosal edema can be seen.
are very limited and should be applied when a sacrifice of the carotid artery and bypass is being considered and not just because of the risk of carotid bleeding. Where possible, include a scan series (CT or MRI) for future image-guided surgery (IGS) in the initial assessment.

Regional and distant metastases may be defined with a positron emission tomography/CT assessment. This technique is a combination of full-body CT and assessment of focal radioactive glucose uptake (18FDG) by cells. This is the most efficient form of staging and can provide standard uptake value information for subsequent follow-up. Imaging of the neck, chest, and abdomen as well as blood tests for calcium and alkaline phosphatase would also suffice. Specific investigations for bone, brain, or other metastasis are usually driven by clinical suspicion rather than being routine.

**Histopathologic Diagnosis**

Obtaining histopathologic confirmation of malignancy and its subtype is critical prior to therapy. This is usually done prior to treatment decision making, and the use of “frozen” or intraoperative specimens is ill advised and not recommended for a definitive diagnosis. This is important as some tumors such as lymphomas are radiosensitive and do not require surgery, whereas a diagnosis of melanoma would prompt an aggressive search for metastasis prior to local treatment.

The WHO classification is listed in Table 19.1 with the most common subtypes included. The epithelial versus nonepithelial distinction is easy and reflects the frequency of tumors. Epithelial tumors are the most common with squamous cell carcinoma (SCC), adenocarcinoma, and adenocystic carcinoma most commonly reported. The nonepithelial tumors are lymphoma (hematologic), olfactory neuroblastoma (neuroectodermal), chondrosarcoma (bone/cartilage), and mucosal melanoma (neuroectodermal).

Endoscopic biopsy can be performed in either a clinic or an operating room. The ability to manage a biopsy site that bleeds is critical. When lesions have already been imaged and the pathology is in the proximal nasal cavity anterior to the middle turbinate, we routinely biopsy these in the clinic as we have bipolar forceps and compression dressings available. This greatly assists in organizing further investigations and treatment decision making.

Patients with distant metastases rarely undergo surgical therapy. The focus of treatment in these patients is symptom control (palliation), and short courses of radiotherapy are often given. With the exception of lymphomas, chemotherapy/radiotherapy or combinations are not curative but given as adjuncts to surgical resection with curative intent. Radiotherapy is used to control local and regional disease. There are complex lymphatic channels in the paranasal sinuses and skull base that prevent full excision of the lymphatic compartments during surgery. Additionally, close surgical resection margins occur next to the orbits, carotid arteries, and cranial nerves that benefit from additional local therapy. Some centers use chemoradiotherapy for sensitive tumors such as olfactory neuroblastoma prior to surgery, as this is generally quick to initiate and can reduce tumor size,

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**TABLE 19.1 The WHO Classification System for Sinonasal Malignancies**

| 1. Malignant epithelial                      |                          |
|                                           | a. Adenocarcinoma       |
|                                           | b. Adenoid cystic carcinoma |
|                                           | c. Squamous cell carcinoma |
| 2. Neuroendocrine                          | a. Carcinoid            |
| 3. Malignant soft tissue                   | a. Sarcomas             |
| 4. Borderline and low malignant potential tumors of soft tissue | a. Hemangiopericytoma |
| 5. Malignant tumors of bone and cartilage  | a. Chondrosarcoma       |
| 6. Hematolymphoid                          | a. Lymphoma             |
| 7. Neuroectodermal                         | a. Mucosal melanoma     |
|                                           | b. Olfactory neuroblastoma |
| 8. Germ cell                               |                          |
|                                           | b. Lung                 |
|                                           | c. Renal                |

The Main Subtypes are Described Here with Common Pathologies.
making surgery less technically demanding (less bulk and bleeding). It is a misjudgment to believe that with this approach, a lesser region of the skull base can be removed as the resection must still follow the originally involved anatomical sites.

**Surgical Technique**

**Image Guidance**

The accessibility and ease of use with image guidance systems make them almost mandatory for modern craniofacial units. Although no surgery should be delayed because the IGS system is not functioning, an available IGS unit should always be used. We prefer to have patients in a Mayfield pin fixation when working in the sphenoclival area or when extensive drilling is required. The image guidance reference point is fixed to the clamp. For simpler tumors of the anterior cranial fossa with frontal sinus and orbital roof involvement, we use a bone-fixed reference point (Fig. 19.5). IGS is useful to define the limits of the frontal sinus and extent of the tumor, identify the ICA near tumor, and define the location of any cranial window to introduce a pericranial flap.

**Preparation**

a. 0.5 × 3 inch cotton pledgets soaked in 1:2,000 adrenaline + 1% ropivacaine
   i. 10 pledgets soaked by 10 mL of solution.
   ii. As many as possible placed in each nasal cavity immediately after intubation.
   iii. Remaining pledgets join the setup for use intraoperatively during the extradural approach.

b. 1% ropivacaine and 1:100,000 adrenaline mixture
   i. 2 × 10 mL solutions made by 9 mL of 1% ropivacaine and 1 mL of 1:10,000 adrenaline.
   ii. Inject any external scalp or eyebrow incision lines with one syringe.
   iii. The other is used endonasally via 22-gauge spinal needle on 10-mL syringe.

   iv. The distal 6 mm of the needle is bent at 45 degrees with bevel up to facilitate injection. The shaft is bayoneted to improve hand position.

   v. Injection: sphenoid rostrum, choana inferiorly, septum, nasal floor, middle turbinate root.

c. Perform the endonasal injections immediately when the endoscope is set up. Replace cotton pledgets under endoscopic control after injecting and complete set up of the surgical field (i.e., microdebriders, bipolar forceps, check that devices are working, check required instruments—as much time as possible).

d. Wait for the systemic effects of injection to resolve before surgery starts if the endoscopic component is first. Usually this occurs when the heart rate is below 70 bpm rather than a measure of mean arterial pressure.

The endonasal component of the resection proceeds by defining uninvolved sinuses to allow for visualization of the medial aspect of the orbits, nasofrontal recesses, and sphenoid sinuses. Bone landmarks (optic canals, carotid canals) are identified. The margins of resection are defined. When the resection is anterior to the anterior ethmoidal artery, visualization of the posterior wall of the frontal sinus via a Draf III frontal sinusotomy is critical, and anatomical landmarks are used to guide the surgeon instead of the variable anatomy of the frontal recess (Fig. 19.6).

We routinely visualize the orbital floor as a key landmark to define the sphenoid/posterior ventral skull base. Once this occurs, the orbital axis from the medial wall to the optic canal can be localized. Ligation of the internal maxillary artery is usually performed on the predominant side of the tumor to help control bleeding.
and gain access to the pterygopalatine and infratemporal fossa (Fig. 19.7). A Draf III frontal sinusotomy is performed to identify the posterior table and anterior ventral skull base. The ethmoidal arteries are controlled.

After consideration as to whether a nasoseptal flap is appropriate, a full posterior septectomy is used when dealing with tumors in the anterior cranial fossa. The sphenoid ostium is widened superiorly so that the level of the planum/roof can be visualized on the uninvolved side or it is identified by debulking and using the orbital floor as a guide. A large backbiting forceps is used to engage the posterior edge of the septum as close to the floor of the nose as possible. This nasal floor release of the septum comes anteriorly to the anterior wall of the frontal sinus and in line with where the anterior limit of the Draf III frontal sinusotomy will be. The 2-mm Kerrison rongeur is then engaged at the anterior limit of this backbiting forceps-made incision, and a vertical channel is made in the septum to the level of the roof of the sphenoid (now in view). The microdebrider can be used to remove some mucosa of the septum to view the contralateral turbinates/nasal cavity (although this may be primarily tumor). An inferior vertical channel of sphenoid bone is removed on either side of the midline. A large straight Mayo scissor, double action or thru-cutting, is used to define a superior incision in the remaining septum and continued into the intersinus septum of the sphenoid sinus. The roof of the sphenoid sinus, which is visible, is the guide. A large grasping forceps is used to remove the septum and sphenoid rostrum. The remaining anterior wall of the sphenoid is removed or tumor debulked laterally and superiorly to expose the roof and lateral opticocarotid recess. This creates a true posterior septectomy with a vertical anterior limit down to the floor of the nose and is ideal for instrument access.

The options for the cranial access are determined by what is required to manage the pathology.

1. No local reconstruction option available

When no local mucosal flap is available, the coronal approach can be used primarily to provide the pericranial flap based on one supraorbital vessel pedicle or the temporoparietal fascia based on the superficial temporal artery. These fascial flaps can be introduced to the anterior skull base through a simple window in the nasion.
region for the pericranial flap (Fig. 19.8) or passed via an infratemporal fossa tunnel to the posterior maxilla for a temporoparietal fascial flap. No formal craniotomy is required, and it avoids the potential for necrosis of bone flaps in patients undergoing radiotherapy, additional dural or venous injury, and subdural collections.

2. **Tumor with limited orbital roof, superolateral optic canal involvement, and ICA control**

The supraorbital approach is ideal when the tumor is located laterally and superiorly over the optic canal, orbital roof, and ICA. Here, the intradural approach offers limited brain retraction, the ability of both surgeons to work concomitantly, great cosmesis, and the ability to manage pathology lateral to the ICA that ensures good vascular control (Fig. 19.9).

The head is placed in the Mayfield pin fixation with the head turned 30 degrees to the contralateral side and the head extended to bring the malar prominence uppermost. The side of the approach is determined by the lateral projection of the tumor. The skin incision is placed in the superior border of the eyebrow, lateral to the supraorbital nerve (Fig. 19.9). A pericranial flap is reflected inferiorly and the keyhole exposed after skin and muscle dissection, which are retracted superiorly using fish hook retractors. A single burr hole is made and a free supraorbital bone flap, approximately 20 mm in height or approximately the width of an open bipolar shaft, is created. The inner table of the supraorbital rim is then drilled down along with the bony protuberances of the floor of the anterior cranial fossa to gain additional exposure. The dura is opened in a

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**FIGURE 19.8**
Pericranial flap being introduced through a craniotomy window when only pericranial fascia is required from the open exposure.

A. Small bone window at the level of nasion and below the level of cranial base.

B. Pericranial flap inserted through the bone window.

**FIGURE 19.9**
An example of a meningioma lateral to the carotid bifurcation (A). The A1 take off from the bifurcation is only seen in the distance with a 30-degree endoscope and does not represent safe access (B). The supraorbital incision (C) and approach (D).
C-shaped manner and reflected inferiorly. Under microscopic vision, the dura is identified over the orbit and the arachnoid of the carotid cistern is identified and opened to allow release of cerebrospinal fluid (CSF). No fixed brain retraction is used. Standard microsurgical techniques of tumor removal are used and the optic canals opened when required for complete removal of the tumor and decompression of the optic nerves. After removal of the tumor, the dura is closed watertight, and the bone flap replaced using two Craniofix clamps (Aesculap Inc., Center Valley, PA). The bone flap is approximated flush to the upper border of the craniotomy and the resulting inferior margin bone defect filled with Surgicel (Ethicon Inc., Johnson and Johnson, Piscataway, NJ), to reduce depressions in the forehead. The pericranial flap is carefully reapproximated, and the galea and skin are closed without tension. A subcuticular nylon running suture provides the best cosmetic outcome for skin closure.

3. Excision required of the orbital roof and anterior wall of the frontal sinus or need for cranialization of the frontal sinus
   A coronal incision is performed to expose the orbital rims. A “widow’s peak” in the incision allows for easy reorientation on closure. A “stepped” or “broken” incision can be useful to avoid an obvious incision when the hair is wet on the sides (Fig. 19.10). The incision is made posteriorly across the scalp in men when male pattern baldness is predicted. In women, a hairline trichophytic incision and closure can sometimes be used.
The traditional craniotomy can be modified (often via IGS) to encompass the need of the surgical access. When simple cranialization needs to occur, then a limited craniotomy (Fig. 19.11) can be used. This must be extended laterally to manage extension to the roof of the orbit. The bone flap must be discarded in cases of tumor involvement of the anterior wall of the sinus. Split calvarial grafts work well to avoid a cosmetic defect. Only in cases of extensive removal of the wall of the orbit is it reconstructed with titanium mesh. Contrary to traditional teaching, large segments of the medial wall and roof can be discarded without reconstruction with preservation of orbital stability.

**Closure**

Overall, reconstruction follows the principles of dural reconstruction and preventing CSF leaks, separating the intracranial cavity and the aerodigestive tract, covering nerves and blood vessels of the neck and skull base with well-vascularized tissue, supporting the orbit, separating the nasal cavity from the oral cavity, and restoring facial contour and function.

The dural defect is directly closed from above where possible. Vascularized flaps are preferred over free grafts. When a local fascial flap is used, it is an underlay flap on top of the skull base defect. Duragen, fascia, or other collagen substitute is used as a second layer to close the defect on the cranial side superior to the flap. When a local mucosal graft is used, the Duragen is placed intracranially (but not extradural), and the mucosal graft is an onlay flap. Tissue glue is used only on the nasal cavity side. Silastic sheets 0.5 mm (Medtronic, Jacksonville, FL) are used to cover the septum and any donor mucosal sites. It is secured with a 2/0 Prolene or 4/0 silk suture anteriorly through and through the anterior septum. Tie the knot on the left as this makes dividing the right loop in the clinic simple and easy for removal. Dissolvable packing (Gelfoam, Spongistan, Nasopore) is placed against the reconstruction. A Foley 16-gauge urinary catheter is used to compress the Gelfoam pack against the flap. The balloon is used to hold the Gelfoam in place. There is no uniform direct pressure applied or required on the flap by the balloon.

**POSTOPERATIVE MANAGEMENT**

Postoperative lumbar drainage is considered in all patients but rarely used unless the patient is at high risk for a postoperative leak. Those at high risk are obese patients or those with known elevated intracranial pressure, post-radiotherapy patients, and those with a resection cavity that is in free communication with a high-flow CSF cistern.

When used, the balloon is removed during the hospital stay. Most of the patients who have had a transdural approach are hospitalized for 5 to 7 days. Blowing the nose is avoided for 3 weeks when the dura or periorbita has been reconstructed. Silastic 0.5-mm sheets are used to cover any mucosal flap donor site for 3 weeks. The balloon is removed on days 3 to 4, and patients are observed for a further 48 hours. This may be conservative for some centers, but we feel that if a CSF leak has not occurred in the first 72 hours, then the chance of breakdown of the reconstruction after this point is uncommon. The risk of meningitis is also significantly reduced beyond 5 days. Patients are seen in clinic at 3 weeks post-op, and the silastics are removed. There is no need to see patients earlier with this suggested routine.

Nasal saline irrigation starts on day 7. There is no role for simple nasal sprays except for moisturizing crusts in the first 7 days. All postoperative recoveries must include high-volume positive pressure saline irrigations used twice a day. These are isotonic, and we do not promote special mixtures such as Ringer lactate, or hypertonic or hypotonic solutions as there is little clinical evidence that they offer any additional benefit over isotonic saline. Bactroban 2% ointment (the water-soluble propylene glycol version) is used topically in the nasal vestibule twice/day to minimize crusting and reduce *Staphylococcus aureus* colonization. Antibiotic coverage
is given for 10 days postsurgery or as long as dressings remain in the paranasal sinus. Our philosophy of long-term antibiotic use is not to prevent perioperative complications (such as meningitis) but to reduce the bacterial colonization that occurs in heavily operated and nonfunctioning sinuses.

**COMPLICATIONS**

The most common immediate complications are nasal bleeding, CSF leak (+/− pneumocephalus), and meningitis. Epistaxis is usually from a transected septal branch that has not been cauterized with bipolar diathermy during widening of the sphenoid inferolaterally; it usually occurs on the contralateral side to the septal flap. CSF leak is almost always a technical error or shift in reconstructive layers when they occur early (<48 hours) and a mucosal flap has been used. Early reexploration and revision are recommended. Lumbar drainage can be used when there appears to be good early healing but an event, such as the patient straining or blowing their nose, occurs and a small amount of CSF leak is evident. Cautious use of lumbar drainage may provide an avenue for closure without reexploration. Long-term follow-up of tumor recurrence and secondary effects such as post-radiotherapy hypopituitarism is ongoing. It may take up to 12 months before mucosal crusting fully resolves if there has been an extensive resection and radiotherapy. Ongoing nasal saline irrigations provide great assistance with this, and the goal is to provide a long-term functional cavity that is easy to evaluate (Fig. 19.12).

**RESULTS**

Comparable results have been noted for completely endoscopic, endoscopic-assisted, and standard craniofacial approaches for properly selected tumors. The selection of a surgical approach depends on multiple factors including the experience and comfort of the surgical teams.

**PEARLS**

- Always take great care in raising the pericranial flap. If the pedicle is compromised, a temporoparietal flap based on the superficial temporal may be harvested to replace it. Undermine the posterior incision to increase its length. One can never have too much.
- If the entire sphenoid sinus is full of pathology, then use a tranethmoid approach on the least affected side and use the orbital floor to locate the sphenoid sinus at a safe level below the skull base.

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**FIGURE 19.12**
An endoscopic view of the sinonasal cavity 1 year postexcision and radiotherapy of a T4 SCC of the septum. An inferior turbinate flap was used in the reconstruction. Leaving the cavity in this state allows for easy irrigation by the patient and surveillance by the physician.
Create your surgical access so that the procedure proceeds with a 0-degree endoscope and straight instruments. Avoid angled endoscopes; although the view may be good, the dexterity, manipulation, and access with instruments are often limited.

Cover all demucosalized nasal regions with an occlusive dressing (usually silastic sheets 0.5 mm) to prevent crusting and allow for quick granulation to occur in the first 21 days. Reepithelialization occurs quickly over granulation tissue but slowly over dry crusts.

**PITFALLS**

- In patients receiving induction chemotherapy prior to surgery, it is a misjudgment to believe that a lesser region of the skull base can be removed as the resection must still follow the originally involved anatomical sites.
- Visualization of the posterior wall of the frontal sinus via a Draf III frontal sinusotomy is critical, and anatomical landmarks are used to guide the surgeon instead of the variable anatomy of the frontal recess.
- Postoperative epistaxis is usually from a transected septal branch of the sphenopalatine artery that has not been cauterized with bipolar diathermy during widening of the sphenoid inferolaterally.

**INSTRUMENTS TO HAVE AVAILABLE**

Useful instruments for endoscopic-assisted craniofacial resections.

- Endoscopic drill: 5-mm 15-degree coarse diamond suction–irrigated ASB burr and protected high-speed irrigation burrs.
- Coblation is an excellent transnasal endoscopic tissue removal device and bipolar instrument. The Precise EZ Wand is malleable, low profile, and most suited to this work.
- Doppler ultrasound probe.

**SUGGESTED READING**


INTRODUCTION

In the late 1980s, Ivo P. Janecka and colleagues at the University of Pittsburgh proposed a new and radical surgical approach to the central cranial base. This operation became known as the facial translocation approach (FTA). At that time, the relatively new and still-evolving discipline of skull base surgery was becoming the focus of intense interest from neurosurgeons, otolaryngologists, plastic surgeons, maxillofacial surgeons, and others who were faced with the considerable challenges of caring for patients afflicted with benign and malignant tumors, infections, and deformities affecting the cranial base.

By then, the concept of craniofacial surgery had been known for decades, largely through the work of Paul Tessier, who revolutionized the treatment of congenital craniofacial deformities. The idea of “disassembling” the face and rearranging its components was now not only possible but broadly accepted at least for these deformities.

Janecka, a visionary thinker who had extensive training in otolaryngology, plastic surgery, and neurosurgery and who had studied under the great head and neck surgeon, John Conley, was interested in applying the principles of craniofacial disassembly to the management of the most deeply situated tumors of the central skull base. Specifically, he focused on tumors involving the nasopharynx, clivus, parasellar region, and infratemporal fossa.

The problems associated with operations in these compartments were daunting. The complex anatomy, with intimate proximity to the brain, carotid artery, cavernous sinus, orbital apex, and related cranial nerves, along with the aggressive transdural nature of some of the pathologies, added up to a very high-risk proposition for patients. Surgical access to these areas, usually attempted through narrow corridors with limited access, was usually unsatisfying, incomplete, and (by today’s standards) sometimes unsafe. Transnasal, transbasal, transpalatal, transsphenoidal, transtemporal, and other approaches all provided some access, but none in a comprehensive way that allowed adequate exposure for the safe recognition and protection of critical neurovascular structures. Therefore, CSF leaks, meningitis, sepsis, stroke, hemorrhage, blindness, other cranial nerve deficits, and severe deformity were all consequences of cranial base surgery at that time. Failure to achieve the desired oncologic goal was common. In many cases, the risks outweighed the benefits, and patients were sometimes relegated to palliative care or a slow, painful demise.

Applying and expanding Tessier’s principles of craniofacial disassembly, Janecka reasoned that a safer way to approach the central skull base would be to displace the external craniofacial anatomy to achieve a three-dimensional comprehensive exposure. This would allow methodical access to central skull base pathology in a way that made it possible to “control the perimeter,” and to identify and preserve the critical anatomy both proximal and distal to the pathology, at once providing enough room to achieve an oncologically meaningful and complete tumor resection, as well as a safe, functional, and aesthetic reconstruction.

A paper proving the anatomical concept of the FTA was published by Arriaga and Janecka in 1989, and the first clinical series was published in 1990. As clinical experience increased, a variety of modifications and extensions of the concept were also reported, and the indications for the operation were expanded. In addition
to publication in scientific journals, Dr. Janecka’s work was featured in a front-page article in the *Wall Street Journal*.

The FTA can be explained conceptually as a stepwise, modular disassembly of the face and skull, for the purpose of safe, three-dimensional, wide access to the central skull base. As Janecka wrote in one of the early reports, the FTA involved displacement of “complex but oncologically uninvolved craniofacial anatomy, which represents a barrier between the surgeon and the pathology.”

**HISTORY**

Neoplasms that are suitable for a FTA are a diverse group and may involve the central and lateral skull base. Symptoms are often nonspecific and delayed in onset and may include nasal obstruction, rhinorrhea or post-nasal drainage, epistaxis, headache, loss of olfaction, epiphora, hearing loss, facial pain, facial hypesthesia, trismus, dysarthria, diplopia, visual loss, and facial swelling.

**PHYSICAL EXAMINATION**

Physical examination includes a complete examination of the head and neck region, including endoscopy of the upper airway and assessment of cranial nerve function. Inspection of the head may reveal subtle asymmetry from extension of a tumor mass to the masticator space or infratemporal fossa. Otoscopy may reveal a retracted tympanic membrane or serous middle ear effusion secondary to eustachian tube dysfunction. The conductive nature of the hearing loss can be confirmed with tuning forks. Nasal endoscopy should supplement anterior rhinoscopy to provide complete visualization of the nasal cavity and nasopharynx. Small or recurrent cancers of the nasopharynx may involve the fossa of Rosenmüller. Tumor involvement of the muscles of mastication may result in trismus. Assessment of cranial nerve function may reveal sensory or motor dysfunction of the trigeminal nerve with decreased muscle contraction and drift of the jaw to the involved side with opening. Examination of the hypopharynx and larynx is important to assess the function of the vagus nerve. Deviation of the tongue with protrusion, fasciculation, and atrophy are indicative of hypoglossal nerve involvement.

**INDICATIONS**

Indications for the FTA are listed below. (Examples of lesions approached via FTA are shown in Figs. 20.1 to 20.4.)

1. Extensive juvenile nasopharyngeal angiofibromas extending through the skull base to the middle cranial fossa and cavernous sinus
2. Carcinomas of the nasopharynx originating primarily on the lateral wall of the nasopharynx
3. Chordomas of the clivus and the surrounding structures, especially those with extension across the midline and to the craniovertebral junction
4. Sarcomas of the sphenoid rostrum
5. Transcranial lesions such as meningiomas, nerve sheath tumors, and congenital tumors extending to the infratemporal fossa and nasopharynx
6. Extensive neoplasms of the parotid with intracranial, infratemporal fossa as well as lateral pharyngeal extent

**FIGURE 20.1**

Coronal MRI of a 16-year-old boy with an extensive juvenile nasopharyngeal angiofibroma (JNA).
As more experience was gained, the FTA was used to address other neoplasms, and also certain non-neoplastic disorders including complex encephaloceles, CSF leaks, and advanced infectious processes of the central skull base that were refractory to other treatments.

CONTRAINDICATIONS

There are no absolute contraindications for the FTA, but this approach has been replaced by other less invasive approaches for smaller tumors. Alternative approaches include transnasal, transmaxillary, and infratemporal skull base approaches. In particular, endoscopic endonasal approaches provide good visualization and access to the central skull base for clival lesions. Relative contraindications include a desire to avoid facial scars or temporary paralysis of the temporal branches of the facial nerve.

PREOPERATIVE PLANNING

Radiologic imaging usually includes both CT and MRI due to the complementary information they provide. They can help differentiate between tumor invasion of a sinus and obstructed secretions. MRI can provide evidence of periorbital or dural invasion. Nowadays, radiologic imaging is performed according to protocol in anticipation of intraoperative image-guided navigation. (It is important to note that the FTA was introduced before image guidance was commercially available; at that time the wide exposure was needed in order to safely visualize and protect the vital neurovascular structures. Currently, image-guided navigation, along with

**FIGURE 20.2**
Coronal CT of a 58-year-old man with a giant schwannoma of V3.

**FIGURE 20.3**
Coronal MRI of a 36-year-old man with a chondrosarcoma.
Other improvements in surgical technologies, sometimes makes it possible to use less invasive approaches. Refer to additional discussion below in Results.)

Orbital symptoms may prompt a complete ophthalmologic evaluation with assessment of visual fields. Electrical testing of motor cranial nerves is not necessary but may be useful in confirming subclinical deficits. A short differential diagnosis can usually be established with radiologic imaging. Preoperative biopsy of accessible lesions is advised if not a vascular tumor. Deep-seated lesions can be biopsied using CT-guided fine needle aspiration.

Preoperative planning includes informed consent with a complete discussion of alternative treatments, risks of the FTA, and the relative merits and disadvantages of alternative surgical approaches.

**SURGICAL TECHNIQUE**

**Preparation**

The patient is positioned supine on the operating table, with the endotracheal tube secured using either a dental wire to the maxillary teeth or a circummandibular wire, on the side contralateral to the surgery. This is important because it provides airway security while allowing the head to be turned and repositioned as needed for best exposure during the procedure. The patient’s head rests on either a flat bed or a Mayfield horseshoe but usually not in fixation pins unless extensive intracranial microdissection is anticipated.

The hair will have been washed with antibacterial soap before arriving in the operating room, and the skin of the face and scalp are now prepped in sterile fashion. The nose and mouth are irrigated with antibiotic solution, usually clindamycin. Intravenous antibiotics are administered prophylactically. Antithromboembolism stockings are applied to the legs, and the body is appropriately padded to prevent pressure-related ischemia if the operation is expected to be long.

Electromyographic (EMG) monitoring of the frontalis branches of the ipsilateral facial nerve is routinely performed, as this facilitates rapid identification and tagging of these nerves (to be described in detail below). Other electrophysiologic monitoring (e.g., somatosensory evoked potential, electroencephalography) is also initiated at this time, if needed.

**Incisions and Soft Tissue Flaps**

Incisions for FTA involve a combination of a lateral rhinotomy incision, a hemicoronal incision with preauricular extension, and an inferior fornix incision of the eyelid. All these incisions are contiguous, joined by a horizontal incision across the zygomatic region (Fig. 20.5). This horizontal incision is the key to combining the facial access with the temporal access, giving the essential three-dimensional craniofacial and orbital exposure that is so crucial to maximizing the deeper planes of access (Fig. 20.6). Depending on the specific pathology and the extent of the tumor, an upper neck incision may also be useful for proximal control of the carotid artery or to manage concomitant neck disease.
The incisions are marked, and injected with Xylocaine and epinephrine (1% and 1:100,000) to aid in hemostasis. The first incision is the horizontal incision across the temple, at the level of the zygoma; it begins just behind the lateral canthus and extends to the preauricular crease. This is carried through the skin and superficial subcutaneous tissues, which are gently retracted, and then using loupe magnification and EMG nerve stimulation, the frontalis branches of the facial nerve (“VII f”) are identified and gently exposed for a short distance of 5 to 10 mm (Fig. 20.7). Typically, there are between three and six separate branches that cross over the zygoma at this level to innervate the frontalis muscle. Note that the innervation to the circular orbicularis oculi muscle enters below this line, and orbicularis function is therefore preserved.

This horizontal incision was a source of controversy when the FTA was first introduced. (Other aspects of the operation that were initially criticized included concern over facial scars and the elective transection of the infraorbital nerve—to be addressed below.) It required a willingness to deliberately transect the upper branches of the facial nerve at the point where they cross the zygoma. However, as subsequent reports showed, the temporary forehead paralysis always recovers, provided the surgeon is meticulous in identifying and tagging these branches and in reattaching them at the end of the operation.

There are multiple ways to ensure that the forehead will become reanimated, but the essence is to be able to accurately find and recognize as many VII branches as are present and to then put them all back together at the end. An intimate knowledge of the layered anatomy of the temporal region is essential to this end.

I identify each VII nerve branch (again, using loupes and EMG), and transect it, placing a 7-0 nylon suture on each of the transected ends so that they can be easily found again at the end of the operation. Once all the branches have been found, tagged, and transected, the incision is then carried through the temporal pad of adipose tissue and down to the zygomatic arch itself.

The resulting lower facial soft tissue flap (“cheek and eyelid flap”) is then released in the plane of the parotid–masseteric fascia and reflected down to the level of the palate. This parotid–masseteric plane is deep to the parotid gland and the lower facial nerve branches, which are then out of harm’s way. This provides direct exposure of the masseter muscle and simple access to the condyle and coronoid processes, as well as the ramus, of the mandible.
FIGURE 20.6
Exposure of the craniofacial skeleton after reflection of soft tissue envelope.

FIGURE 20.7
Intraoperative photo of horizontal temporal incision (left side of the patient), showing four separate frontalis branches of the facial nerve.
In certain cases, the pathology may make it necessary to dissect and expose the proximal facial nerve, such as in deep-lobe parotid tumors, minor salivary gland tumors, and any tumors that extend into the lateral infratemporal fossa near the main trunk of VII. When this is necessary, the preauricular portion of the incision can simply be extended downward into a modified Blair incision, making this simple to accomplish. EMG monitoring of the lower branches of the facial nerve is of course still possible.

The next step is to perform the lateral rhinotomy, up to the level of the medial canthus (Fig. 20.6). The depth of incision extends to the periosteum of the nasal and maxillary bones, and the lower nose is mobilized off the pyriform aperture to expose the inferior aspect of the nasal cavity.

The fornix of the lower eyelid is then visualized, and the palpebral conjunctiva is incised. This incision is then extended medially, dividing the medial canthus, where it connects with the rhinotomy incision. It then extends laterally through the lateral canthus, and deeply down to the orbital rim and floor, until the eyelid is completely freed from the surrounding orbital skeleton in a subperiosteal plane. The nasolacrimal duct is divided as distally as possible at the medial orbital floor, and at this point, the entire lower eyelid is free to be retracted inferiorly (Fig. 20.8). In releasing the medial canthal ligament, it is helpful to use a marker or drill bit to mark the exact location of the canthal attachment to the nasolacrimal plate so that it can be accurately replaced at the end of the case.

Next, the premaxillary soft tissue is elevated in the subperiosteal plane, and the infraorbital nerve is exposed. As with the frontalis branches of VII, the infraorbital nerve is tagged with fine sutures, is transected, and will be reattached at the completion of the operation, if it is not involved by tumor. To protect this nerve, one simply uses a fine elevator to enlarge the infraorbital foramen slightly, and the transected proximal end of the nerve is pushed through the foramen and up into the orbit, where it remains until the reconstruction.

Of note, the infraorbital artery, which travels with the nerve, may be quite significant here, and sometimes it has to be controlled with bipolar cautery, taking care not to injure the nerve. Having divided the infraorbital nerve, the premaxillary soft tissue is now readily mobilized down to the Le Fort I line, just above the maxillary teeth. At this point, the skeletal features of the lower orbit, nose, maxilla, and zygoma are now fully exposed (see Fig. 20.6).

The hemicoronal incision is now made in the standard fashion and the frontotemporal soft tissues are elevated from the underlying temporalis muscle, taking care to stay deep to the previously tagged VII branches (see Fig. 20.6). The plane of dissection in the forehead is usually subperiosteal to permit osteotomies of the anterior cranial fossa, but if the pathology is confined to the middle fossa floor, this plane can be subgaleal.

Additional dissection in the orbit, using a Cottle elevator or fine Freer, releases the periorbita from the lateral and medial walls and floor, which will facilitate osteotomies (Fig. 20.9). The inferior orbital fissure is readily identified by palpation and can be helpful as a point of reference for placement of the osteotomy. If it is necessary to divide the ethmoid arteries (because of pathology that extends into the superior nasal cavity, anterior cranial fossa, or ethmoid region), they can be easily addressed with bipolar cautery or clips. The soft tissue envelope of the face is now completely mobilized (see Fig. 20.6).

It is noteworthy that the incisions used for FTA are respectful of the vascular territories of the face, and the resulting soft tissue flaps are quite robust in their blood supply from the facial artery and its branches, both ipsilateral and contralateral (e.g., inferior labial artery collateralizing across the midline). If the patient has had previous incisions or traumatic scars in the area, one must take them into account and modify the incisions accordingly to preserve vascularity to the soft tissue envelope.

**Osteotomies of the Facial Skeleton**

Osteotomies are now designed to mobilize the orbital, maxillary, and zygomatic (OMZ) skeleton in order to reach the next level of dissection (Fig. 20.10). These are accomplished using reciprocating or oscillating blades, or fine side-cutting drill bits. For the osteotomies of the orbital floor, the surgeon can use either a modified
right-angle oscillating blade or fine osteotome. It is important to use the thinnest possible saw blades (or side-cutting drill bits) so as to maximally preserve bone, which will facilitate accurate reconstruction when the OMZ segment is replaced at the end.

To separate this OMZ segment completely from the underlying structures, one must also release the origin of the masseter muscle from the zygoma, and release the loose attachments of the temporalis muscle from the undersurface of the zygoma. The osteotomy in the medial orbital wall will open into the ethmoid sinus, and the Le Fort osteotomy line will open into the maxillary sinus. Once all the osteotomies
are complete, it is usually necessary to do some gentle “prying” with an osteotome, or to release minor soft tissue attachments along the lateral maxilla, to fully mobilize and finally explant the OMZ segment (Fig. 20.11). It is then placed in antibiotic/saline solution and preserved for use later when reconstruction begins. Any remaining mucosa on the inside of the explanted OMZ is removed, since the maxillary sinus will be obliterated.

These osteotomies may be extended or customized for the needed degree of exposure depending on the extent of disease. I have extended the access well across the midline or even bilaterally in some cases. Careful planning in these cases is important to preserve vascularity to all affected soft tissues.

**Infratemporal Access**

With the facial soft tissue envelope mobilized and the OMZ skeletal access complete, the next step is access to the deeper extracranial spaces: infratemporal fossa, pterygopalatine fossa, nasopharynx, sphenoid, and clivus. For this purpose, the temporalis muscle must now be detached from its points of origin on the skull (Fig. 20.12). This is accomplished by subperiosteal elevation using sharp dissection. Extensive electrocautery is discouraged, especially near the medial/inferior aspect of the muscle infratemporally, since that is where the blood supply originates.

It is important here, as it was with the facial soft tissue envelope, to give due consideration to the blood supply of the temporalis, especially if the patient has had prior surgery, trauma, embolization, or radiation to the infratemporal fossa, where the maxillary artery gives off its anterior and posterior deep temporal arteries. Sometimes the pathology itself will compromise this arterial supply, and one must be very careful to preserve it, providing that it is appropriate oncologically. If the vascular supply to the temporalis muscle is not adequate, an alternative vascularized flap must be used in the reconstruction. I have used free flaps of several types, and even microvascular reattachment of the temporalis muscle has been described.

It is also important that the temporalis muscle be raised in its entirety as a unit, avoiding the temptation to transect it and leave some of it behind the ear. The relative bulk and volume of the temporalis muscle is variable, and if too little is mobilized, it may not be sufficient for reconstruction later in the case.

Once the temporalis is mobilized away from the skull and lateral orbit, it is reflected as inferiorly as possible. If the pathology extends inferiorly into the infratemporal fossa or nasopharynx, it may be helpful to do an osteotomy of the coronoid process of the mandible, down to the level of the neck of the mandible, which allows generous additional inferior mobilization of the temporalis muscle (Fig. 20.12). This coronoid osteotomy must be done cautiously, staying subperiosteal, so as to avoid injury to the maxillary artery nearby. Another simple method to maximize access is to place a bite block in the mouth on the ipsilateral side, thereby pulling the mandible downward.

As with any vascularized flap, it is important that the temporalis be handled gently, so as not to twist or kink its blood supply, and it should be wrapped in saline-soaked gauze to keep it moist during the extirpative phase of the operation.

The posterior and medial walls of the maxilla can now easily be removed with rongeurs. It may be necessary to ligate the distal branches of the maxillary artery (sphenopalatine branches). An osteotomy of the pterygoid plates at the base of the skull and at the palate is carried out with a reciprocating saw, rongeurs, or a Gigli saw.

The surgeon now has a direct view—and full three-dimensional access—to the entire ipsilateral maxilla, nasal cavity, ethmoid and sphenoid sinuses, nasopharynx, eustachian tubes (bilaterally), clivus, orbital skeleton, foramen rotundum (V2), and infratemporal fossa (see Fig. 20.12). The surgeon can now easily access any point...
along the anterior cranial base, from the frontal sinus posteriorly to the sphenoid, and along the middle cranial base, from the clivus to external auditory canal.

**Craniotomy**

For many extracranial pathologies, the procedure as described up to this point is adequate for safe exposure and extirpation. However, when there is transdural disease, or if the skull itself must be resected to obtain oncologic margins, the next step is to include some form of craniotomy.

At this point, the neurosurgeon joins the team and, depending on the needed access, a frontotemporal or temporal craniotomy is performed in the traditional manner. Whether the intracranial dissection is done intradurally or extradurally obviously varies with the extent of disease. The details of neurosurgical dissection are beyond the scope of this chapter, but it should be clear that the addition of the craniotomy allows another dimension of access to safely separate vital structures (brain, carotid artery, cranial nerves) from the disease process.

Once the intracranial exposure has been achieved, it is now possible to access key anatomic sites, including (from lateral to medial) arcuate eminence, geniculate ganglion (VII), foramen ovale (V3), foramen rotundum (V2), inferior and superior orbital fissures, orbital apex, and cavernous sinus. The full course of the internal carotid artery in its cervical, petrous, cavernous segments is now accessible in one field (Fig. 20.13).

**Reconstruction**

As in all cranial base reconstructions, scrupulous attention to detail is necessary in order to minimize complications. The two most vital concerns are closure of the dura and protection of the carotid artery. If the dura has been opened, it must be closed primarily in watertight fashion. While bone reconstruction is usually not necessary for the floor of the middle fossa, it is important that a well-vascularized layer of tissue be placed against the dura as a barrier to maintain separation between the cranium and the contaminated spaces below. The temporalis muscle flap (TMF) works well for this purpose.

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**FIGURE 20.12** Temporalis muscle detached from the skull and reflected inferiorly to reveal infratemporal exposure.
If the carotid artery has been exposed, it must also be securely covered with vascularized tissue. Again, the TMF is the most frequent choice, but if it is not usable, some other vascularized flap must be used. Failure to adequately cover an exposed carotid artery can lead to its rupture, hemorrhage, and death.

Next in reconstruction is the replacement of the OMZ bone segment. Obviously, the OMZ segment, once it has been removed, is not vascularized. The reason this bone can be explanted and then reimplanted, and stay viable, is the same as the rationale that works for craniotomy bone flaps, the Tessier-style craniofacial osseous reconstructions, and bone grafts elsewhere in the body. That is, although the bone is avascular, it will eventually become revascularized as long as it is rigidly fixed to adjacent healthy bone, and provided there is adequate soft tissue vascularity surrounding it on all sides when it is replaced. Therefore, it is necessary to ensure that well-vascularized soft tissues are positioned to ensure coverage of any reimplanted bone segments. Again, the TMF is almost always the best option for this.

Until one sees the utility and adaptability of the temporalis muscle in this region, it may be difficult to understand how one flap can satisfy all three of the above needs. Fortunately, in the majority of patients, a well-elevated, well-vascularized TMF has just about the ideal volume, length, and breadth to serve all three purposes well. Usually it is folded upon itself so that the proximal muscle abuts the dura and the carotid artery, and the broader distal muscle provides some filling of the infratemporal fossa, and also the bulk against which the OMZ segment will be sandwiched (Fig. 20.14).

The TMF will seldom be too large, but if it is, it can be divided axially into anterior and posterior portions, and the posterior portion can be replaced in the temporal fossa donor site. As for management of the donor site, it is aesthetically important to fill it in, since a noticeable depression in the temple would result. Autologous adipose tissue is, in my experience, the best initial choice because it is well tolerated and usually gives a satisfactory result without concern for rejection or foreign body infection. Polyethylene implants and hydroxyapatite cement are also available for filling in the temporal fossa, but my preference is to use these only if secondary reconstruction is necessary later.
It is the exceptional case that requires free tissue transfer after FTA. Usually these involve patients whose temporalis muscle has been compromised by prior surgery, embolization, tumor infiltration, or high-dose radiation.

When repositioning the OMZ segment, the previously transected proximal infraorbital nerve is guided back through the infraorbital foramen, and a neurorrhaphy is accomplished with 6-0 nylon. Although patients initially have complete V2 anesthesia, significant sensation in the cheek returns in most patients within a year (Fig. 20.15). Neuralgia in these patients is rare, probably because of the clean, deliberate way that the nerve is divided and precisely reattached.

The OMZ segment is then fixed using titanium miniplates, taking care to very accurately reproduce the anatomic relationships along the orbital walls and floor, and at the nasal bone and zygoma. One must be certain that, if the periorbita was violated at any point, any orbital adipose tissue or muscle is properly reduced to avoid entrapment.

During this OMZ repair, the transected nasolacrimal duct is redirected back into its natural canal so it can drain into the nose. A Crawford nasolacrimal tube is used to stent the upper and lower canaliculi during healing; this is usually removed 1 or 2 months later. A few patients will develop dacryostenosis and may require secondary repair.

Next, the soft tissue cheek/eyelid flap is suspended with a few tacking sutures so that the medial and lateral canthi can be accurately reapproximated without tension. Canthal placement must be precise to ensure best aesthetic and functional outcome; the medial canthus is affixed to the previously marked position with a permanent suture. The conjunctiva is then repaired with a few 6-0 fast-absorbing chromic sutures. Because of the gravitational forces and the weight of the cheek/eyelid flap, it is wise to support the eyelids with a temporary tarsorrhaphy suture in mattress fashion over soft plastic “bumpers;” these are removed in about 1 to 2 weeks.

Reapproximation of VII branches is next. The previously tagged nerve ends can be repaired either using traditional direct neurorrhaphy sutures (7-0 or 8-0 nylon) or by entubulation techniques. Reanimation of the forehead predictably returns in approximately 9 to 12 months.

Meticulous closure of all incisions should follow the best principles of plastic and reconstructive surgery. Perfect approximation of all suture lines, in multiple layers, will lead to minimal scar formation.
POSTOPERATIVE MANAGEMENT

Routine wound care is provided following the facial translocation procedure. An antibiotic ointment may be applied to external incisions excluding regions close to the eye. Saline nasal spray is used to minimize nasal crusting and an antiseptic rinse such as Peridex is used intraorally. Antibiotics are continued for 24 to 48 hours postoperatively. Patients are observed for signs of cellulitis and wound breakdown, especially osteomyelitis of the bone graft. Trismus resulting from dissection of the masticator space is treated with a bite appliance (TheraBite) and typically resolves after several months.

The temporary tarsorrhaphy and traction stitch is maintained for 1 to 2 weeks, and nasolacrimal stents are maintained for 1 to 2 months. Artificial tears and lubricant are used as necessary. Nasal endoscopy is performed periodically to debride crusts and monitor viability and healing of the temporalis transposition flap. Mucosalization of the wound is usually complete in several months.

COMPLICATIONS

Complications of the FTA can be understood in the context of the anatomy and surgical steps of the FTA. Facial incisions obviously result in facial scars, but these are cosmetically acceptable due to placement along the margins of facial subunits. Careful multilayer closure is important to achieve optimal results. Scar contracture of the conjunctival incision can cause an entropion or retraction of the lower eyelid. Poor alignment of the medial canthus results in facial asymmetry.

Incomplete regeneration of transected cranial nerves can result in facial hypesthesia (infraorbital nerve) and paresis of the frontal scalp (temporal branches of facial nerve).

One of the most devastating complications is osteomyelitis of the maxillary bone graft. This is usually attributable to poor fixation to surrounding bone and lack of soft tissue coverage, especially in the presence of prior irradiation. Debridement of the necrotic, infected bone is necessary with delayed reconstruction with bone grafts or alloplastic materials. Necrosis of the TMF is usually a result of injury to its vascular pedicle from excessive dissection or use of electrocautery. Necrosis of the TMF will require multiple debridements, and alternative soft tissue coverage of the skull base and carotid arteries may be necessary.

RESULTS

The FTA was a boldly innovative and groundbreaking change in the treatment of difficult lesions of the middle cranial base. As with other ideas that involve breaking tradition, the concept was initially met with some resistance in the world of skull base surgery, primarily because of three concerns: (1) extensive facial incisions with fear of unacceptable scars; (2) transection of the branches of the facial nerve; and (3) transection of the infraorbital nerve. Ultimately, these concerns were refuted as Dr. Janecka was able to demonstrate, through meticulous follow-up, the safety of the procedure and the reproducibility of good outcomes—functionally, aesthetically and oncologically.

Indeed, there was no other operation that could provide the comprehensive, open-field, three-dimensional access to the central cranial base that FTA provided. In my experience, that remains true to this day. The most
obvious advantage of the FTA is the luxurious surgical exposure that one can achieve (Fig. 20.16), providing unimpeded access into the deepest areas of the central cranial base, with safe outcomes and good quality of life (Figs. 20.17 and 20.18).

While there is no single perfect operation to reach these central skull base areas, the FTA certainly provides access that is as good as any other approach. The FTA has many steps, some of which are technically tedious, and therefore it is not an operation that one would use for minor problems. This is an operation used for individuals who have desperate problems for which there are no easy answers.

FIGURE 20.16
Axial CT scans of cadaveric specimen on which FTA is being performed, demonstrating magnitude of access achieved:
A. At the level of maxillary sinuses; before FTA. B. At the level of maxillary sinuses; after FTA. C. At the level of orbits; before FTA. D. At the level of orbits; after FTA.

FIGURE 20.17
A 16-year-old boy with giant angiofibroma (see MRI in Fig. 20.1). A. Incisions outlined; EMG electrodes in place to monitor VII. B. Soft tissue flaps displaced to expose craniofacial skeleton. C. After osteotomies and craniotomy, showing deep access to the central skull base; the infraorbital nerve is being held in forceps, and its proximal attachment at foramen rotundum is seen. D. Tumor removed; the nubbin of tumor at upper right was delivered from the cavernous sinus (arrow).
Fortunately, for patients and surgeons alike, technology has permitted refinements and shortcuts that were simply not available when the FTA was first described. In particular, the introduction of reliable image-guided navigation, exceptionally detailed preoperative imaging studies, sophisticated endoscopic tools and minimally invasive approaches, and improved adjuvant therapies have reduced the need for the kind of wide-open access that the FTA provides. It is now an operation with fairly limited indications.

As an editorial comment, I would offer this personal perspective on the FTA, more than 20 years after it was introduced. Even though the FTA is not now indicated as frequently as it once was, its importance is not diminished. On the contrary, with recent trends toward less-invasive and minimalistic operations, it may be more important now than ever. The clinical discipline of surgery is built upon the basic science discipline of anatomy. For a skull base surgeon, there is simply no substitute for understanding and being able to navigate the extremely intricate anatomy of the central skull base. The FTA should be studied by every student, resident, and surgeon who wishes to understand the cranial base.

**PEARLS**

- There are between three and six separate branches of the facial nerve that cross the zygoma.
- A transconjunctival lower eyelid incision hides the incision and avoids an ectropion that can result from a subciliary incision.
- It is helpful to use the drill to mark the attachment point of the medial canthal tendon on the nasolacrimal bone to facilitate accurate reattachment.
- The orbital osteotomy should connect to the inferior orbital fissure to release the bone.
- The blood supply to the temporalis muscle is located deep to the muscle (deep temporal branches of the internal maxillary artery).
- Transection of the coronoid process increases the mobility and reach of the temporalis muscle transposition without compromising its vascularity.
- Damage to the nerve endings can be prevented by sharply transecting the nerves.

**PITFALLS**

- Failure to carefully reapproximate the nerve endings with 7-0 or 8-0 nylon sutures will not ensure regrowth.
- Failure to secure the bone graft securely with titanium microplates and provide coverage with vascularized soft tissue can result in nonunion and infection of the bone flap.
● Entrapment of orbital soft tissues can be avoided by elevating the periorbita from the bone graft at reconstruction.
● Failure to support the eyelids with a temporary tarsorrhaphy can result in scar contracture and eversion of the lower lid.

INSTRUMENTS TO HAVE AVAILABLE

● Fine dissection scissors
● Magnification (surgical loupes or microscope)
● Periosteal elevators
● Reciprocating and oscillating saws
● Rongeurs
● 7-0 or 8-0 nylon sutures
● Crawford nasolacrimal tubes

SUGGESTED READING

INTRODUCTION

A midface degloving approach was first described in 1927. Casson et al. in 1974 described the current technique that is presented here. Conley and Price as well as many other authors have described this versatile approach. It is extremely useful in exposing the nasal cavity and the maxillary, ethmoid, and sphenoid sinuses. When combined with the coronal approach, access can be gained to the entire craniofacial skeleton. This is useful not only in tumor surgery but also for extensive midface reconstructions. Although it can also be applied in cases of panfacial fractures, a sublabial approach is usually sufficient for this. The operative technique is actually a combination of closed rhinoplasty dissection along with a sublabial approach.

HISTORY

The typical patient who is a candidate for midfacial degloving is one who presents with a complaint of nasal obstruction or epistaxis as a result of neoplasm of the nasal cavity, ethmoid, or maxillary sinus. The presentation is often quite insidious. Involvement of the second division of the trigeminal nerve is often a sign of rather advanced disease. Proptosis, diplopia, and visual loss are signs of invasion of the orbit.

PHYSICAL EXAMINATION

Intranasal examination may reveal a lesion of the nasal septum or of the wall of the nasal cavity involving the turbinates up to the superior aspect of the middle turbinate. It may also extend through the medial wall of the maxillary sinus into the sinus itself. Involvement at or above the middle meatus suggests involvement of the ethmoid sinuses.

INDICATIONS

The approach is typically indicated for patients with a neoplasm of the nasal cavity that does not reach the anterior cranial base. This may involve the wall of the nose, the turbinates, ethmoid sinuses, and the nasal septum. The nasal cavity is also quite readily accessible with this approach, and complete visualization extending to the nasopharynx can be achieved. If the mass involves the anterior cranial base, a midface degloving can be combined with an open technique such as a subcranial approach.
CONTRAINDICATIONS

This approach by itself is contraindicated in patients who present with a neoplasm that traverses the cribriform plate or roof of the ethmoid sinus. It may be used in conjunction with a subcranial approach with removal of the frontal bar, which would then provide complete exposure to the entire nasal cavity as well as the anterior cranial fossa.

PREOPERATIVE PLANNING

Maxillofacial CT scan with contrast including axial, coronal, and sagittal views is essential to determine the extent of tumor involvement. Any areas of bone destruction should be readily apparent. A magnetic resonance imaging (MRI) of the maxillofacial skeleton and cranial cavity is also important as visualization of soft tissue by MRI is far superior to that of a CT scan. This study allows viewing of the cranial nerves, and any enhancement of these areas would suggest perineural spread of malignant tumor.

SURGICAL TECHNIQUE

A sublabial incision is created extending from first molar to first molar along the maxillary alveolus approximately 6 to 7 mm from the gingival mucosal junction (Fig. 21.1). This allows for an adequate cuff of tissue during the closure. Retractors are used to evert the lips and the soft tissues of the cheek, and the first incision is made with electrocautery at right angles to the mucosa only. The second incision is made through this incision at right angles to the underlying bone going through submucosa and the periosteum. Using a periosteal elevator, the soft tissues are elevated over the canine fossa and medial and lateral buttresses up to the inferior orbital rim and onto the body of the zygoma taking care to preserve the infraorbital nerve bilaterally. Attention is then turned to the nose. A complete transfixation incision is made through the membranous columella extending from the tip of the nasal septum along its caudal border down to the anterior nasal spine (Fig. 21.2). This incision is then carried along the floor of the nose down onto the bone of the piriform aperture and then continuing in an superior direction incising between the upper and lower lateral cartilages. At this point, it is helpful to use a double hook inserted at the alar rim with the finger used to evert the lower level cartilage, thus making the junction of the lower and upper level cartilages much easier to identify. This incision continues superiorly and mediially between this inner cartilaginous region until it joins the nasal septal incision connecting with the membranous septum. Small curved iris scissors are then used to elevate the skin from the nasal dorsum taking care to leave the attachment of the upper lateral cartilages to the nasal bones intact (Fig. 21.3). This is done bilaterally at this point; attention is then redirected to the intraoral incision. Using wide retractors evertting the lips, the entire midfacial complex is then elevated superiorly using a periosteal elevator to release any remaining...
soft tissue attachments (Fig. 21.4). With complete exposure of the piriform aperture, osteotomies of the medial buttress with its removal will allow resection of a tumor of the nasal wall. The inferior osteotomy through the medial buttress is made with a saw blade more than 5 mm superior to the canine root tip. A vertical osteotomy is made through the lateral buttress. A transverse osteotomy connects the lateral buttress with the piriform aperture just inferior to the infraorbital nerve. Using a curved osteotome placed in the nasal cavity behind the medial buttress, the anterior maxilla is removed exposing the maxillary sinus and nasal wall. Reconstruction is then accomplished either by replacing the medial buttress or with an outer table calvarial graft. The skin is then redraped over the nasal dorsum. Absorbable sutures are used to close all intranasal incisions. Attention is then turned to the intraoral incision where prior to the main closure, one or two absorbable sutures are placed transversely in the midline so as to recreate the frenulum of the upper lip. This avoids the tethering effect of the upper lip to the underlying maxilla. Using a 3-0 absorbable suture starting from the midline and working laterally on each side, the suture is used to close the incision going through mucosa and submucosa in a horizontal running fashion. Once this is accomplished on each side, 4-0 absorbable sutures are used to close the mucosal edges in a simple running fashion catching only the mucosal edges. At the end of the closure, the incision is

**FIGURE 21.2**
Circumvestibular incisions are made allowing the lower lateral cartilages to be reflected with the nasal skin.

**FIGURE 21.3**
Scissors are used to elevate the nasal skin in a fashion similar to a closed rhinoplasty.
PART II Anterior Cranial Fossa

This avoids any long-term scar contracture that can result in gingival recession and exposure of tooth roots.

POSTOPERATIVE MANAGEMENT

Postoperative management is applying an ointment to the incisions and also saline irrigations not only to keep the incisions clean but also to clean the cavities in cases of tumor resection. Nasal saline spray is also useful to maintain moisture in the nasal cavity itself. After 1 to 2 weeks, nasal irrigation with saline spray is also quite useful to prevent crusting of the nasal cavity.

COMPlications

Almost all of these patients have decreased sensation in the distribution of the infraorbital nerve; however, with the nerves being preserved, resolution may take up to 18 months. On rare occasions there may be midfacial weakness from excessive retraction of the soft tissues and injury of the buccal branches of the facial nerve. Vestibular stenosis may occur; however, with meticulous mucosal closure, this should not occur. If vestibular stenosis does occur, it is most commonly seen in patients who have had postoperative radiotherapy.

RESULTS

The midface degloving approach affords excellent exposure to the anterior maxilla and nasal cavity. It can be combined with a Le Fort I osteotomy, which results in extending the field into the nasopharynx. The postoperative cosmetic result is superior to the lateral rhinotomy and Weber-Ferguson approaches.

PEARLS

- Elevation of the soft tissues of the midface may be done quickly with the surgeon standing at the patient’s head and using two elevators scooping toward the surgeon. This does require having an assistant holding retractors and another assistant maintaining the suction.
- Each end of a Penrose drain can be placed through each nostril and out then through the upper lip to use as a retractor.
- Preoperative and postoperative steroids are given to reduce the amount of postoperative edema.

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CHAPTER 21  Anterior Craniofacial Resection: Midfacial Degloving

PITFALLS

- The main pitfall of this technique is vestibular stenosis, which in some cases is unavoidable when patients are receiving postoperative radiotherapy.
- Excessive retraction of the midfacial soft tissues may result in temporary anesthesia in the distribution of the second division of the trigeminal nerve followed by paresthesia as sensation returns.
- Excessive retraction may also result rarely in weakness of the buccal branches of the facial nerve with a temporary loss of movement of the midfacial soft tissues that may take anywhere from 1 to 6 months to recover.

INSTRUMENTS TO HAVE AVAILABLE

- Standard head and neck tray
- Retractors
- Rhinoplasty tray

SUGGESTED READING

INTRODUCTION

The term lateral rhinotomy does not refer to a specific surgical procedure; rather it describes an incision placed on the face between the medial canthus and the anterior midline of the nose within the nasal–facial groove. The lateral rhinotomy incision can be used either in combination with the bifrontal craniotomy to manage the inferior aspect of tumors of the paranasal sinuses and medial orbit or as a stand-alone approach to craniofacial resection for tumors of the paranasal sinuses with limited intracranial extension anteriorly. In this section, the discussion is limited to a description of the technique as it applies to a combined approach with a separate craniotomy.

The lateral rhinotomy approach has been the traditional method of access and exposure of tumor of the superior ethmoid sinus and lateral nasal wall and was used in the early series of combined craniofacial resections. Detractors of this approach have cited the facial incision as a significant cause for using alternative methods. I find that with meticulous suturing technique and attention to detail, the incision can be minimized yielding an excellent aesthetic result. The decision on how best to manage the inferior and medial components of a tumor requiring a craniofacial resection is based on several factors including (1) anatomic site of origin of the tumor, (2) degree of involvement of the medial orbital structures, and (3) inferior tumor extension and involvement of the lateral nasal wall.

HISTORY

Patients often present with a long-standing history of nasal obstruction and rhinorrhea, frequently refractory to over-the-counter systemic or topic nasal decongestants. Patients with tumors of the ethmoid sinus, lateral nasal wall, and medial wall of the orbit requiring craniofacial resection with lateral rhinotomy will present with a history of unilateral nasal symptoms of obstruction, epistaxis, and/or purulent rhinorrhea. Masses extending laterally into the medial orbit or inferiorly into the inferior meatus may obstruct the lacrimal apparatus resulting in unilateral epiphora. Generalized symptoms of headache, (retro-)orbital pain, and facial pain can be due to blockage of the sinuses with inspissated secretions; however, consideration should also be given to extension of tumor to the periorbita or dura of the anterior cranial fossa.

PHYSICAL EXAMINATION

Patients with sinonasal malignancies involving the anterior cranial base should have a comprehensive head and neck examination including nasal endoscopy and flexible fiberoptic nasopharyngolaryngoscopy. Visual fields, extraocular movements, and visual acuity should be documented, and any patient with any abnormal findings should have a comprehensive ophthalmologic examination. A mass in the medial canthus, broadening of the nasal dorsum, or distortion of the normal anatomy of the nasomaxillary crease can be observed (Fig. 22.1).
Orbital extension can result in diplopia, restriction of gaze, proptosis, or changes in visual acuity. Skin involvement indicates an aggressive malignancy (Fig. 22.2). All patients should undergo biopsy prior to treatment. Tumors of this region are characteristically friable and tend to hemorrhage when manipulated; therefore, for safety purposes, consideration of biopsy in the operating room is warranted (Fig. 22.3). A comprehensive physical examination including risk stratification for patients with cardiopulmonary disease is necessary in all patients being considered for craniofacial resection.

**INDICATIONS**

The role and timing of surgery in patients with malignant neoplasms of the anterior cranial base depends upon the biology of the primary neoplasm and the patient’s willingness to accept craniofacial resection and its possible complications. Surgery remains the standard of care in the management of patients with minor salivary gland tumors of the anterior cranial base and lacrimal region, some neuroendocrine carcinomas, and adenocarcinomas. Sinonasal undifferentiated carcinoma, poorly differentiated squamous cell carcinomas, and other very high-grade neoplasms may be treated with multidrug neoadjuvant chemotherapy followed by definitive chemoradiation. The management of olfactory neuroblastoma (ONB) remains somewhat controversial in that some groups favor primary nonsurgical therapy with surgical salvage while others believe ONB is most amenable to treatment with definitive surgery.

**CONTRAINDICATIONS**

Contraindications for craniofacial resection via lateral rhinotomy include aggressive histology with poor prognosis, extensive involvement of the facial skin (limiting ability to obtain negative margins), radiographic evidence of extensive perineural invasion, poor performance status, and extensive involvement of the brain parenchyma and clinical or radiographic evidence of metastatic disease. A relative contraindication is lateral rhinotomy and partial maxillectomy in an only-seeing eye.

**PREOPERATIVE PLANNING**

Computed tomography (CT) and magnetic resonance imaging (MRI) should be viewed as complementary imaging modalities, and both are helpful in the preoperative evaluation of a patient undergoing craniofacial resection.
with lateral rhinotomy. The superior bony detail rendered by the CT provides useful information regarding the amount of bone destruction of the ethmoid labyrinth and nasal wall particularly on the contralateral side of the tumor. The MRI is able to more clearly identify transcranial extension of tumor and to delineate tumor from retained secretions in the sinuses (Fig. 22.4). The role of combined positron emission tomography–computed tomography (PET–CT) scanning in the preoperative evaluation of advanced skull base tumors is limited to the detection of cervical and retropharyngeal adenopathy and distant metastatic disease. I obtain PET–CT scan on patients with high-grade malignances and any patient presenting with cervical lymphadenopathy.

**SURGICAL TECHNIQUE**

When combined with bifrontal craniotomy for anterior craniofacial resection, the lateral rhinotomy is usually performed after the intracranial portion of the procedure, assessment of intracranial and intradural margins, and the reconstruction of the dura of the anterior cranial fossa.

The skin incision is marked prior to infiltration with local anesthetic (lidocaine 1:100,000 with epinephrine) to avoid distortion of the aesthetic units of the nose that are integral to the design of the incision. Ophthalmic ointment is placed in both eyes, and a suture tarsorrhaphy can be placed on the contralateral side to protect the cornea. I place a plastic corneal protector on the ipsilateral side to obviate the need for a tarsorrhaphy, which could distort the skin and make monitoring the eye more difficult. The incision begins under the ipsilateral eyebrow just medial to the supraorbital notch palpated in the supraorbital rim. The incision is beveled parallel to the hair follicles of the upper eyebrow and camouflaged along the inferior border of the eyebrow. The incision is extended inferiorly into the medial canthus where it is broken with the soft “W” or “Z” that will prevent webbing of the medial canthus. The apices of the broken incisions should be broad enough to prevent necrosis of the distal tip of the skin triangle, and monopolar cautery should be avoided in this portion of the incision. Failure to
break the incision in the medial canthus or necrosis of the distal portions of the incision will lead to unsightly webbing of the medial canthus. The incision is then extended inferiorly respecting the aesthetic units of the nose in a vertical line along the nasal–maxillary crease, around the alar crease and into the philtrum. Traditionally, the lateral rhinotomy incision terminated into the nasal vestibule; however, this places the integrity of the lateral attachment of the lower lateral nasal cartilage at risk resulting in nasal valve collapse. Based on the extent of resection necessary, a separate ipsilateral gingiva–buccal incision can be added to increase exposure to the maxillary antrum. Alternatively, the incision can be extended inferiorly to include an upper lip split if a radical maxillectomy is required. I have found that the subciliary extension (Weber-Fergusson incision) often results in an unfavorable functional and aesthetic result and is rarely needed even for radical maxillectomy. Upper and lower eyelid transconjunctival incisions can be added for orbital exenteration. Should bilateral exposure of the superior ethmoid vault be necessary, the incision can be extended across the midline with a 15- to 20-mm horizontal extension across the nasal dorsum (Fig. 22.5) at the level of the nasion.

Following the skin and ipsilateral gingiva–buccal sulcus incisions, subperiosteal dissection proceeds with exposure of the anterior face of the maxilla medial and lateral to the infraorbital neurovascular bundle, the bone of the nasal dorsum, the medial inferior orbital rim, and the pyriform aperture. The medial attachment of the medial canthal tendon to the anterior lacrimal crest is marked to facilitate the correct reapproximation of the tendon, and a medial canthotomy is performed tagging the tendon with a 4-0 clear nylon suture. The lamina papyracea and medial orbit are inspected, and, if needed, the medial periorbita can be resected and assessed with frozen sections. If there is no involvement of the periorbita, sharp subperiosteal dissection proceeds posteriorly into the orbit along the frontoethmoidal suture with identification of the anterior and posterior ethmoidal arteries. If not managed during the intracranial portion of the procedure, the vessels should be bipolar coagulated and transected. A small amount of the anterior lacrimal crest is removed with a Kerrison rongeur to facilitate the exposure and subsequent delivery of the lacrimal sac. The lacrimal sac is transected at the junction of the lacrimal sac and nasolacrimal duct and opened widely. The dacryocystorrhinostomy is completed by suturing the open sac to the periorbita anteriorly and posteriorly to maintain patency. If this procedure is being performed for a malignant tumor, then I place Crawford Silastic lacrimal stents into the superior and inferior lacrimal ducts delivered into the nose to maintain patency of the lacrimal system. If bilateral ethmoid and anterior cranial base resection is being performed, a subperiosteal plane must be developed over the nasal dorsum to the contralateral medial canthus, paying particular attention to keep the opposite medial canthal tendon intact. Finally, a portion of the anterior wall of the maxilla is removed and the maxillary antrum is inspected. Frozen sections of the antrum can be evaluated as necessary.

Complete mobilization of the soft tissue envelope provides the necessary access to the facial skeleton for the required osteotomies. Osteotomies are made with a high-speed reciprocating saw and antibiotic irrigation. Beginning inferiorly, a horizontal osteotomy is made from the maxillary antrum across the floor of the nose in the inferior meatus below the inferior turbinate. The second osteotomy is vertically oriented and placed

![FIGURE 22.5](image-url)

Incision placement for lateral rhinotomy. Incision can be extended across the midline with a 15- to 20-mm horizontal extension across the nasal dorsum (dashed line).
5 to 8 mm medial to the inferior orbital foramen and extends superiorly through the inferior orbital rim and the residual anterior maxillary wall into the orbit. Smooth malleable retractors and 1 × 3 cm neurosurgical pledgets soaked in lidocaine 1%, 1:100,000 with epinephrine are used to protect the orbital contents. Placement of the nasal osteotomies depends on whether the procedure is unilateral or bilateral. In unilateral cases, an osteotomy is placed in the nasofrontal suture; for bilateral procedures, the osteotomy is extended across the midline at the nasal dorsum with the saw and a contralateral osteotomy of the frontonasal sutures is performed with an osteotome as if one were performing a rhinoplasty. For a classical medial maxillectomy for an extracranial tumor of the nasal cavity, the superior osteotomy is made with the saw 5 mm inferior to the frontoethmoidal suture. When the medial maxillectomy is performed in conjunction with a transcranial approach, the superior osteotomy is more commonly made from the intracranial aspect through the fovea ethmoidalis and the roof of the orbit. Placing the osteotomies in this manner allows for the en bloc resection of the cribriform plate, fovea ethmoidalis, medial wall of the orbit, and lateral wall of the nose. Following the osteotomies, the remaining soft tissue attachments are divided with curved Mayo or right-angled scissors and the specimen is delivered anteriorly. Since the bony anterior cranial base is being removed as a part of the specimen, care must be taken to not disturb the anterior fossa dural reconstruction or compress the frontal lobes during the mobilization of the specimen. Visualizing the defect both intra- and extracranially will avoid such an injury. Brisk bleeding accompanies the transection of the branches of the internal maxillary artery; this is initially controlled with tamponade and then with bipolar electrocautery or titanium hemoclips. The anterior face of the sphenoid sinus and the nasofrontal recess are opened widely to ensure ventilation of the sinuses. The mucosa of the maxillary antrum and sphenoid sinus are assessed histologically for final surgical margins. Following establishment of definitive hemostasis, the wound is closed (Fig. 22.6).

Meticulous attention to detail at the time of closure prevents aesthetic and functional complications as discussed below (Fig. 22.7). The previously tagged medial canthal tendon should be approximated to the residual nasal bone for proper alignment of the orbit. The dacyrcoystorhinostomy should be reinspected and the lacrimal stents secured. The wound is closed in three layers beginning with approximation of the periosteum with buried polyglactin sutures. The subcutaneous tissue is closed with buried absorbable suture as well. The skin is closed with fine (6-0) monofilament nylon suture, a fast-absorbing chromic suture, or subcuticular closure; the latter two require reinforcement with Steri-Strips. The gingiva–buccal incision is closed in two layers with polyglactin suture for the periosteum and chromic suture for the mucosa. If the lip has been split, a multilayer closure beginning with meticulous realignment of the vermilion is performed; magnification with loupes is

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**FIGURE 22.6**
En bloc resection of lateral nasal wall and anterior cranial base. (#, inferior turbinate; *, crista galli.)

**FIGURE 22.7**
Favorable functional and aesthetic result following lateral rhinotomy.
helpful to ensure a good cosmetic result. If bilateral nasal osteotomies are required, a firm external nasal splint is applied to stabilize the nasal bone fragments, and after assessing vision in the recovery room, the ipsilateral eye is patched and a light pressure dressing is applied to reduce facial and eyelid edema. The denuded surfaces of the maxillary and sphenoid sinuses can be lightly lined with Gelfoam soaked in thrombin to reduce oozing. If there is persistent bleeding from bone or mucosal edges, the defect can be packed with antibiotic-impregnated nasal tampons or gauze.

POSTOPERATIVE MANAGEMENT

The additional of the lateral rhinotomy adds little to the routine postoperative care of a patient undergoing a craniofacial resection. Patients are extubated at the completion of the procedure to allow for a neurologic examination and assessment of vision. The eye on the ipsilateral side is patched, and a light pressure dressing is applied to the face overnight to reduce edema, and the head can be elevated 15 to 30 degrees. Normal saline nasal irrigations can begin on the 3rd postoperative day, and the packing can begin to be removed on the 5th postoperative day. The skin incision should be cleaned three times a day with hydrogen peroxide; topical antibiotics are not needed as they may cause local irritation. Appropriate ophthalmic lubrication should be used, and if a gingiva–buccal sulcus incision was needed, mouth rinses with 0.12% chlorhexidine gluconate mouthwash are prescribed.

COMPLICATIONS

Complications from craniofacial resection have been described previously and include meningitis, intraparenchymal hemorrhage, cerebral venous or arterial insufficiency, bone loss, cranial deformity, and systemic complications such as pneumonia, sepsis, and respiratory failure. Particular complications from the lateral rhinotomy separate from those of the craniofacial resection can be divided into hemorrhage, ophthalmologic, and aesthetic. Cerebrospinal fluid fistula has been described as a complication of the medial maxillectomy performed via lateral rhinotomy when the superior horizontal saw cut or osteotomy is made at or above the frontoethmoidal suture. In cases in which the lateral rhinotomy is performed in conjunction with craniofacial resection, the anterior fossa floor and superior medial orbit are resected and dura should be reconstructed in a watertight fashion. Vascular or hemorrhagic complications result from failure to control the internal maxillary artery or its branches. Large-caliber vessels should be ligated with titanium clips immediately upon removal of the specimen before they retract into bony canals and become more difficult to manage.

Loss of vision can occur if any of the osteotomies are carried too far posteriorly and result in damage to the optic nerve at the orbital apex. Excessive traction on the specimen during delivery can result in enough indirect tension of the globe to cause a traction injury to the optic nerve. Failure to reattach or accurately reposition the medical canthal tendon can result in enophthalmos, dystopia, and diplopia. A wide dacyrcoystorhinostomy and lacrimal stenting is necessary to prevent stenosis of the lacrimal apparatus, particularly during postoperative external beam radiation. Delayed epiphora may require dilation of the puncta and lacrimal ducts or, rarely, revision (conjunctivo-) dacyrcoystorhinostomy.

When meticulous closure techniques are applied, the healed lateral rhinotomy incision is barely perceptible. The skin incisions must be placed in such a way as to respect the aesthetic units of the nose. Minimal use of the monopolar cautery and gentle manipulation of the tissue edge are needed to prevent skin necrosis and unsightly scarring. Fine sutures should be used for the subcuticular and skin closures (Fig. 22.8).

RESULTS

The craniofacial approach to tumors of the anterior skull base was originally described by Ketchum in 1963. The lateral rhinotomy component of this approach provides excellent exposure of the sinonasal complex. Using this exposure, a medial maxillectomy procedure is carried out. The transcranial approach to the skull base may be done prior to or following transfacial surgery and the entire specimen removed from below.

With meticulous attention to surgical detail, complications such as penetration of the periorbita or dura can be avoided. A dacyrcoystorhinostomy will prevent epiphora, and fixation of the medial canthal tendon to the bone will prevent telecanthus.

PEARLS

- Mark skin incision prior to infiltration with lidocaine–epinephrine.
- Carefully mark attachment of medial canthal tendon and reattach with nonabsorbable suture.
- Control internal maxillary artery bleeding immediately.
Use broad gingiva–buccal incision to facilitate lateral exposure.
No need to sacrifice inferior orbital nerve.
Anchor the base of the lower lateral cartilage to the lateral periosteum of the face to prevent nasal valve collapse and a misshapen ala.

**PITFALLS**

- A skin graft placed in the intranasal defect will produce malodorous crusting.
- Inaccurate reattachment of the medical canthal ligament will result in telecanthus.
- Excessive retraction on the globe may result in blindness.
- Failure to do a dacryocystorhinostomy will result in epiphora.

**INSTRUMENTS TO HAVE AVAILABLE**

- High-speed reciprocating saw
- Sharp osteotome
- Malleable retractors
- Lacrimal dilators, probes
- Silastic lacrimal stents
- Topical hemostatic materials (Gelfoam, thrombin)
- Curved Mayo or right-angled scissors

**FIGURE 22.8**
Illustrative case of resection of a fibrosarcoma of the nose and anterior cranial base solely via lateral rhinotomy: (A) preoperative appearance, (B) exposure at the time of resection, (C) en bloc lateral nasal wall and cribriform specimen and (D) postoperative appearance at 9 years free of disease.
SUGGESTED READING

INTRODUCTION

Anterior craniofacial resection is defined as an open surgical procedure for the treatment of malignant tumors arising from the nasal cavity and paranasal sinuses, involving or transgressing the anterior skull base and the orbits. The procedure combines a frontal craniotomy with additional transfacial approaches, such as a lateral rhinotomy. In 1963, Ketcham published the first series and concluded that this exposure allowed appropriate staging of the extent of the tumor along with successful en bloc resection. Craniofacial resection has become the method of choice and gold standard for approaching malignant tumors of the anterior skull base over the years; however, later reports continued to document a considerable complication and mortality rate with this procedure. Numerous papers by others described different technical variations and modifications. Cantu summarized them in four categories: (1) classical transcranial/transfacial, (2) transcranial only, (3) transfacial only, and (4) subcranial, avoiding facial incisions.

In 1972, Derome was the first to describe an anterior extradural transbasal craniotomy-only approach allowing neurosurgeons to remove midline tumors of the anterior cranial fossa transcranially, yet avoiding transfacial procedures. He further noted that more centrally located structures, such as the clivus, potentially could be reached by this procedure. As a major disadvantage, the olfactory filaments were sacrificed, resulting in permanent anosmia. Further modifications of the original transbasal approach consisted of variations of the frontal craniotomy, the extent of orbital and nasal osteotomies, as well as the detachment of the medial canthal ligaments.

The subcranial extended approach was introduced by Raveh in 1978 mainly for the treatment of traumatic anterior disruptions of the skull base. Later adaptations included the correction of congenital and acquired craniofacial anomalies and finally, in 1980, the removal of benign and malignant neoplasms of the skull base. The differences from most earlier reported transfrontal techniques do not primarily lie in the location of the craniotomy and extension of the naso-orbital osteotomy lines but much more in the surgical exposure and direction of the approach.

The major advantages are the broad anterior and inferior exposure of the skull base plane including the roof of the ethmoid and sphenoid up to the clivus, laterally across the roof of both orbits toward the temporal bones, as well as caudally along the nasal and maxillary sinus region to the floor of the palate. This wide exposure enables optimal demarcation of the borders of the tumor and facilitates intra- and extradural radical removal of the tumor. Dural detachment is possible without major retraction of the frontal lobes, while preserving vital structures such as optic nerves, the optic chiasm, and carotid arteries.

The extended anterior subcranial approach may be combined with additional well-known procedures such as the midfacial degloving, Le Fort I down-fracture, or orbitozygomatic approaches, for even more extensive tumor invasion into the inferior maxilla, the orbit, or the middle cranial fossa and lower clivus. Nevertheless, disfiguring facial incisions are still avoided or invisibly hidden intraorally or transconjunctivally.

The efficiency of the Raveh technique has been confirmed by many others. In particular, publications by Fliss et al. provided numerous useful modifications, results and survival data including quality of life studies.
A uniformly accepted terminology regarding open surgical approaches to the anterior skull base does not exist in the literature, and the basic differences and similarities of the various modifications are often confusing. This lack of a common understanding inhibits communication and results in many passionate discussions.

**HISTORY**

Patients with sinonasal tumors often present with nonspecific symptoms that can be difficult to differentiate from inflammatory conditions. Common presenting symptoms of sinonasal tumors include nasal obstruction, rhinorrhea, epistaxis, loss of olfaction, epiphora, and headache. Extension laterally to the orbit can displace the orbit and result in diplopia or proptosis. Intracranial extension is often silent but may be associated with subtle changes in personality and mood, impairment of higher cognitive abilities, and memory loss. Loss of smell and taste may be the only symptom of a frontal lobe tumor such as an olfactory groove meningioma.

**PHYSICAL EXAMINATION**

A complete examination of the head and neck is performed. Nasal endoscopy is important to assess the extent of intranasal tumor and to obtain tissue for diagnosis. The orbit is examined for evidence of proptosis and decreased extraocular motility. Diplopia may result from displacement of the orbital tissues or from paralysis of extraocular muscles. Widening of the nasal dorsum may result from remodeling of bone from a slowly growing benign tumor or soft tissue invasion by a malignant tumor. Erosion of the anterior table of the frontal sinus may result in frontal swelling or a palpable defect in the bone. A complete neurologic assessment is performed with testing of visual acuity, olfactory function (if appropriate), and sensory and motor function (cranial nerves 3, 4, 5, 6, and 7). Involvement of multiple cranial nerves is a poor prognostic sign and suggests involvement of the skull base.

**INDICATIONS**

Indications for the extended subcranial approach include craniofacial trauma requiring repair of cranial, orbital, and midface fractures; correction of congenital and acquired craniofacial anomalies; and the removal of benign and malignant neoplasms of the base of the skull. The extended subcranial approach is an alternative to the standard craniofacial resection for most benign and malignant tumors. It can also be applied to the treatment of inflammatory disease of the frontal sinus when obliteration or cranialization is necessary.

**CONTRAINDICATIONS**

There are few contraindications to the extended subcranial approach. If tumor pathology extends to the inferior maxilla, the orbit or the middle cranial fossa, and lower clivus, the extended anterior subcranial approach may be combined with additional well-known procedures such as the midfacial degloving, Le Fort I down-fracture, or orbitozygomatic approaches. Additionally, many tumors with involvement of the skull base can now be effectively treated with endoscopic endonasal techniques.

**PREOPERATIVE PLANNING**

Preoperative assessment of pathology often requires both CT and MRI for evaluation of bone and soft tissues. These are obtained using a navigation protocol for intraoperative image guidance. If the tumor is accessible for endoscopic biopsy, this is preferred. Biopsies are not performed if there is concern about the vascularity of the tumor or there is a risk of a cerebrospinal fluid (CSF) leak. A complete ophthalmologic consultation is obtained in patients with visual symptoms. This may include visual field testing.

**SURGICAL TECHNIQUE**

**The Subcranial Extended Anterior Approach—Raveh Technique**

The patient is placed under general oral endotracheal anesthesia in the supine position. For stabilization and fixation, the head is fixed in a skull clamp (MAYFIELD Modified Skull Clamp System), prepped and draped with the upper face exposed. The BrainLAB bone anchored reference array is then fixed to the scalp through a small incision with a self-tapping screw behind the hairline in view of the camera. The three support pins prevent rotation during surgery. The surface anatomy is scanned with the wireless Z-touch laser device to calculate
the registration algorithm for intraoperative navigation. The standard bicoronal flap is then elevated with subperiosteal dissection up to the orbital rims, taking care to preserve the pericranium for possible use during reconstruction (Fig. 23.1). The supraorbital nerves are released from their canals using a Kerrison rongeur. The flap is dissected down to the frontozygomatic suture lines bilaterally and to the rhinion and piriform apertures in the midline. The periorbita is dissected from the superior, medial, and lateral walls of the orbit back to the apex on either side, and the anterior ethmoid arteries are clipped and cut. Raising the scalp and face flap induces traction on the orbital contents to a certain degree which causes no harm. In contrast, a procedure such as lateral retraction of the globes that puts pressure on the orbital contents should be performed carefully and only intermittently. The outline of the frontal sinus is identified with light from an endoscope and the intended bone flap is traced. The line of the nasofrontal segment may be deliberately extended cranially and laterally depending on the tumor extension (Fig. 23.2). The thin blade of a powerful high speed oscillating saw (TPS, Stryker SA, Montreux, Switzerland) is then used under water irrigation to perform the osteotomies across the frontal bone, down to and along the orbital roofs and medial orbital wall into the nasomaxillary groove just anterior to
FIGURE 23.3
Osteotomies are performed across the frontal bone, down to and along the roofs of the orbit, medial wall of the orbit into the nasomaxillary groove just anterior to the lacrimal crest. The lacrimal duct is removed from its canal. (Adapted from an illustration courtesy of Professor Dan M. Fliss.)

FIGURE 23.4
Following separation just anterior to the crista galli using a chisel, the frontonasal segment is detached providing direct vision to the nasal and sphenoidoethmoid extracranial part of the tumor. Further removal of the posterior wall of the frontal sinus allows exposure of the planum sphenoidale and intracranial neurosurgical dissection. (Adapted from an illustration courtesy of Professor Dan M. Fliss.)

The lacrimal crest (Fig. 23.3). The lacrimal duct is taken out of its bony canal. A vertical chisel osteotomy performed from the side just anterior to the crista galli allows detachment of the frontonasal segment and exposure of the anterior skull base. The nasofrontal segment is now elevated under direct vision. While careful attention is paid to the removal of all mucosa to expose the nasal and sphenoidoethmoid extracranial tumor part, using its lateral and caudal borders as guides, broad access is now provided to mobilize the caudal part of the tumor (Fig. 23.4). Cranial burr holes are then performed with diamond drills near the junction of the posterior wall of the frontal sinus and the roof of the ethmoid and dissectors inserted along the roofs of the orbits to protect the dura. Using the tumor borders as guides, more bone is removed, and the dura is divided circumferentially around the olfactory groove and the involved dura, facilitating exposure of the planum sphenoidale. The medial wall of the optic nerve canal is also unroofed by this access, and the optic chiasm and nerves can be exposed bilaterally. The last step consists of the microscopic intracranial neurosurgical dissection and finally
en bloc removal of the tumor. The exposed nasosphenoethmoidal resection cavity as well as the clival aspect are cleaned of remaining mucosa, and frozen section specimens are taken from critical locations.

Resection of a tumor mass creates a large dead-space defect with communication between the sterile intracranial space and the sinonasal cavity. Satisfaction regarding functional and cosmetic outcome always depends as much on the reconstruction as it does on the tumor resection. Dural defects resulting from intradural tumor involvement must be closed to restore a water- and airtight barrier between the intracranial contents and any communication with the sinonasal cavity or nasopharynx to avoid a CSF leak, pneumocephalus, or meningitis. Free fascia is the standard, harvested from fascia lata, pericranium, or the superficial temporalis fascia. The first layer is adapted and sutured to the edges of the resected dura. Further overlapping sheaths are meticulously applied and sealed with fibrin glue intracranially under the bone level between the lateral resection borders of the planum sphenoidale, orbital roofs, and frontal cranial vault. An additional collagen sponge coated with fibrinogen and thrombin coagulation factors (TachoSil®, Nycomed, Denmark) is glued over the superficial fascia layer toward the sinonasal cavity, which reaches from the exposed frontal lobes up to the clivus (Fig. 23.5A–D).

Significant osseous defects are likely to produce functional disturbances or aesthetic contour deformities such as enophthalmos or diplopia, if left unrepaired. The anatomical restoration of the missing medial wall and floor of the orbit to their original internal shape is therefore crucial to achieve a normal position of the globe. For this purpose, a high molecular resorbable l-lactide-co-glycolide preshaped triangle form orbital plate (Synthes Polymax) is heated in a hot water bath to a malleable state, then contoured to the desired shape before becoming rigid in air temperature again. This self-reinforced resorbable material shows high initial strength and mechanical stability similar to titanium and is consequently suitable for reconstructive procedures in non–load-bearing areas, even if later radiation is planned. A stable bridge of soft tissue should remain after complete degradation within 12 to 24 months.

Finally, I apply a vaseline-coated gauze along the skull base planes to provide additional support against brain pulsation, being removed transnasally after 8 to 10 days. The frontal sinus must be cranialized by removing the posterior table and removing all of the mucosa from the undersurface of the nasofrontal segment. The bone flap is then repositioned precisely to reproduce the original anatomical position and fixed with three-dimensional titanium microplates. Telecanthus should be prevented by bilateral fixation of the canthal ligaments. This is accomplished by passing a nonabsorbable suture through the medial canthal ligament and then guiding it under the nasofrontal segment to the contralateral anterior wall of the frontal sinus. Bilateral tightening of the suture results in medial, downward, and inward traction, thus achieving correct positioning of the canthal ligaments. The last step of the procedure consists in the application of suction drains and closure of the bicoronal incision in layers. In the absence of manifest signs of early postoperative CSF leakage, no lumbar drainage is instituted.

**FIGURE 23.5** A–D. Dural repair. A. Defect resulting from intradural tumor resection, showing posterior wall of the sphenoid sinus (S) and planum sphenoidale (PS). B. First layer of fascia lata (F) is adapted and sutured to the edges of the resected dura. C. Further overlapping layers of fascia lata (F) are applied over the bony borders of the resection. D. An additional collagen sponge (T) coated with fibrinogen and thrombin coagulation factors (TachoSil®, Nycomed, Denmark) is glued over the superficial layer of fascia toward the sinonasal cavity, which reaches from the exposed frontal lobes up to the clivus. (Adapted from an illustration courtesy of Professor Dan M. Fliss.)
Examples

Case 1: Esthesioneuroblastoma. This 83-year-old but physically younger and very active former airline pilot was flying a small aircraft, when he suffered a sudden frontal headache during rapid descent. The sinus barotrauma was first treated with topical decongestants and antibiotics, while endoscopic examination manifested a tumor mass in the left nostril that bled easily. Histopathologic findings of the biopsy revealed a high-grade esthesioneuroblastoma Hyams grade III. High-resolution CT and three-plane contrast-enhanced MRI confirmed a considerable tumor extending into the nasal cavity and ethmoid sinus along with intracranial tumor spread and erosion of the medial wall of the orbit. Accordingly, the tumor was classified as Kadish stage C or T4b according to the AJCC-UICC classification, respectively (Fig. 23.6A and B). Further medical investigation revealed a slight stenosis of the subclavian artery with absence of symptoms, hypertension, and cardiac right bundle branch block. Since this circumstance did not appear to be a major risk factor for the development of perioperative cardiac complications, there seemed to be no contraindication for surgery. Complete resection of tumor was achieved with an extended subfrontal approach as described above without complication.

Immediately following removal of the nasal packing at postoperative day 8, high-resolution CT and three-plane contrast-enhanced MR imaging were performed and demonstrated complete absence of the tumor (Fig. 23.7A–C). Nevertheless, for local tumor control, robotic and image-guided fractionated intensity-modulated radiation therapy (IMRT) with a total dose of 66 Gy was administered (Novalis Tx). No major complications occurred, and this patient is now free of disease at 44 months (Fig. 23.7D).

Case 2: Adenoid Cystic Carcinoma. The medical history of this 40-year-old female patient in the 6th week of pregnancy began with chronic nasal obstruction, hypernasality, slight swelling of the right eyelid with displacement of the globe, and mild pain in the upper jaw. Due to increasing complaints, 3 weeks later, an endoscopic maxillary sinus puncture and drainage of a presumed mucocele was carried out under local anesthesia without preoperative imaging. However, the drainage was suspicious for the presence of a low-grade adenocarcinoma. Therefore, the question whether or not this patient should undergo an MR examination during pregnancy week 13 did not arise; however, intravenous gadolinium was not used. The investigation revealed an extensive tumor mass in the right nasal cavity and paranasal sinuses up to the skull base, with possible erosion of the bony orbit and palate, as well as involvement of the globe (Fig. 23.8A and B). Despite the fact that the level of diagnostic radiation is too low to harm the fetus, a high-resolution thin-section CT scan to clarify the bony aspects was not performed at that time, leaving this important question open. The neuro-ophthalmologic examination revealed a slight asymmetry of the position of the globe with normal eye movement and no diplopia. The open biopsy under general anesthesia revealed an adenoid cystic carcinoma.

Diagnosis of cancer during pregnancy is rare, and the conflict between the diagnostic and therapeutic benefits against their risk to the unborn baby must be carefully weighed. Cancer rarely affects the fetus directly, but some cancer treatments may harm it. Following careful interdisciplinary consideration to optimize the safety of the mother and the unborn baby, our treatment planning at this stage of pregnancy and cancer stage T4BN0M0 according to AJCC-UICC was as follows:

- Delayed surgery in pregnancy week 20, posing little hazard to the fetus, yet with a residual risk of miscarriage
- Cesarean section after pregnancy week 32
- Proton therapy after delivery
- No breast-feeding

![FIGURE 23.6 A and B. Esthesioneuroblastoma Hyams Grade III. A, Preoperative coronal high-resolution CT. B, Contrast-enhanced MR imaging indicating the extent of the tumor into the nasal cavity and ethmoid sinus along with intracranial intradural tumor spread and erosion of the medial wall of the orbit.](image-url)
The management of involvement of the orbit is controversial. Although tumor infiltration of the periorbita and orbital adipose tissue can rarely be controlled by simple excision or irradiation, total orbital exenteration must be considered as a disfiguring and mutilating procedure that may only be performed with curative intention and preoperative agreement with the patient. Restoration of the defect always represents a challenge, and in more extensive cases, the boundaries between the empty orbit and adjacent resection cavities must be reestablished with free tissue transfer. Considering this psychologically and ethically most extreme scenario for the pregnant patient, her family, and the medical staff, I decided to omit both a maxillectomy and orbital exenteration at this first stage.

The extended anterior subcranial approach was done as described in case 1 (Fig. 23.9A and B). In order to gain control of the inferior tumor extension of the nasal cavity and maxilla, an additional modified midfacial degloving approach was selected in the same procedure. Following intraoral infiltration with an epinephrine-containing local anesthetics, a gingivobuccal incision was done and the anterior maxillary wall with the piriform aperture exposed. A full transfixion incision with vestibular extensions allows degloving of the midface and nose. It is now possible to gain access to the inferior aspect of the tumor both in the inferior aspect of the nasal cavity and the maxilla. The tumor is dissected by following the involved bony structures, and free margins are achieved avoiding hemimaxillectomy, with preservation of the tooth-supporting alveolar ridge (Fig. 23.10A and B). En bloc removal of the tumor is now possible via the subcranial route.

Four days after surgery, the patient was transferred from the intensive care unit to the maternity clinic, where 2 months later, she delivered a healthy girl by cesarean section in pregnancy week 33. Proton radiation therapy started 2 months later. The total radiation dose was 76 Gy at the critical locations, transferred in 30 fractions. High-resolution CT and three-plane contrast-enhanced MR imaging follow-up confirmed a tumor-free status (Fig. 23.11A and B).

Despite regular professional nasal care and repeated antibiotic drugs, chronic episodes of rhinosinusitis and intermittent inflammatory periorbital swelling appeared. Later, crystalline particles of the polymer were removed endonasally, and the clinical situation improved. This local foreign body reaction probably occurred
because of the decreased vascularity of the recipient site secondary to radiation and exposure of the implant in the nasal cavity. Two years after the initial treatment, a follow-up positron emission tomography–CT detected a hypermetabolic region in the anterior skull base fossa, but further imaging procedures and endoscopic biopsies were negative.

**POSTOPERATIVE MANAGEMENT**

The patient is monitored postoperatively in the intensive care unit for one night. Antibiotics are given for up to 10 days. Immediately following removal of the nasal packing at postoperative day 8, high-resolution CT and three-plane contrast-enhanced MR imaging are performed to assess the completeness of resection. For local tumor control, surgery is often supplemented with robotic and image-guided fractionated IMRT (Novalis Tx). Unpleasant nasal crusting along with a constant foul-smelling odor is frequently encountered following treatment of this sort. This condition is easily managed with repeated nasal salt water irrigation, to wash out the crusts. Daily nasal hygiene with mechanical loosening of the crusts and application of oily nose drops, emulsions, or ointments are essential.

**COMPLICATIONS**

Even though the majority of the tumors reported in the above series were extensive, the complication rates were low. Major damage to intracranial nerves was not encountered, only a mild impairment of vision in two cases.

The early and late complications related to the extended subcranial approach are listed as follows: pneumocranium (4.9%) or immediate CSF leakage (3.2%) mostly developed after accidental removal of the nasal packing in the early postoperative stage. These leaks were successfully controlled by a lumbar drain. In three patients with inadequate primary fascia lata alignment, revision surgery was necessary. Enophthalmos (11.4%) was most probably caused by secondary resorption of orbital adipose tissue, whereas telecanthus (6.5%) developed after collapse of the nasal framework. Both were more aesthetic than functional problems. Two of three cases with mucocele formation (2.4%) needed revision surgery several years later. In contrast to earlier reports, partial resorption of orbitomaxillary bone grafts (8.1%) and necrosis of the nasofrontal segment (2.4%) were observed more frequently.

With one exception, all of these patients underwent postoperative radiotherapy. Two patients with near-total segment necrosis developed a nasofrontal fistula, which made a local repair necessary. The collapsed frontonasal segments were successfully reconstructed in three cases. A patient with major cosmetic disfiguring needed difficult free flap reconstruction.
RESULTS

Due to the lack of a uniform international clinical classification and the heterogeneity in the reporting of the tumor extension—mainly for intraorbital and intracranial extension—the treatment outcome differs substantially among different publications in the literature. A combination of benign and malignant tumors within the same statistics is not acceptable. Only a proper histopathologic classification and cancer staging allow a correct and reliable evaluation, interpretation, and comparison of the results. However, the detailed references to the state of disease and overall survival rate related to the extended subcranial Raveh approach are beyond the scope of this article and are stated elsewhere.

FIGURE 23.9  A–C. Anterior view of the classical subcranial exposure offering direct vision of the superior aspect of the tumor. A. Schematic drawing (Adapted from an illustration courtesy of Professor Dan M. Fliss.). B. Intraoperative view before resection of the tumor. C. Subcranial exposure following resection of the tumor with preservation of the globe and minimal intracranial exposure along the cribriform plate.
The latest retrospective evaluation containing our material compared the surgical approaches—open vs. endoscopic—in 123 patients treated from 1992 to 2008, including information on tumor stage, histology, treatment, and follow-up. Squamous cell carcinoma was the most common histopathologic entity, diagnosed in 30.9%, melanoma was found in 19.5%, and adenocarcinoma in 17.1%. Following, in descending order of prevalence, were esthesioneuroblastoma at 8.9%, lymphoma at 5.7%, undifferentiated carcinoma at 4.9%, adenoid cystic carcinoma at 4.9%, plasmacytoma at 3.3%, metastatic disease at 1.6%, fibrosarcoma at 1.6%, and leiomyosarcoma at 1.6%. Open surgery was performed in 45% and endoscopic resection in 23% of the cases. Nineteen patients were treated with primary radiation therapy, 15 had primary chemoradiation, and four underwent primary chemotherapy. Two patients died prior to the onset of therapy. Adjuvant radiation therapy followed surgery in 64% of the open approach patients and in 68% of the endoscopic resection patients.

The 5-year and 10-year disease-specific survival rates were 63% and 59%, respectively, and the recurrence-free survival rates 49% and 35%, respectively. The comparison of the survival rates and recurrence-free time did not show a significant difference between the treatment groups. However, since most patients with advanced T3 and T4 tumor stages were treated with an open approach, it is likely that the difference, even if not statistically significant, is biased by patient selection. Not surprisingly, patients who underwent endoscopic resection had significantly fewer postoperative complications. Most accepted unfavorable prognostic factors are the involvement of the dura and the intradural spread, extension into the orbits—particularly the apex—as well as invasion of the infratemporal fossa and the skin.
PEARLS

- Preoperative imaging including both three-plane high-resolution CT and contrast-enhanced MRI is essential for exact tumor staging.
- The outline of the nasofrontal segment depends upon the anatomy of the frontal sinus, the tumor size, and location in regard to the intracranial extension.
- Type A osteotomy leaves the posterior wall of the frontal sinus intact to be removed in a second step, whereas type B osteotomy includes the posterior wall in a one-step procedure.
- Special care is taken to preserve a small bridge of bone over the anterior part of the nasal bone, which facilitates later reconstruction of the nasal dorsum.
- If the tumor is unilateral, preservation of the olfactory filaments on the contralateral side may be possible.
- The osteotomies are performed using the thin blade of a high-speed oscillating saw under water irrigation in an oblique manner, providing sufficient bone contact for optimal healing.
- Combinations with classical approaches such as pterional, orbitozygomatic, or Le Fort I osteotomy enable additional exposure to the parasellar region and infratemporal and sphenopalatine fossa, providing en bloc rather than a piecemeal resection, while avoiding injury to vital adjacent structures.
- For dural repair, the fascia must be prepared, so that all adipose tissue and excess tissue is removed to optimize tissue adherence.
- Fibrin sealants are not absolutely necessary, but they do assist as an adjunct to prevent leaking and hemorrhage.
- The frontal sinus is cranialized by total removal of the posterior wall.
- Wrapping of the nasofronto-orbital segment with the pericranial flap should prevent resorption and osteoradionecrosis.
- The extended subcranial approach as developed by Raveh and endoscopy are not two fundamentally opposing principals: in fact, application of endoscope-assisted minimally invasive techniques can be helpful by achieving the goal of a safe and radical resection.

PITFALLS

- Plating and bone grafts along the skull base are contraindicated.
- Free bone grafts exposed to the sinonasal or pharyngeal cavity are vulnerable to infection and necrosis. Covering the grafts with vascularized tissue should reduce these complications.

**FIGURE 23.11** A and B. Postoperative contrast-enhanced MR imaging confirming tumor-free status.
● Decreased vascularity of the recipient site secondary to preexisting scar formation or high radiation doses compromises a normal healing process and acceptance of any biomaterial.
● The extensive use of expensive alloplastic materials is only justified if the donor site morbidity and operation time are significantly reduced and relevant complications can be avoided.

INSTRUMENTS TO HAVE AVAILABLE

● Neurosurgical tray
● Colorado microdissection needle
● Raney clips
● Bipolar forceps
● Orbital retractors
● Brain spatulas
● Osteotomes and Mallets
● Rongeurs (Kerrison, Blakesley)
● Awl
● High-speed pneumatic drill
● Oscillating saw
● Plating systems
● Endoscopes
● Surgical microscope

SUGGESTED READING


INTRODUCTION

Cranialization of the frontal sinus is used in the management of a number of disease processes. Classically, it has been employed as part of anterior craniofacial resection in which the posterior wall of the frontal sinus is removed, which allows for the expansion of the frontal lobes and effectively obliterates the frontal sinuses. Other instances in which this procedure has been employed include disease processes such as fungal sinusitis and isolated tumors of the frontal sinus that erode through the posterior wall of the frontal sinus, in some instances involving the dura and/or brain. The last instance in which cranialization may be employed is in both blunt and penetrating trauma with disruption of the posterior wall of the frontal sinus.

HISTORY

The most common history for patients undergoing cranialization of the frontal sinus classically is the presence of a malignant tumor of the anterior skull base requiring craniofacial resection. These patients typically present with symptoms of nasal obstruction, epistaxis, visual changes, and mucopurulent discharge.

For the patients presenting with trauma, the history can consist of both blunt and penetrating trauma. This again covers a wide spectrum of traumatic events including high-velocity vehicular trauma, falls from heights, and a series of other blunt and penetrating traumas, including gun shots and other penetrating injuries. In evaluating these patients, appropriate history includes signs of orbital dysfunction, visual loss, cerebrospinal fluid (CSF) rhinorrhea, meningitis, and other injuries to the craniomaxillofacial skeleton.

For patients with either isolated tumors or sinusitis, symptoms are typically relegated to the region of the frontal sinus. This can include orbital proptosis, pressure, epistaxis, or fever. Prior history of sinonasal surgery, including nasal tumor surgery, is a salient feature of the history. Specifically, a prior history of inverted papilloma resected from the lateral nasal wall may present with an isolated recurrence in the frontal sinus.

PHYSICAL EXAMINATION

Physical examination of the patient being considered for frontal sinus cranialization will again be predicated on the aforementioned underlying pathology.

For those who are undergoing anterior craniofacial resection, the necessity of performing nasal endoscopy, assessment of orbital function, and sensory testing of the trigeminal distribution is essential. It is also critical to exclude metastatic cancer in the cervical lymph nodes.

For those who have sustained trauma, it is critical to exclude additional craniomaxillofacial and skull base fractures. Orbital function should be assessed. Evaluation to exclude CSF rhinorrhea should be performed with nasal endoscopy. Orbital function including pupillary response and the absence of a Marcus Gunn pupil (afferent papillary defect) is critical. Formal ophthalmologic examination may be indicated on a selective basis.
Evaluating the anterior wall of the frontal sinus to exclude a penetrating wound and a comminuted fracture is critical. Moreover, looking for and palpating for subcutaneous air is an important part of the examination and will provide clues as to the extent of the injury.

For individuals presenting with a suspected isolated tumor of the frontal sinus or infection, palpation of the wall of the anterior frontal sinus to exclude erosion is critical, including the presence of a soft tissue mass. It is important to assess ocular function. Nasal endoscopy will often provide significant clues as to previous intranasal surgery. It may also provide insights regarding the presence of active infection.

**INDICATIONS**

Cranialization of the frontal sinus is performed as an alternative to a frontal sinusotomy with preservation of normal sinus drainage and obliteration of the sinus with an adipose graft or other tissue. If the pathologic process can be treated with preservation of normal anatomy and drainage pathway, then this is usually the preferred option. The development of advanced endoscopic techniques has dramatically reduced the need for open frontal sinus procedures. A Draf III frontal sinusotomy provides access for the drainage of mucoceles and chronic frontal sinusitis, removal of benign tumors such as osteomas and inverting papilloma, and oncologic resection for sinonasal malignancy.

Open approaches for frontal sinus disease are typically reserved for pathologic processes associated with destruction of the walls of the frontal sinus or complications such as intracranial infection (Table 24.1). If the frontal craniotomy is confined to the anterior table of the frontal sinus, then the frontal sinus can be preserved or obliterated with tissue (adipose tissue or pericranial flap). If the frontal craniotomy incorporates the entire sinus, then cranialization is preferred since this avoids future problems with frontal sinus drainage and mucocele formation. When a craniofacial resection is performed for sinonasal malignancy, cranialization provides an additional oncologic margin.

Inability to preserve a drainage pathway for the frontal sinus requires obliteration or cranialization. Cranialization is generally preferred since it avoids the risk of delayed mucocele formation and possible infection from incomplete removal of mucosa from the sinus and simplifies the radiographic interpretation of follow-up scans.

**CONTRAINDICATIONS**

There are no absolute contraindications to this surgery. However, patients with severe medical comorbidities, such as cardiovascular disease, pulmonary impairment, debilitation, or severe dementia, and those with end-stage renal disease may not benefit from undergoing the indicated surgical procedure. In patients suspected

<table>
<thead>
<tr>
<th>TABLE 24.1 Diseases Necessitating Frontal Sinus Cranialization</th>
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<tbody>
<tr>
<td>1. Neoplasms</td>
</tr>
<tr>
<td>a. Malignant tumors</td>
</tr>
<tr>
<td>i. Adenocarcinoma</td>
</tr>
<tr>
<td>ii. Adenoid cystic carcinoma</td>
</tr>
<tr>
<td>iii. Esthesioneuroblastoma</td>
</tr>
<tr>
<td>iv. Mucoepidermoid carcinoma</td>
</tr>
<tr>
<td>v. Sarcoma</td>
</tr>
<tr>
<td>vi. Sinonasal undifferentiated carcinoma</td>
</tr>
<tr>
<td>vii. Squamous cell carcinoma</td>
</tr>
<tr>
<td>b. Benign tumors</td>
</tr>
<tr>
<td>i. Fibrous dysplasia</td>
</tr>
<tr>
<td>ii. Inverted papilloma</td>
</tr>
<tr>
<td>iii. Osteoma</td>
</tr>
<tr>
<td>c. Metastatic disease</td>
</tr>
<tr>
<td>i. Cancer of the breast</td>
</tr>
<tr>
<td>ii. Melanoma</td>
</tr>
<tr>
<td>iii. Renal cell carcinoma</td>
</tr>
<tr>
<td>2. Infection</td>
</tr>
<tr>
<td>a. Chronic frontal sinusitis</td>
</tr>
<tr>
<td>b. Invasive fungal sinusitis</td>
</tr>
<tr>
<td>c. Pott's puffy tumor</td>
</tr>
<tr>
<td>3. Trauma</td>
</tr>
<tr>
<td>a. Blunt trauma</td>
</tr>
<tr>
<td>b. Penetrating trauma</td>
</tr>
</tbody>
</table>
of having advanced malignancy, with massive brain invasion, bilateral orbital invasion, or cavernous sinus involvement, surgery may be contraindicated. Also, in patients with a known primary in which the frontal bone neoplasm represents metastatic disease, palliative therapy may be indicated, rather than a heroic effort at resection.

PREOPERATIVE PLANNING

Imaging Studies

Imaging plays a critical role in the evaluation of patients being considered for frontal sinus cranialization. Both computed tomography (CT) and magnetic resonance imaging (MRI) are used in the evaluation of this patient population. CT scan with contrast provides considerable information about the integrity of the bone of the frontal sinuses including the roof of the orbit. CT scan also provides insight into soft tissue filling the frontal sinus. MRI provides improved definition between any soft tissue mass in the frontal sinus and adjacent soft tissues, such as the orbit, dura, and/or brain. Edema of the frontal lobe is frequently indicative of invasion through the dura with involvement of the frontal sinus, by any disease process. MRI is also helpful in differentiating tumor from secretions in obstructed sinuses.

Preoperative Biopsy

For patients with an isolated process in the frontal sinus, it is the rare instance in which a preoperative biopsy is feasible. In patients suspected of having either a benign or malignant tumor destroying the anterior wall, it may be feasible to perform direct needle biopsy of the soft tissue mass. The other instance in which biopsy may be feasible is a patient with a tumor in the superior nasal cavity or frontal duct region. Care must be taken in performing the biopsy to avoid injury to the dura and/or brain.

SURGICAL TECHNIQUE

The classic surgical technique is readily used for the patients with suspected isolated tumors of the frontal sinus, as well as those with chronic inflammatory and infectious process. A similar approach is also employed for patients undergoing anterior craniofacial resection. A cosmetically appealing incision is designed using a bicoronal approach in the hairline. This allows for preservation of the skin and access down to the superior orbital rims bilaterally. As will be described, a galeal–pericranial flap can be elevated for reinforcement of any dural defect. The frontal sinus is removed in a monobloc fashion, including the anterior and posterior walls of the sinus. Assistance can be obtained with the use of a neuronavigation device in designing osteotomies. The posterior wall of the frontal sinus is removed with preservation of the underlying dura.

Any breach or involvement of the dura and/or brain is resected, and in these instances, multilayer closure of the dura is performed to prevent a CSF leak. In the instance of involvement of the anterior wall of the frontal sinus or in a comminuted fracture, reconstruction may be indicated. Due to the risk of infection, this may be performed as a secondary procedure. Care must be taken to obstruct the frontal ducts with temporalis muscle fascia or other adjacent available tissue to prevent communication between the nasal cavity and the exposed dura. All mucosa must be removed from the frontal sinus to prevent secondary mucocele formation.

Description of Technique

The patient is placed under general endotracheal anesthesia with paralytic agents, and the endotracheal tube is secured at the oral commissure. The patient is prepped and draped in a sterile fashion with exposure of the superior portion of the nose, the orbits, and the forehead. The eyes are protected with tarsorrhaphies bilaterally taking care not to injure the eye during placement. Every effort is made not to shave the head except for a narrow strip along the incision line in parallel to the hairline approximately 2 cm posterior to the hairline, from one anterior temporal region to the other anterior temporal region. Typically, I employ a three-drug combination of antibiotics for prophylaxis: CMV—ceftazidime, metronidazole and vancomycin. Steroids are typically administered to prevent cerebral edema. In rare instances in which concerns exist regarding dural reconstruction, a lumbar drain is placed at the beginning of the surgical procedure.

The bicoronal incision is carried through the skin and subcutaneous tissue. I usually harvest a galeal–pericranial flap. The distal one-half of the flap consists purely of the pericranium to allow for closure of the galea at the incision site. Galea is incorporated in the more proximal one-half of the flap to provide a more vigorous and thicker flap. As one approaches the supraorbital vessels, care must be taken not to interrupt the vessels, as they provide the blood supply to the flap. This provides exposure to the frontal bone and allows for direct inspection to assure integrity of the anterior aspect of the frontal bone.
In instances where neuronavigation is employed, registration of the device is performed using fiducials or anatomical landmarks prior to beginning the procedure. This can assist in appropriately designing the anterior frontal bone osteotomies and preventing inadvertent injury to the dura and/or brain. A small burr hole can be performed with a rotating high-speed drill. This will assure entry into the frontal sinus. A fine side-cutting burr is used to minimize bone loss and prevent a visually evident or palpable step-off at the osteotomy site. The frontal bone flap is secured on the back table in a sterile preparation. The contents of the frontal sinus as well as the posterior frontal sinus wall are removed (Fig. 24.1). All of the mucosa is stripped from the remnants of the frontal sinus as well as the bone flap. The posterior table of the frontal sinus is removed with rongeurs and smoothed with the drill (Fig. 24.2). It is important to remove all vestiges of mucosa from the frontal sinus with the drill (Fig. 24.3). In instances of involvement of the dura and/or brain, the neurosurgical team is included. This is the case for primary tumors of the frontal sinus and any inflammatory/infectious process. In the instance of open anterior craniofacial resection, the cribriform plate is usually resected with the dural invaginations involving the cribriform plate and the fovea ethmoidalis. This necessitates reconstruction of the dura. Typically, bovine pericardium is employed to close the dural defect as part of a multilayer closure.

A galeal–pericranial flap is employed as a second-layer closure to reinforce the primary dural closure and prevent a CSF leak (Fig. 24.4). By removing the posterior wall of the frontal sinus, the brain expands and essentially fills the frontal sinus. Care must be taken to remove all the mucosa from the anterior osteoplastic frontal sinus flap to prevent subsequent mucocele formation. Care must also be taken to plug the frontal sinus ducts to prevent communication between the contaminated nasal cavity and the exposed dura and brain. Moreover, in patients suspected of having chronic infection, cultures should be performed including aerobic, anaerobic, acid-fast bacilli, and fungal organisms.

In patients with either a comminuted fracture of the anterior wall or invasion by infection or tumor, the anterior wall of the frontal sinus is also resected. Although one can collect the bone remnants of a comminuted fracture, it is rare that it is feasible to adequately plate these bones together and provide an intact frontal sinus wall. The decision must be made whether to perform immediate reconstruction of the frontal bone defect or allow for collapse of the wound and secondary reconstruction. In patients with open comminuted fractures or osteomyelitis of the anterior wall of the frontal bone, delayed reconstruction is typically indicated.
the patients with primary tumors, immediate reconstruction can be performed with a number of materials. Potentially, this could include use of a free bone graft harvested from the iliac crest, the scapula, or from another portion of the cranium. Free tissue transfer from the iliac crest or the scapula is also feasible but is a challenge given the spherical structure of the frontal bone. Alloplastic materials such as mesh, synthetic material, or hydroxyapatite bone paste have all been employed. The major risk associated with the use of alloplastic materials is the potential for either infection and/or extrusion. Finally, when there is loss of the frontal skin due to avulsion or frontal skin flap loss due to local vascular insufficiency, a free flap is essential, accepting the cosmetic limitations at this site.

When the skin and the frontal bone flap are preserved, the anterior frontal bone flap is secured with multiple titanium miniplates (Fig. 24.5). As noted earlier, there is no need to fill the frontal sinus defect as the brain will expand and effectively fill the space. The bicoronal incision is closed in multiple layers with 2-0 Vicryl sutures, and the skin edges are reapproximated with staples. In the majority of the cases, a Hemovac drain is placed above the frontal bone and below the skin flap and is left in place for several days. A turban-style pressure dressing is kept in place for 1 or 2 days.

POSTOPERATIVE MANAGEMENT

The Hemovac is placed to self-suction for 1 to 2 days. Once drainage has tapered, the drain is removed. The pressure dressing is removed on postoperative day 2. Staples are removed on postoperative day 7 to 10 during the first operative visit. The patient receives approximately 2 to 3 days of the previously described regimen of intravenous antibiotics.
Complications of the surgical procedure are listed in Table 24.2. Hematoma is a rare event occurring in less than 5% of procedures. Infection is rare with the use of the three-drug regimen; but when it occurs, it is associated with loss of the anterior bone flap and the need for secondary reconstruction, as well as prolonged intravenous antibiotics as an outpatient.

Injury to the eye including blindness is an extremely rare occurrence and occurs in less than 1% of patients. Loss of the skin flap is an extremely rare event and can be avoided by preserving the superior orbital blood supply bilaterally. Again, this occurs in no more than 1% or 2% of cases. CSF leak is also a rare event, especially in patients with intact dura. There is a slightly higher incidence when patients require a dural reconstruction; a meticulous multilayer closure with use of the galeal–pericranial flap reduces the risk to less than 5%. Occasionally, there may be hair loss at the site of the incision. Meticulous management of the soft tissues with preservation of the subdermal tissue prevents injury to the hair follicles.

RESULTS

It is often challenging to assess the results of a surgical procedure that is employed for a number of disease processes. Cranialization of the frontal sinus after traditional open craniofacial resection has been associated with a low incidence of frontal bone osteomyelitis, a low incidence of CSF leak, and favorable oncologic outcome for many patients with sinonasal/skull base malignancy. Similarly, in the patients with trauma to the frontal sinus, this approach has been associated with prevention of frontal sinus mucocele, acceptable cosmetic outcomes depending on the degree of soft tissue injury to the face and skin, and management of any intracranial injury. In patients with inflammatory and chronic infectious processes involving the frontal sinus necessitating cranialization, this technique is often successful in controlling local symptoms. Many of these patients will require prolonged antibiotics based on intraoperative cultures.

Two patients are worth describing. One patient presented with an isolated recurrence of an inverted papilloma extending to the frontal sinus and involving the posterior wall of the frontal sinus and dura. The patient underwent transfrontal resection of the tumor with cranialization. The patient did require a limited dural resection with immediate reconstruction with a dural graft and galeal–pericranial flap. There was no evidence of malignant degeneration, and the patient remains free of disease 7 years after extirpation.

The second patient presented with severe frontal headaches. Imaging studies revealed a soft tissue process involving the frontal sinus, posterior wall of the frontal sinus, and the adjacent dura and brain. Using the frontal osteoplastic approach, the patient underwent resection of the frontal sinus soft tissue mass including the posterior wall, dura, and involved brain. Intraoperative frozen section showed fungal hyphae. The patient received prolonged postoperative antifungal antibiotics and recovered with no sequelae.

<table>
<thead>
<tr>
<th>TABLE 24.2 Complications—Frontal Sinus Cranialization</th>
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<tbody>
<tr>
<td>• Blindness</td>
</tr>
<tr>
<td>• Contour deformity</td>
</tr>
<tr>
<td>• CSF leak</td>
</tr>
<tr>
<td>• Frontal bone flap osteomyelitis</td>
</tr>
<tr>
<td>• Frontal skin loss</td>
</tr>
<tr>
<td>• Hair loss</td>
</tr>
<tr>
<td>• Hematoma</td>
</tr>
<tr>
<td>• Infection</td>
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</table>
PEARLS

- Perform a thorough radiologic assessment prior to surgical management.
- Educating the patient regarding postoperative appearance and possible complications is critical. Expected results will differ significantly based on whether the patient is undergoing this procedure for trauma, neoplasm, or chronic frontal sinusitis.
- Elevation of the galeal–pericranial flap will allow for secondary closure and reinforcement of any dural defect and prevent CSF leak.
- Removal of all remaining mucosa from the anterior wall of the frontal sinus will prevent mucocele formation.
- Meticulous management of the soft tissues of the bicoronal flap will prevent hair loss resulting in a superior cosmetic outcome.

PITFALLS

- Incomplete imaging preoperatively may result in unanticipated findings at the time of surgery.
- Injury to the supraorbital vessels may result in loss of the galeal–pericranial flap or loss of the skin flap.
- Failure to use broad-spectrum antibiotics may result in osteomyelitis of the frontal bone.

INSTRUMENTS TO HAVE AVAILABLE

- High-speed drill with cutting burr and low-profile side-cutting burr.
- Titanium microplating system.

SUGGESTED READING

INTRODUCTION

The frontal sinus osteoplastic flap was first described in 1904 by Hoffman. Because it provided maximum visualization and access to all regions of the frontal sinus, the osteoplastic flap procedure served for decades as the gold standard procedure for surgical treatment of inflammatory, infectious, and neoplastic lesions of the frontal sinus. With the advent of endoscopic approaches to the frontal sinus, the indications for external approaches to the frontal sinus have been relegated to a more limited scope of frontal sinus pathology. However, even with the most assertive endoscopic transnasal approaches to the frontal sinus, there remain lesions for which osteoplastic flap is the surgical approach of choice.

HISTORY

Frontal sinus pathology may present with a wide range of symptoms. Most characteristically, expansile lesions of the frontal sinus, whether inflammatory or neoplastic, will first be noticed by the patient because of headache, pressure, or pain in the forehead region. This may be due to frontal sinusitis resulting from obstruction of the frontal sinus or to neuropathic effects of compression of branches of the supraorbital nerve. Lesions that have eroded the bony boundaries of the frontal sinus may permit contiguous extension of acute frontal sinusitis to adjacent structures. Patients with periorbital cellulitis may present with periorbital pain or pressure, or diminished visual acuity. Patients with lesions that have eroded the posterior table of the frontal sinus may present with acute frontal sinusitis complicated by meningeal signs or altered mental status. Frontal sinus pathology may also be asymptomatic, detectable only by subtle changes in facial appearance, or incidentally on radiographic imaging for nonsinus indications.

PHYSICAL EXAMINATION

The examination of patients who are candidates for the frontal sinus osteoplastic flap procedure has a twofold purpose: (1) assessing the extent of disease as it may relate to expansion beyond the confines of the frontal sinus and (2) presurgical planning.

First, the face and head should be examined carefully for signs of extrasinus extension of frontal disease. Prefrontal subcutaneous soft tissue thickening, induration, or erythema may suggest infectious erosion of the anterior table of the frontal sinus with possible frontal osteomyelitis, subcutaneous abscess, and Pott’s puffy tumor. Proptosis or orbital displacement inferiorly and/or laterally may result from expansile lesions of the frontal sinus such as a frontal sinus mucocele. The changes in eye position typically occur gradually, such that the patient can often accommodate for significant alterations in globe position successfully without diplopia or disconjugate gaze. Some patients with orbital displacement will have diplopia.
If an osteoplastic flap is deemed necessary, the patient should be examined with respect to potential incisions and surgical approaches. Bald patients, or young men with an aggressively receding hairline, will not be favorable candidates for a coronal incision due to cosmetic considerations. In these patients, a forehead rhytid incision or a gull wing brow incision will be a better aesthetic choice. Examination of the cranial nerves should be performed and documented, especially with regard to the trigeminal and facial nerves, as branches of these nerves are subject to possible injury during elevation of the osteoplastic flap or during obliteration.

Diagnostic nasal endoscopy should also be performed. In cases of chronic rhinosinusitis, endoscopic cultures of purulent discharge should be taken for planning of perioperative antimicrobial therapy. Endoscopic sinus surgery may be indicated for treatment of concurrent ethmoid, sphenoid, or maxillary sinus disease, and thus careful observation for polyposis and anatomic variants is important in surgical planning.

**INDICATIONS**

Contemporary indications for frontal sinus osteoplastic flap are more heavily weighted toward treatment of frontal sinus tumors and fractures rather than the treatment of inflammatory disease. Surgical candidates for an osteoplastic flap include patients with laterally or superiorly based tumors (e.g., osteoma, inverted papilloma) (Fig. 25.1A and B). Depending on the extent of frontal pneumatization, lesions in the peripheral aspects of the frontal sinus may be beyond the reach of extended transnasal endoscopic approaches such as the endoscopic modified Lothrop procedure.

Although the majority of cases of frontal sinusitis can be managed successfully using endoscopic techniques, the osteoplastic flap does remain an important alternative for revision of severe frontal sinusitis cases. In patients in whom extensive scarring renders the frontal recesses severely stenotic, an osteoplastic flap approach to the frontal sinus may be considered. Infectious complications of frontal sinusitis, such as Pott’s puffy tumor or frontal osteomyelitis, may require an osteoplastic flap to access infected frontal bone for debridement or resection. The addition of obliteration to the osteoplastic flap procedure is an option for treatment of inflammatory and infectious cases; however, a nonobliterative approach may be preferred in patients with tumors of the frontal sinus since the obliterative material may obscure detection of early recurrences of tumor and may make radiologic surveillance difficult.

Fractures of the frontal sinus may also be best managed by an open osteoplastic flap approach, allowing for direct visualization and manipulation of bony fragments of the anterior and posterior table.

**CONTRAINDICATIONS**

There are few absolute contraindications to osteoplastic flap surgery. In considering an obliterative versus nonobliterative approach, one must consider relative contraindications to frontal sinus obliteration. In the setting of frontal sinus trauma, posterior table fractures demonstrating extensive comminution or severe displacement are managed more favorably by frontal sinus cranialization than by frontal obliteration. In addition, when neoplasms of the frontal sinus are removed through an osteoplastic approach, radiographic surveillance of tumor recurrence will be more difficult in an obliterated compared to a nonobliterated sinus.

**FIGURE 25.1**

A and B. Coronal and sagittal images show a large left frontoethmoid osteoma. Because of the lateral and superior extension of the lesion, an osteoplastic flap was elected. A nonobliterative approach was chosen in order to preserve the normal mucosa of the contralateral frontal sinus as well as the uninvolved mucosa of the ipsilateral side. The procedure for this patient is demonstrated in Figures 25.2 to 25.6.
PREOPERATIVE PLANNING

Obliteration Versus Nonobliteration

A key decision point in preoperative planning for frontal osteoplastic flap surgery is to determine whether obliteration of the frontal sinus is indicated as an adjunctive procedure. The osteoplastic flap provides outstanding surgical exposure of the frontal sinus, but it does not necessarily need to be accompanied by stripping of the frontal sinus and obliteration, depending on the pathology being approached. There are several advantages of preserving the frontal sinus mucosa (osteoplastic flap without obliteration): (1) preservation of frontal sinus function, (2) improved ability to interpret postoperative imaging, and (3) reduced risk of chronic frontal neuropathy.

Patients with smaller tumors of the frontal sinus are, in general, good candidates for preservation of noninvolved frontal sinus mucosa, unless there is direct involvement of the frontal outflow tract by tumor that would require circumferential removal of the mucosa thereby predisposing the patient to frontal ostial stenosis. Similarly, management of trauma of the frontal sinus has trended toward more conservative approaches. Fractures of the frontal sinus requiring an osteoplastic flap for surgical exposure may not necessarily require obliteration, unless there is gross traumatic involvement of the frontal infundibula.

Choice of Obliteration Material

When obliteration is indicated, the time-tested material of choice for filling the frontal sinus is adipose tissue, usually harvested from the abdomen. Alternatively, the frontal sinus can be obliterated with hydroxyapatite cement, pericranium, or autologous bone chips.

Preoperative Imaging

Preoperative imaging should include thin section noncontrast computed tomography (CT) of the frontal sinus. Unilateral obliteration may be considered for unilateral disease. An extensively pneumatized frontal sinus will be more challenging to obliterate owing to the extended mucosal surface area of the frontal sinus that must be completely exenterated. In addition, erosion of the posterior table or floor is a relative contraindication to obliteration, owing to the difficulty of completely removing mucosa from periorbita or dura in areas of bone erosion. CT studies should be performed with a protocol enabling computer navigation, as delineation of the boundaries of the osteoplastic flap is greatly facilitated by computer navigation.

Alternatively, plain film imaging may be used to create a template to demarcate the boundaries of the frontal sinus. A 6-foot Caldwell view will produce a 1:1 image of the frontal sinus. The film may be cut out around the frontal sinus outline and sterilized as a template for making the frontal osteotomies.

SURGICAL TECHNIQUE

The patient is placed in the supine position with the head positioned 180 degrees away from anesthesia to facilitate complete access to the frontal region. The hair can be parted without shaving the scalp to prepare for the scalp incision; the hair should be bundled in rubber bands to keep the hair clear of the incision. If surgical navigation is planned, a bone-anchored navigation reference post should be placed prior to skin prep (Fig. 25.2). Tarsorrhaphy sutures or other form of eye protection should be employed.

The traditional coronal incision extends bilaterally from the vertex of the head toward the root of the helix, stopping in the temporal tuft within 1 to 2 cm of the auricle. Raney clips should be placed along the cut edges

FIGURE 25.2
The hair is parted and bundled, obviating the need for shaving the head. The reference post for computer navigation is anchored to the skull with fixation screws just posterior to the planned incision.
of the scalp incision to minimize blood loss. In patients with a significantly receding hairline, a broken line incision may be considered for cosmetic reasons in anticipation of possible further hair loss. In patients who are bald, the incision may be placed in a forehead rhytid or in a brow gull wing pattern.

The frontal skin flap is developed in a subgaleal plane using either scalpel or electrocautery, advancing the dissection to the level of the superior orbital rims, evertting the frontal skin as the flap is further developed. By keeping the plane of dissection deep to the superficial layer of deep temporalis fascia, inadvertent injury to the frontal branch of the facial nerve can be averted. Elasticized neurosurgical hook retractors are helpful for maintaining retraction of the frontal flap. After elevation of the skin flap, the pericranium is outlined and elevated as a caudally based U-shaped flap (Fig. 25.3). The flap should be designed generously to ensure complete coverage of the osteotomies on its replacement.

Next, the frontal osteotomies are created. When the goal of surgery is obliteration, it is important for the osteotomies to follow the contour of the frontal sinus closely to facilitate complete exenteration of mucosa. However, if the mucosa of the frontal sinus is intended to be preserved, the osteotomy can be planned from a functional perspective; a simplified osteotomy contour can ensure adequate surgical access to the sinus while mitigating the risk of inadvertent entry into the anterior cranial fossa. The osteotomies can be outlined using either a plain film template (sterilized) from a Caldwell view radiograph or, now more commonly, computer-assisted navigation based on the preoperative CT scan. A reciprocating high-speed saw is used to perform the osteotomies, beveling them inward to minimize the risk of entering the intracranial compartment (Fig. 25.4). Particular care must be taken in performing osteotomies along the superior orbital rims. Inadvertent exposure of orbital adipose tissue can complicate the handling of frontal sinus pathology and can compromise the integrity of the extraocular muscles.

Once the bone flap has been elevated and removed from the field, the frontal sinus pathology can then be addressed (Fig. 25.5). In cases in which the osteoplastic flap will be performed without obliteration, mucosa-preserving techniques should be used when possible. In cases of osteoplastic flap with obliteration, removal/correction of the frontal sinus abnormality should be followed by meticulous removal of the mucosa of the entirety of the frontal sinus (bilaterally as indicated), even in areas uninvolved by the frontal pathology. The mucosa must also be removed from the bone flap. After removing the mucosa, the underlying bone should be polished with a diamond burr to ensure complete removal of all mucosal remnants. The drilling of bone is typically done under microscopic or endoscopic visualization for magnification and enhanced

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CHAPTER 25 Frontal Sinus Osteoplastic Flap with and without Obliteration

illumination. More extensively pneumatized frontal sinuses may be more difficult to obliterate owing to potentially deeper pockets and crevices that require meticulous handling to ensure complete removal of the mucosa.

Management of the frontal infundibulum and ostium varies according to the planned procedure as well as the surgeon’s preference. In the osteoplastic flap without obliteration, the goal is to attain a frontal sinus with fully restored mucociliary function. Therefore, surgical manipulation of the frontal infundibular region should be minimized in order to preserve the functional patency of the frontal outflow tract. In the obliteration technique, the management of the frontal infundibulum varies according to surgeon preference. As classically described, the frontal sinus ostia are occluded with muscle, bone chips, or other biomaterials to ensure complete isolation of the frontal sinuses from the ethmoid sinuses. However, there may be advantages to leaving the frontal outflow tracts intact if they are uninvolved by the frontal pathology (as is the author’s preference). The rationale for not obliterating the frontal infundibula is to permit later access to the frontal sinuses via a transethmoid endoscopic route should delayed complications such as frontal mucocele arise.

Prior to completion of the procedure, the frontal sinus is filled with abdominal adipose tissue for obliteration cases. An adipose tissue graft is most readily harvested from the subcutaneous deposits in the abdomen. A periumbilical incision offers satisfactory cosmesis, but it may be difficult to harvest an adequate amount of adipose tissue. Alternatively, a 4- to 5-cm incision in the right or left lower quadrant should provide adequate exposure. After adequate control of bleeding, the wound can be closed in layers without a drain.

After filling the frontal sinus with adipose tissue, the bone flap is then replaced and secured with mini- or microfixation plates (Fig. 25.6). The pericranial flap is draped over the osteotomies and plates, and the frontal skin flap is replaced. Layered scalp closure is performed over one or two active drains to evacuate the subcutaneous space, followed by staples for the skin. A head dressing is not required if active drains are used.

POSTOPERATIVE MANAGEMENT

Patients undergoing an osteoplastic flap with or without obliteration can expect a one-night stay in the hospital, primarily receiving supportive care. Drains are removed prior to discharge, and patients will follow up in the outpatient clinic for staple removal 7 to 10 days postoperatively.
COMPLICATIONS

Complications of the osteoplastic flap procedure can be categorized as either intraoperative or postoperative.

Intraoperative complications relate primarily to the risk of injury to associated structures adjacent to the frontal sinus. Elevation of the frontal skin flap in an overly superficial plane around the temporalis muscle can cause paralysis of the frontal branch of the facial nerve, which runs deep to the superficial temporal fascia but superficial to the deep temporal fascia (which has superficial and deep layers). Errant osteotomies can result in brain injury or cerebrospinal fluid leak. The orbital contents may also be injured during osteotomies at the orbital rims. Additional risk to the orbits is incurred during surgical manipulation of the floor of the frontal sinus, which constitutes the thin bony orbital roof, which may potentially be further attenuated by chronic frontal sinusitis.

Postoperative complications of osteoplastic flap include chronic pain and delayed mucocele. It is unclear whether the etiology of the pain relates to the flap elevation or to the removal of the mucosa; the incidence of pain after osteoplastic flap without obliteration is not well documented. Delayed mucocele formation of the frontal sinus is attributable in most cases to incomplete removal of sinus mucosa at the original procedure. Mucoceles that present at the inferomedial aspect of the frontal sinus may be successfully managed with a minimally invasive approach. The persistence or recurrence of chronic infection in an already obliterated frontal sinus is a troubling problem. Apart from attempts to sterilize the obliterated sinus with long-term antibiotics, few options remain except to consider repeat osteoplastic flap. Some surgeons have advocated for converting obliterated cavities to an “unobliterated” cavity by removing the adipose tissue during revision osteoplastic flap procedures or even endoscopic “unobliteration” procedures. In rare circumstances, the frontal bone flap may not be viable and may be propagating the infection. In such cases, the frontal bone flap may need to be discarded and the frontal sinus fully exteriorized into the subcutaneous space according to the Riedel procedure.

RESULTS

When performed meticulously, the osteoplastic flap procedure is a reliable method of managing complex frontal sinus disease. The popularization of nonobliterative approaches to osteoplastic flap surgery may improve the functional outcomes of the approach with potentially lower risk for delayed mucocele formation and chronic pain.

PEARLS

- The incision for the osteoplastic flap procedure should be adjusted to the patient’s hairline for optimal cosmesis. Options include coronal incision, midforehead rhytid incision, and gull wing brow incision.
- The frontal osteotomies may be planned and executed with computer navigation or a plain film template.
- Obliteration is an optional adjunct to the osteoplastic flap procedure and is employed primarily for inflammatory or infectious frontal disease. When obliteration is performed, meticulous removal of the mucosa is necessary using a drill under microscopic or endoscopic visualization.

PITFALLS

- Elevation of the frontal flap must be performed carefully in the area of the temporalis fascia to avoid injury to the frontal branch of the facial nerve.
- Failure to bevel the osteotomies may increase the risk of intracranial entry.

INSTRUMENTS TO HAVE AVAILABLE

- Navigation system
- Raney clips
- Reciprocating saw
- Drill with diamond burr
- Plating system
CHAPTER 25 Frontal Sinus Osteoplastic Flap with and without Obliteration

SUGGESTED READING


INTRODUCTION

Surgery of the cavernous sinus (CS) represents a considerable challenge due to the anatomical complexity and high functional value of the structures contained in the parasellar space. It is the cornerstone of treatment of neoplasms of the CS because it allows histopathologic diagnosis, tumor debulking, and, in some cases, the opportunity to cure the patient. For malignant and/or unresectable tumors, CS surgery can be a step in a multidisciplinary strategy including pharmacologic and/or radiation therapy. A single gold standard surgical technique does not exist since the approach has to be adapted to the exact location and features of the tumor and to the preference of the surgeon.

In this chapter, we discuss the endoscopic endonasal suprapetrous approach to the lateral CS. To gain access to the lateral CS, the midline transsphenoidal endoscopic approach (MTea) may not be sufficient, and a lateral enlargement using “extended approaches” is necessary.

The transpterygoid approach, first described by Bolger (1999), accessed the lateral wall of the sphenoid sinus to treat meningoceles of this area. We used the same technique called the ethmoido-pterygo-sphenoidal endoscopic approach (EPSea) to access the lateral CS. In 2001, at the European Skull Base Congress in Copenhagen, we reported our preliminary experience with this approach. It remains our preferred choice because it provides wide exposure enabling the surgeon to operate in this region mainly with a 0-degree endoscope; furthermore, it gives direct access to the mass, allowing good visual control of the course of the carotid artery and avoiding dangerous trajectories crossing the cranial nerves.

The CS is located near the center of the head lateral to the sella and the body of the sphenoid bone. The term “lateral CS” is incorrect because the CS is a unique and undivided structure. “Laterality” is a purely descriptive term identifying the part of the CS located lateral to the course of the carotid artery as it appears on a magnetic resonance imaging (MRI) coronal view. More precisely, the intracavernous course of the carotid artery allows the cavernous venous spaces to be divided into four virtual compartments: medial, lateral, posterosuperior, and anteroinferior that are continuous with each other. Due to the oblique converging direction of the paired CSs, the medial and posterosuperior compartments can be reached through a midline approach while the lateral and, frequently, also the anteroinferior compartments require a laterally extended approach. For these reasons, when talking about tumors of the lateral CS, we are referring to tumors located in the anteroinferior and/or lateral compartments, approachable through an “extended” approach.

Tumors of the CS can be divided into primary, for example, meningiomas, neurogenic tumors, and hemangiomas, and secondary, for example, pituitary adenomas, chordomas, chondrosarcomas, perineural spread of head and neck malignancy, and hematogenous spread from distant lesions. The first group involves the lateral compartment more frequently. The second group has a more variable behavior depending on the site of origin and the direction of growth of the neoplasm; for example, pituitary adenomas more frequently invade the medial and posterosuperior compartments because they have a medio-lateral growth; conversely, chondrosarcomas and chordomas, which emerge from the clival region, frequently involve the anteroinferior compartment of the CS from which they can spread either to the medial and/or to the lateral CS.
Endoscopic endonasal CS surgery is an attractive alternative to other more invasive techniques for tumors invading the CS. It is a well-tolerated approach, giving direct access to the CS through its medial wall, which is devoid of cranial nerves. Its introduction into the neurosurgical landscape is relatively recent; in the beginning, it was mostly proposed for tumors growing in the medial compartments, accessible using an MTea approach. In the present chapter, we have described its far lateral variant, the suprapetrous approach to the “lateral CS,” which allows removal of tumors in the lateral and anteroinferior compartments of the CS or tumors involving the entire CS. This approach is called “EPSea,” and we have used it mostly in removing pituitary adenomas and chordomas. The results confirm that it is a safe and effective surgical approach. Actual invasion of the CS can only be determined surgically. Surgery may allow radical resection of the mass, and, in a subset of patients, it is possible to obtain an endocrinologic cure. In all cases, it at least permits debulking of the tumor, which promotes symptom remission and favors the efficacy and safety of complementary treatments.

**HISTORY**

The clinical presentation of CS tumors includes impairment of the oculomotor nerves, Horner’s syndrome, and sensory loss of the first or second division of the trigeminal nerve in various combinations. Oculosympathetic and parasympathetic involvement may be present. The patient may complain of variable degrees and quality of pain. For the clinical diagnosis, medical history such as age at onset, speed of progression, presence or absence of pain, and past infections or tumors is extremely important. Neoplastic etiology is more frequent in the adult age group, and symptoms are slowly progressive.

**PHYSICAL EXAMINATION**

Severe chemosis and exophthalmos are usually absent or moderate with neoplastic disease and are more suggestive of a vascular or infection etiology. Metastatic disease should be suspected in adults in case of a history of malignancy or of clinical presentation with painless ophthalmoplegia. A complete and severe CS syndrome in CS tumors is rare because symptoms (pain and diplopia) induce a precocious neuroradiologic examination and early diagnosis.

**INDICATIONS**

Only symptomatic and/or growing tumors are considered for surgery, and the approach is selected according to the compartments involved by the tumor. When invasion is confined to the medial and posterosuperior compartments, an MTea may be appropriate. When the tumor invades the anteroinferior and lateral compartments of the CS or invades the entire CS, the EPSea is required. In the case of tumors exceeding the boundaries of the CS, it may sometimes be advisable to combine different approaches: for example, for tumors extending from the lateral compartment through the foramen rotundum to the pterygopalatine fossa, the EPSea may be combined with the transmaxillary transpterygoid endoscopic approach; likewise, for tumors involving the lateral CS compartments and the clivus, the EPSea may be combined with the transclival endoscopic approach. In rare circumstances where the tumor invades the intradural spaces extending lateral to the plane of the cranial nerves, the endoscopic endonasal approach could be combined with a transcranial approach (in the same session or in staged procedures).

**CONTRAINDICATIONS**

A major contraindication is related to the poor medical condition of the patient. The presence of a vascular malformation is an absolute contraindication since it could be better managed by a transcranial approach. The presence of intradural extension of the tumor is not an absolute contraindication, provided that it is located medial to the plane of the cranial nerves.

**PREOPERATIVE PLANNING**

MRI is the examination of choice and represents the first step in the diagnostic evaluation of CS neoplasms. Since the diagnostic power of MRI is not the subject of this paper, we simply report the information that we hope to derive from this examination: (1) a precise picture of the morphology and extension of the tumor, (2) a presumption of its consistency, (3) the relationship between the tumor and the neurovascular structures, and 4) a conclusive hypothesis on the type of tumor. Precise knowledge of the morphology and extension of the tumor using modern high-field MRI is not critical. Instead, in secondary CS tumors, such as pituitary adenomas and chordomas, it may be extremely difficult to distinguish between true invasion and simple compression of the CS.
In our opinion, the most reliable sign of invasion (although a late one), especially in pituitary adenomas, is total encasement of the carotid artery. Conversely, the most reliable sign of compression of the CS is the preservation of the medial wall of the CS. Unfortunately, at present, the extreme thinness of the medial wall makes it difficult to detect on MRI. The consistency of the tumor may be inferred based on the signal intensity on T2-weighted images, but this method includes a wide margin of error. The consistency of the tumor may also be inferred from diffusion-weighted studies, and this method is currently being researched. In our opinion, through its different projections, MRI is the best method of studying the relationships between the tumor and the course of the carotid artery. Only the evaluation of these relationships permits the definition of how many and which CS compartments are involved by the neoplasm. In the majority of cases, the entire body of information allows the surgeon to determine the nature of the tumor, which is of paramount importance in deciding upon the surgical strategy.

CT scan is a useful complement to MRI. It provides more precise information on the craniofacial anatomy and bony landmarks; it facilitates the diagnosis through a clearer evaluation of bone changes (simple compression vs. bone erosion). Furthermore, microcalcifications of the tumor that may escape detection by MRI are better seen on CT scan. Digital angiography is seldom necessary. In our experience, the main indication is hemodynamic stroke risk assessment when encasement of the carotid artery and infiltration of its wall suggest a high risk of bleeding. Navigation is routinely used during the EPSea. For this purpose, we perform a dedicated CT scan (normally a CT angiogram) together with an MRI.

**SURGICAL TECHNIQUE**

**Ethmoido-Pterygo-Sphenoidal Endoscopic Approach**

The procedure can be schematically divided into four stages.

**Stage I—Approach Phase (Fig. 26.1)**

This stage is performed holding the endoscope freehand. A 0-degree endoscope is normally sufficient; a 30-degree endoscope is seldom required. The middle turbinate is resected through the ipsilateral nasal fossa (Fig. 26.1A), increasing the peripheral view, improving the maneuverability of the surgical instruments and preserving the integrity of the mucoperiostium of the turbinate for harvesting of a mucosal graft. An ethmoidal route is used, and a complete sphenoethmoidotomy with a wide meatomy is performed (Fig. 26.1B). The posterior margin of the medial wall of the maxillary sinus is resected to expose the posterior wall of the maxillary antrum and the vertical process of the palatine bone (Fig. 26.1C). After ligation of the sphenopalatine artery, the medial pterygoid process is drilled out (Fig. 26.1D). The resection of the medial pterygoid process permits exposure of the inferolateral...
portion of the CS. As in the MTea, contralateral access to the surgical field is gained by removing a portion of the posterior aspect of the nasal septum along its attachment to the sphenoid rostrum.

At the end of this phase, a frontal view of the posterior wall of the sphenoid sinus is obtained, allowing the recognition of many bone landmarks in a pneumatized sinus (Figs. 26.2 and 26.3): the optic protuberance, the optic recess, the parasellar carotid protuberance, the planum, the tuberculum sellae, the sella, the paracarotid carotid protuberance, and the clival indentation. In the poorly pneumatized sphenoid sinus, it is especially important to identify the course of the vidian nerve on the floor of the sinus; it has a mediolateral direction from anterior to posterior, indicating the genu between the petrous carotid artery and the paracarotid carotid artery (Figs. 26.4 and 26.5).

We emphasize the importance of the transpterygoid phase which is crucial to increase the maneuverability of the surgical instruments in a caudocranial direction and to expose the lateral wall of the sphenoid sinus and the inferior (lacerous) portion of the CS. The amount of pterygoid process resection depends on the pneumatization of the sphenoid sinus: a more pneumatized sinus requires a more extensive resection of the pterygoid process in order to expose the lateral wall of the sphenoid sinus. Many bony landmarks may be visible on the lateral sphenoidal sinus wall and, in a caudocranial and anteroposterior direction, they consist of: the pterygoid foramen and the pterygoid protuberance posteriorly showing the lacerous portion of the paracarotid carotid artery, the foramen rotundum about 1 cm above and lateral to the pterygoid foramen, the protuberance of the maxillary nerve, the orbital apex, and the optic protuberance (Figs. 26.3 to 26.5).

Stage II—Exposure and Opening of the Cavernous Sinus
We divide the opening phase into two steps: (1) removal of the bone in front of the CS and (2) opening of the dura of the CS.

1. Removal of the bone. The bone to be removed is a quadrilateral-shaped portion of the lateral sphenoid sinus wall that is located between the optic–carotid recess and the paracarotid carotid protuberance medially, and the orbital apex and the trigeminal nerve protuberance laterally (Fig. 26.3). Bone removal over the internal carotid artery (ICA) is carried out by means of a Kerrison punch, curette, and smooth hook, avoiding the drill. The vidian canal on the floor of the sphenoid sinus is a useful landmark because it indicates the junction of the horizontal, petrosal portion of the carotid artery with the ascending paraclival segment of the vessel, and, therefore, it is a guide to the inferior portion of the CS (5) (Figs. 26.3 to 26.5).

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CHAPTER 26  Suprapetrous Approach to the Lateral Cavernous Sinus

FIGURE 26.3  Intraoperative view of the patient in Figure 26.2. Image (A) shows a sphenoidal sellar variant with all main landmarks clearly visible: optic carotid recess (OCR), expanded sella, clivus, and parasellar and paracaval internal carotid artery (ICA) protuberance. With imaginary lines joining the landmarks, it is possible to highlight the projection onto the sphenoid wall of the cavernous sinus (CS). The following images show the dural opening (B), the intracavernous view after removal of the tumor in the medial compartment (C) and anteroinferior compartment (D) in the right CS. The preserved pituitary gland is clearly visible.

FIGURE 26.4  This image shows intraoperative CT angiography navigation in a poorly pneumatized sphenoid sinus (patient in Fig. 26.1). A chordoma is growing in the right petroclival area (arrow) just behind the petrous portion of the ICA. The medial suction tube (not navigated) points toward the clivus in the midline; the navigated suction tube is located between the vidian nerve (Vn) and the second division of the trigeminal nerve (V2) in the same plane and points toward the junction of the horizontal, petrosal part of the ICA with the ascending paracaval segment of the ICA (anterior genu). (sph a, sphenopalatine artery.)
2. Opening of the dura of the CS. This step is carried out using the endoscope fixed in a holder. The opening of the CS is carried out on the inferior CS wall (or sphenoidal part of the medial wall) that is devoid of nerves (Fig. 26.3C). Keeping in mind the relationship between the tumor and the carotid artery, and mapping the course of the carotid artery, using either the navigation system, the Doppler probe, (Fig. 26.6C) or both, the surgeon chooses the site of dural incision in a safe area as far away as possible from the vessel (Figs. 26.3 to 26.5). In tumors of the lateral compartment, the ICA, in a coronal plane, is displaced medially. In this circumstance, since the main tumor mass is located in the lateral compartment, it may be approached directly by performing a vertical incision on the dura lateral to the carotid artery.

In tumors of the anteroinferior compartment, the ICA, in a sagittal plane, is displaced posteriorly, and the mass interposed between the dura and the vessel makes the opening of the dura safer. The dural incision begins in the sellar region and is progressively extended, following the tumor from its medial to its lateral and/or inferior portion (Fig. 26.6). Maximal care is required during the sectioning of the dura in front of the carotid artery not only to avoid injury to the vessel but also to avoid injury to the abducens nerve that, in the inferior portion of the CS, runs close to the dura in a superolateral direction toward the superior orbital fissure.

**Stage III—Tumor Resection**

The technique of tumor resection is microneurosurgical technique with the surgeon handling the instruments with both hands. In all cases, initial debulking of the tumor is advisable. The surgical strategy varies depending on the type of tumor; in some tumors (hemangiomas, neurinomas), a centripetal resection is possible after debulking and dissection from any adhesions. In others (adenomas, chordomas), piecemeal or centrifugal suction may be more appropriate (Fig. 26.7A).

**Stage IV—Final Exploration and Closure of the Surgical Defect**

At the end of the resection, inspection of the surgical field through angled endoscopes (30 degrees and 45 degrees) permits the detection and removal of any residual tumor under direct view (Fig. 26.7C).

Venous bleeding is usually not excessive and can be controlled with cotton packing and/or hemostatic agents.

In the absence of a cerebrospinal fluid (CSF) leak, we do not perform a complex repair; we just cover and protect the exposed carotid artery with the mucoperiostium from the sacrificed middle turbinate. Conversely, if a CSF leak occurs, we prefer a multilayer reconstruction. The nasal fossa of the affected site is packed with a single Merocel tampon that is usually kept in place for 2 days.

**POSTOPERATIVE MANAGEMENT**

After an overnight stay in the intensive care unit, the patient returns to the ward where clinical parameters are carefully monitored, and, in uncomplicated cases, the patient can stand up immediately. On the 2nd day, the nasal packing is removed and the patient is taught how to perform multiple daily nasal washings with saline (this practice should be continued for months). In cases with intraoperative CSF leak, bed rest is maintained for...
2 days, and on the 3rd day, the patient may stand up. On the 3rd day, we frequently perform an MRI (with and without contrast medium) which allows early evaluation of the surgical results and contributes to better understanding of MRI scans carried out later. In fact, interpretation of the postoperative MRI of the CS is extremely difficult; early imaging is disturbed by artifact due to blood and/or packing material, and delayed imaging (3 months postoperatively) is disturbed by artifact due to the healing process. It is our opinion that early and delayed MRIs furnish complementary information, improving final understanding of the images. On the 4th postoperative day, patients without complications may be discharged.

The following checkups are carried out: (1) ambulatory examination in the ENT department at 10 and 30 days and then as needed. These are of great value in preventing infections, contributing to a better quality of nasal functionality through an early resolution of crusting and the prevention of synechiae. (2) Endocrinologic assessment is usually carried out at 1 and 3 months after surgery and then yearly. (3) MRI and neurosurgical visits are scheduled for 3 months postoperatively. At the same time, a neuro-ophthalmologic assessment is performed, and additional checkups are scheduled as needed. Complementary treatments are planned 3 months after surgery, according to the histopathology and the verified results.

**COMPLICATIONS**

Theoretically, due to the high functional value of the neurovascular structures of the CS, numerous complications can be expected. In practice, they are few if we consider only damage to the nerves or injury to the carotid artery (other complications, such as CSF leak, pituitary insufficiency, or diabetes insipidus, are not strictly related to CS management). Profuse bleeding as reported by other authors has been very rare in our series. We feel that this difference can be explained by the operative position we adopted (semi-sitting) and by case selection. In our series, there was nerve injury in three pituitary adenomas and one chordoma (1.8%).
PART III Middle Cranial Fossa

We experienced two cases of injury to the carotid artery (0.9%), one in an adenoma and one in a chordoma. In both cases, it was possible to temporarily control the intraoperative bleeding with packing allowing a subsequent definitive endovascular carotid occlusion. In both patients, the postoperative course was uneventful without neurologic deficits.

RESULTS

Comparing the results of extended transsphenoidal CS surgery is extremely difficult because there are only a few series to which they can be compared and these were composed of small cohorts of patients treated with different techniques and with short follow-up. The Bologna series is presently the largest cohort of patients, comprised of 212 operations (adenomas: 171; chordomas: 36; chondrosarcomas: 5). One hundred and seven procedures were MTeas and 105 were EPSeas. The latter approach was reserved for larger tumors involving the entire CS or when they involved the anteroinferior and/or the lateral compartments of the CS. In the entire series, adenomas were the most numerous, followed by chordomas. Due to their site of origin and direction of growth, pituitary adenomas rarely invade the lateral compartment but more frequently invade the anteroinferior compartment; conversely, chordomas frequently invade both compartments of the “lateral CS” (anteroinferior and lateral) and, due to their irregular extension, frequently require combined approaches (EPSea + transcervical and/or transmaxillary). It is noteworthy that adenomas and chordomas, which are the best candidates for endoscopic endonasal cavernous surgery, are the tumors with the worst surgical results in the intracranial series. Gross total resection was obtained in 117 pituitary adenomas (68.5%) (Kitano et al. 72%; Ceylan et al. 65%) and in 20 chordomas (55.5%). In functional adenomas, remission was obtained in 28/75 patients (37%) (Kitano et al. 67%; Ceylan et al. 66.6%). If we also consider nonfunctioning adenomas without residual tumor and without endocrinologic deficit (58/96 [60.4%]), the total percentage of remission in adenomas is 50.2%.

Preexisting cranial nerve deficits associated with pituitary adenomas resolved in 14 patients, improved in three, and were unchanged in eight (in the Kitano series, they regressed in 3/3), and in chordomas, they regressed in seven, improved in five, and were unchanged in nine.
PEARLS

- The key step in exposing the anteroinferior and lateral portion of the CS area is to drill out the superior aspect of the pterygoid process.
- The vidian nerve is the main landmark in localizing the lacerum portion (genu) of the paraclival ICA at the junction with the petrous portion.
- Computer-assisted navigation and micro-Doppler are useful complementary devices.
- The key point for treating tumors of the CS is to distinguish between real invasion, which means a tumor growing through the envelopes and occupying the CS space, and compression of its walls from a tumor growing outside the CS. Obviously the latter condition (compression) presents a better outcome.

PITFALLS

- The possibility of achieving radical tumor removal is not related to tumor extension but to its consistency and diffuse invasion of the dura.
- The lateral limits of the CS are not the ICA and dura but the plane of the cranial nerves.

INSTRUMENTS TO HAVE AVAILABLE

- Xenon 300 W cold light fountain source
- Endoscopic video camera and video recorder
- Endoscopes (0-degree, 30-degree, and 45-degree Hopkins telescopes, 4 mm in diameter and 18 mm long with an endoscope holder)
- Computer-assisted navigation and micro-Doppler

SUGGESTED READING

INTRODUCTION

Transsphenoidal approaches to the sella have been performed for over a century with progressive improvement in outcomes aided by advances in technology such as the operating microscope and fluoroscopy. However, it was the addition of the endoscope that allowed the expansion of endonasal approaches outside of the sphenoid sinus, especially laterally into the “coronal plane,” which simply could not be visualized with the microscope. Endoscopic, transnasal transsphenoidal approaches initially allowed access to the cavernous sinus (previously felt to be inoperable) by allowing visualization of the entire sphenoid. Surgical teams including both otolaryngology and neurosurgery discovered that the addition of a transpterygoid approach, via a maxillary antrostomy, allowed access to Meckel’s cave and even the middle fossa in select cases.

The challenge of a medial approach to Meckel’s cave and the middle cranial fossa is proper case selection, respecting the key principle of minimizing neurovascular manipulation. The advantage of an endoscopic endonasal approach (EEA) to this region is that it completely avoids any retraction of the temporal lobe and provides direct access to tumors that originate or extend into the paranasal sinuses or infratemporal fossa.

HISTORY

Lesions that involve Meckel’s cave and the middle cranial fossa can have variable presentations including pain, facial numbness, and incidental discovery. Schwannomas and other similar benign tumors involving the trigeminal nerve typically cause trigeminal dysfunction late in their course. However, tumors or inflammation of Meckel’s cave often present with ipsilateral headache or retro-orbital pain. Other cranial neuropathies such as palsies of the abducens or oculomotor nerves are also late findings and are often an indication of atypical or aggressive pathology. Indeed, meningiomas rarely cause any cranial nerve dysfunction, and the presence of diplopia, especially acute onset, should raise concern. Perineural spread of a sinonasal malignancy with Meckel’s cave involvement, on the other hand, always has neuropathy in the form of numbness with or without pain. Sinus symptoms such as congestion, anosmia, or epistaxis should also be noted as they could direct diagnosis.

Extension to the middle cranial fossa may lead to irritation and/or edema of the mesial temporal lobe resulting in seizures. Very large tumors can create enough mass effect to cause aphasia, though these would be unlikely to be amenable to endonasal resection.

PHYSICAL EXAMINATION

A complete examination of the cranial nerves is critical, focused on the 3rd to 6th cranial nerves, as these are most likely to be affected and ophthalmoplegia indicates cavernous sinus extension. Facial sensation should be tested in all three distributions with light touch, pinprick, and temperature and compared for symmetry with the contralateral side. Rarely, large tumors could affect facial nerve function by direct compression; perineural
spread can occur through anastomoses between the trigeminal and facial nerves. If there is any question of compromise of orbital function, a complete neuro-ophthalmologic evaluation is mandatory.

If there is suspicion of a sinonasal tumor, nasal endoscopy should be performed to look for obvious masses and consider preoperative biopsy. Perineural invasion with involvement of multiple branches of the trigeminal nerve can result from a barely perceptible mucosal lesion. Care should be taken to examine all mucosal surfaces including the fossa of Rosenmüller in the nasopharynx. In addition, a complete examination of the neck for evidence of regional spread is critical as this can significantly alter treatment options.

Assessment of memory and speech is important to identify gross deficits in cognitive function caused by middle fossa tumors, though these are usually quite subtle if present at all.

INDICATIONS

EEAs to Meckel’s cave and the middle fossa should be limited to those tumors that present directly to the lateral recess of the sphenoid sinus or base of the pterygoid since these are situations that allow for direct access to the lesion with little or no neural dissection or manipulation. The simplest example is a middle fossa meningocele that herniates into the lateral recess of the sphenoid. An open approach requires unnecessary temporal lobe retraction to access the medial defect whereas an EEA gives direct access to the lesion via the sphenoid sinus. Similarly, many schwannomas or meningiomas of Meckel’s cave are adjacent to the sinus, providing a natural corridor to the tumor with no retraction of the brain, and the only neural manipulation is related to direct tumor involvement (Fig. 27.1).

Perineural spread of sinonasal carcinoma to Meckel’s cave generally carries a poor prognosis, but, in the absence of radiographic or clinical evidence of cavernous sinus invasion, debulking, and/or removal of recurrent disease in this location, followed by focal irradiation for residual microscopic disease, can improve local control or palliation of neuropathic pain.

Rarely, tumors with a medial origin will extend to Meckel’s cave. Pituitary adenomas, nasopharyngeal angiofibromas, chordomas, and chondrosarcomas can all be followed into Meckel’s cave with relatively low risk, as they tend to displace the neural contents laterally without direct invasion of the nerve.

Rarely, inflammatory diseases (e.g., sarcoidosis), infections (e.g., tuberculosis), or metastatic disease (e.g., meningeal carcinomatosis) primarily involve the trigeminal nerve and/or Meckel’s cave. Their diagnosis can often be made by other means such as CSF analysis or inferred from other tests, but sometimes they do require biopsy. These biopsies can be performed endonasally with minimal morbidity or delay in subsequent treatment.

CONTRAINDICATIONS

The EEA is contraindicated for tumors that originate and are primarily growing in the posterior or lateral middle fossa with minimal extension into Meckel’s cave or the anteromedial middle fossa. Attempting to resect such tumors would require transection or extensive, unnecessary manipulation of the Gasserian ganglion.

Sinus infection is a relative contraindication for intradural endonasal surgery that requires treatment with antibiotics alone or in combination with drainage. Once the infection has resolved, intradural resection can...
proceed. Biopsy of the maxillary branch of the trigeminal nerve, peripheral to Meckel’s cave, is generally safe even in the setting of infection.

Neoplastic involvement of the petrous internal carotid artery (ICA) is a relative contraindication depending on the goals of surgery and the experience of the surgical team. If proximal control of the ICA is desired, an infratemporal skull base approach may be considered.

PREOPERATIVE PLANNING

Given the complexity and variability of pathologies, both magnetic resonance imaging (MRI) and computed tomography (CT) angiography are generally recommended for evaluation and operative planning. FIESTA or fine-cut T2 MRI sequences can help to determine the relationship of the proximal trigeminal nerve to the tumor. Coronal, postcontrast studies reveal the degree of involvement of the branches of the trigeminal nerve as they exit their neural foramina and can also reveal if there is tumor extension to the cavernous sinus. These factors should also be evaluated on fine-cut (SPGR) postcontrast axial images as they can significantly change the role, extent, or goals of surgery. It is often impossible to know the relationship of the trigeminal nerves and ganglion to the lesion, though this could prove critical for planning of the surgical approach. In the future, high-definition fiber tracking techniques may help to better define these types of relationships.

CT angiography is important to evaluate both bony involvement or erosion and vascular involvement and displacement, both of which are common with Meckel’s cave and middle fossa pathology. Enlargement of the foramen ovale and/or rotundum, erosion of the floor of the temporal fossa, tumor-related hyperostosis, and degree of pneumatization of the lateral recess of the sphenoid sinus all play a role in either surgical planning or differential diagnosis. Tumors such as schwannomas and meningiomas that enlarge Meckel’s cave over time can significantly displace the horizontal petrous, paraclival, and cavernous segments of the ICA. The position of the artery can affect accessibility as well as safety of resection and/or biopsy. Narrowing of the artery is a sign of significant involvement of its wall, and consideration should be given to balloon test occlusion, depending on the goals of surgery.

Both CT and MRI should be evaluated for signs of sinusitis so that it can be treated preemptively.

SURGICAL TECHNIQUE (VIDEOS 27.1 AND 27.2)

A team consisting of an otolaryngologist and a neurosurgeon working in tandem performs all surgeries. Endoscopic endonasal surgery (EES) lateral to the paracaval and cavernous ICA requires a team with significant experience working in the sellar and parasellar regions. ICA exposure and manipulation are likely to be necessary, and comfort with possible management strategies in the event of an injury is critical before attempting these intradural resections.

Patients are placed in three-pin Mayfield head fixation with their head in slight extension, rotated approximately 15 to 20 degrees to the right and with slight lateral flexion of the vertex to the left. Any head positioning should be tempered by concern for cervical spine immobility or stenosis. The patient is placed in reverse Trendelenburg position to decrease venous hypertension and blood loss. Decongestion of the nasal cavity is achieved by placement of oxymetazoline-soaked pledgets. Image guidance is registered, and then the midface and abdomen are prepped with Betadine and draped. Neurophysiologic monitoring includes monitoring of cerebral function with somatosensory evoked potentials (given the potential for ICA manipulation) and electromyography (EMG) of the motor branch (mandibular/V3) of the trigeminal nerve, third, fourth, and sixth nerves to help with their identification and preservation.

A binaural approach to Meckel’s cave is preferred since this improves visualization and access. The need for a vascularized flap for coverage of an exposed ICA or closure of a dural defect is anticipated. A contralateral septal mucosal flap pediced on the posterior septal branch of the sphenopalatine artery is elevated and stored in the nasopharynx or maxillary sinus (ipsilateral to the flap) until needed. The posterior septum is detached from the sphenoid rostrum, and the bone of the rostrum is removed. Bilateral wide sphenoidotomies are performed. Resection of approximately 1 cm of the posterior septum improves the exposure.

A maxillary antrostomy is performed on the same side as the lesion. The sphenopalatine artery is sacrificed, and the sphenopalatine foramen is enlarged with a 1 mm Kerrison rongeur. The bone of the posterior wall of the maxillary sinus is removed to fully expose the contents of the pterygopalatine space. Within the sinus, the infraorbital nerve (branch of the maxillary nerve) is identified along the floor of the orbit as it courses medially toward the foramen rotundum.

The vidian nerve and its canal are a key anatomic landmark for this approach. The pterygopalatine contents should be carefully retracted laterally to identify the vidian nerve as it enters the bony canal within the pterygoid base (Fig. 27.2). The palatosophenoidal (also known as palatovaginal) canal can also be followed from the nasopharynx along the inferomedial aspect of the pterygoid “wedge” to locate the vidian canal. The vidian canal angles posterolaterally toward the anterior genu of the petrous ICA. The vidian nerve crosses over the petrous ICA lateral to the genu to join with the greater superficial petrosal nerve on the floor of the

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middle fossa. The pterygoid base must be drilled to gain access to the middle fossa and Meckel’s cave, and the pterygoid/vidian canal serves as a good guide during this drilling, especially if the lateral recess of the sphenoid is poorly pneumatized. Attempts to preserve this nerve while accessing Meckel’s cave will limit access to the even more critical neurovascular structures in the depth. Anatomic preservation is likely to require excessive manipulation with loss of function.

The foramen rotundum should be identified superolateral to the vidian canal by retracting the contents of the inferior orbital fissure and following the edge of the sphenoidotomy (lateral recess) to the foramen. Some of the bone overlying the inferior orbital fissure just below the orbital floor can be removed to facilitate this, taking care not to enter the orbit. Drilling of the bone of the pterygoid base, between the foramen rotundum and the vidian canal, will lead to complete exposure of Meckel’s cave and, laterally, the middle fossa. Additional exposure can be achieved by mobilizing the greater palatine neurovascular bundle from its canal. The pterygoid bone posterior to the canal can be drilled with preservation of the nerve. Further inferior drilling of the pterygoid bone (lateral to the vidian canal) can be done to access the foramen ovale that guards the lateral aspect of the horizontal segment of the ICA. The bone over Meckel’s cave can be removed in the same fashion as the bone of the sella, though the angle of the bone surface is unfavorable for the use of a Kerrison rongeur. Once the bone overlying the maxillary branch (V2) and mandibular branch (V3) of the trigeminal nerve have been removed, complete access to Meckel’s cave has been achieved. The bony opening can be extending superiorly to the superior orbital fissure and lateral cavernous sinus, though tumor resection in these regions is usually limited due to unwarranted risk to the oculomotor nerves. Extension of the approach lateral to V3 is limited superiorly by the orbital apex and maxillary nerve but can provide access to the floor of the middle fossa and temporal lobe. Medially, the vertical petrous (paracaval) ICA can be uncovered by carefully drilling the bone overlying and medial to it and then dissecting it free from the dura that protects it. This will allow for safe medial retraction of the ICA during tumor resection but may not be necessary in the setting of biopsy.

Biopsy of primary tumors of Meckel’s cave or perineural spread of sinonasal cancers can be done with relative ease as long as the ICA is properly identified. In addition to relying on anatomical landmarks in conjunction with image guidance, a thin, long ultrasound probe is invaluable. Approaching lesions at or below the level of the foramen rotundum will avoid accidental entry into the adjacent and contiguous lateral cavernous sinus. Opening of the dura should be done parallel to the closest trigeminal branch, keeping in mind that V2 and V3 form a 45-degree angle with each other as they enter Meckel’s cave (Fig. 27.3). Opening in this manner will help to merely split rather than sever the nerve if it is displaced medial to the lesion. Dissection is performed with a Kartush nerve stimulating dissector to identify and preserve the cranial nerves in and around

**FIGURE 27.2**
Intraoperative, endoscopic endonasal view of the left vidian nerve (VN) entering the vidian (pterygoid) canal (VC) (arrow). (CR, clival recess; MC, Meckel’s cave behind the lateral recess of the sphenoid; S, sella.)

**FIGURE 27.3**
Intraoperative, endoscopic endonasal view during dissection of the left Meckel’s cave portion of the tumor shown in Figure 27.1. A Kartush electrical nerve stimulator is being used to identify motor nerves in Meckel’s cave (MC) and the adjacent cavernous sinus (CS). (FR, foramen rotundum; ICA, internal carotid artery [paracaval/vertical petrous]; S, sella.)
Meckel’s cave. Resection of tumors such as schwannomas proceeds with internal debulking followed by extra-capsular dissection, recapitulating standard microdissection techniques. Trigeminal schwannomas respect the adjacent oculomotor nerves, displacing them superiorly while tumors such as meningiomas and sinonasal carcinomas tend to be much more invasive, increasing the risk to these nerves. Pituitary adenomas and chondroid tumors are variable but tend to displace the dura of Meckel’s cave as well as its contents.

The limits of dissection are anatomical and include the lateral cavernous sinus superiorly (unless the nerves therein are already affected), the paraclival ICA medially, horizontal petrous ICA inferiorly, and trigeminal ganglion, middle fossa dura, and temporal lobe laterally (Fig. 27.4). Dissection and resection can extend to the middle fossa if the tumor has created a corridor through which to access it (Fig. 27.5). In the depth, the entrance to the posterior fossa from Meckel’s cave can be dilated, allowing for greater access to this region from an anterior approach, but this can prove to be a limitation as well, and dissection should not proceed blindly past this point.

Reconstruction depends on the extent of exposure to CSF. Occassionally, Meckel’s cave has an arachnoid diverticulum that can lead to CSF leak during even simple biopsy. Normally, unless dissection extends to the

**FIGURE 27.4** A. Intraoperative, endoscopic endonasal view following complete removal of the tumor shown in Figure 27.1. (CS, cavernous sinus; FR, foramen rotundum; ICA, internal carotid artery [paraclival/vertical petrous]; P, pons; PA, petrous apex; S, sella.) B. Postoperative, T1-weighted, postcontrast axial MRI showing complete tumor removal of Meckel’s cave tumor (MC) shown in Figure 27.1. The nasoseptal flap used for reconstruction enhances brightly (arrow).
proximal Gasserian ganglion, there is little risk of intraoperative CSF leak. In the absence of a leak or ICA exposure, application of fibrin sealant or a free mucosal graft is adequate. Otherwise, vascularized flaps such as the nasal septal flap (see Chapter 42) are used to cover the opening into Meckel’s cave or the middle fossa as well as exposed segments of the ICA.

**POSTOPERATIVE MANAGEMENT**

Lumbar drainage is used only in the setting of high-flow intraoperative CSF leaks (dissection in an arachnoid cistern). Intravenous, broad-spectrum antibiotics such as a third or fourth generation cephalosporin are administered for 24 to 48 hours postoperatively and then converted to a similar oral regimen until nasal packing is removed. Corticosteroids are used in cases with high risk or evidence of cranial nerve injury.

In the absence of a CSF leak, nasal packing can be removed in 24 to 48 hours. If a vascularized septal flap is used to repair a dural defect, packing is left in place for 5 to 7 days. Silastic nasal splints are removed at 1 week if a septal flap is not used and at 3 weeks if one is used. The Silastic splints maintain humidification and improve mucosalization of exposed septal cartilage. Patients are encouraged to use saline nasal spray throughout the day. Saline flushes of the nasal cavity are instituted at 3 weeks. Patients are advised to avoid activities that increase CSF pressure for at 4 weeks if a dural reconstruction is performed. If a patient requires continuous positive airway pressure (CPAP) for treatment of obstructive sleep apnea, it is generally safe to resume 1 week following surgery (after nasal packing is removed).

**COMPLICATIONS**

CSF leak is the most common complication after EES in general but has decreased significantly with the use of vascularized flaps. Dry eye is an inevitable consequence of vidian nerve sacrifice, though most patients are not aware of nor symptomatic from this loss of emotional tearing. Care must be taken to avoid both vidian nerve and V1 (ophthalmic branch of trigeminal nerve) dysfunction, as this creates a dry, insensate eye that may be destined for corneal keratopathy. Corneal sensation should be tested and appropriate precautions and care provided in case of its absence. Diplopia can be transient and unless a nerve is severed, allow 3 to 6 months for recovery. Intraoperative injury of the ICA is rare, but respect for the significant learning curve associated with EES will allow for appropriate management. Any surgery lateral to the ICA is considered high risk and should only be performed following extensive experience with sellar and parasellar lesions as well as planning for management of intraoperative vascular injury. Advanced skull base surgery requires endovascular support for immediate angiography and potential sacrifice, coiling, or stenting. Injury to the motor branch of the trigeminal nerve results in muscle atrophy with attendant cosmetic defect, decreased chewing strength, and jaw drift with opening. Temporary trismus is common if there is dissection of the pterygoid muscles.

**RESULTS**

EEAs are widely accepted for the treatment of middle fossa meningoencephaloceles extending into the lateral recess of the sphenoid sinus. In addition, they have been used successfully for biopsy and resection of benign and malignant pathologies involving Meckel’s cave and the middle fossa, including meningiomas (typical and atypical), schwannomas, and sinonasal carcinomas (such as adenoid cystic carcinoma and squamous cell carcinoma).
The most consistent and classic pathology of Meckel’s cave is trigeminal schwannoma. Between 2003 and 2009, 11 trigeminal schwannomas were resected by EEA at our institution. They all had some degree of Meckel’s cave involvement but were primarily growing in the following areas: four in Meckel’s cave, two in the middle fossa, two in the orbital apex, and three in the infratemporal fossa. Their average diameter was 3.5 cm, and two patients underwent EEA combined with a retromastoid craniectomy. Seven patients (64%) underwent gross total resection, three (27%) near total resection (Fig. 27.6), and one (9%) subtotal resection. Out of 11 trigeminal schwannoma patients, two patients (18%) developed a sensory deficit only, two patients (18%) developed motor and sensory deficits, and one patient (9%) developed a motor deficit only after EEA. Overall, four patients (36%) developed new sensory deficits and three patients (27%) developed new motor deficits postoperatively. There were two new postoperative cranial neuropathies (III and VI nerve palsies) that were improved at last follow-up (>1 year). On the other hand, three patients had improvement in trigeminal (sensory) function and three of four patients with preoperative abducens palsies recovered. One preoperative oculomotor palsy improved. Importantly, there were no CSF leaks following EES for trigeminal schwannoma. All of these rates compare favorably with conventional or open skull base approaches.

**PEARLS**

- Drilling of the pterygoid bone between the foramen rotundum and the vidian canal provides direct endonasal access to Meckel’s cave. They converge posteriorly on Meckel’s cave, and the distance between them depends on the pneumatization of the lateral recess of the sphenoid.
- The vidian nerve has to be sacrificed to achieve full, safe access to Meckel’s cave.
- Dissecting at or below the level of V2 should prevent damage to the oculomotor nerves.

**PITFALLS**

- Preoperative imaging is used to determine the relationship of the trigeminal nerve to a tumor in Meckel’s cave. A different approach should be considered if the nerve is displaced medially by tumor.
- The vidian nerve provides a good landmark for access to Meckel’s cave, but does NOT lead directly to the anterior genu of the ICA but rather turns laterally to cross over the horizontal petrous ICA.
- Invasion of and attachment to cranial nerves varies by tumor type and should be taken into consideration when planning resection.
- Drilling medial to the vidian canal can still result in injury to the ICA.
- Sacrifice of the vidian nerve can result in a dry eye in elderly patients and should be avoided if possible in patients with absence of corneal sensation (V1).
INSTRUMENTS TO HAVE AVAILABLE

- Zero- and 45-degree rod lens endoscopes (Storz)
- Extended tip micro-Doppler probe (for ICA identification)
- Standard sinus instruments
- Monopolar needle tip and suction electrocautery tips
- High-speed electric drill with extended tip and extended, coarse diamond drill bit (Stryker)
- Extended tip neurodissectors (KLS Martin)
- Pistol-grip Kurze microscissors (straight, curved left and right, and rotatable) (Storz)
- Pistol-grip bipolar electrocautery (side angle, “up-toe,” and fine, straight tip) (Storz)
- Kartush stimulating dissector to be used with EMG

SUGGESTED READING


INTRODUCTION

Transsphenoidal approaches to the sella have been performed for over a century with progressive improvement in outcomes associated with the addition of technologies such as the operating microscope, fluoroscopy, intraoperative image guidance, and modified specula. However, these approaches remain limited in the paramedian regions of the skull base requiring alternate approaches such as anterior transmaxillary approaches that themselves have significant limitations below the sphenoid sinus. The introduction of the endoscope allows expansion of endonasal approaches outside of the sphenoid sinus, especially laterally into the “coronal plane” and inferiorly into the nasopharynx and parapharyngeal space. The addition of a transpterygoid approach, via a medial maxillotomy, provides access to the pterygoid base and foramen lacerum. Combining these caudal and paramedian approaches has made it possible to resect lesions that extend to or originate from the jugular tubercle, jugular foramen, and medial occipital condyle in select cases.

Proper case selection must respect the basic principle of endoscopic endonasal surgery (EES), which is to minimize the manipulation of normal neural and vascular structures. The advantage of an endoscopic endonasal approach (EEA) to this region is that it completely avoids an external incision and associated trauma to normal tissues, requires no cerebellar retraction or manipulation of the vertebral artery or lower cranial nerves, and provides direct access to tumors that originate or extend into the clivus, paranasal sinuses, or parapharyngeal space.

HISTORY

Lesions involving the jugular foramen would logically affect the lower cranial nerves, often presenting with dysphagia or hoarseness. Those that arise medially or caudally may be more likely to affect the hypoglossal nerve first, with dysarthria as a primary complaint. All of these may be subtle at first, with only occasional coughing or choking on liquids and voice changes that may be missed if not specifically questioned. Patients adapt very well to slowly progressive deficits and may present with large tumors by the time overt symptoms have developed.

Occipital headache can be specific to lesions in the clivus or jugular foramen/tubercle. Involvement of the occipital condyle can lead to instability with mechanical neck or head pain. Bone tumors classically present with pain that is worse at night and relieved by nonsteroidal anti-inflammatory drugs. Large masses with brainstem or cerebellar compression may present with ataxia or even quadriplegia.

PHYSICAL EXAMINATION

A detailed examination of the lower cranial nerves is critical for the evaluation of tumors of the jugular foramen region. This should include observation of palatal function with gag testing, and assessment of trapezius muscle strength (shoulder shrug, head turning) and tongue function (atrophy or fasciculations, weakness, and deviation
Laryngoscopy should be performed to observe vocal cord mobility and assess the degree of aspiration. A full examination of the head and neck with palpation of the soft tissues is important to identify soft tissue masses or associated lymphadenopathy. A large parapharyngeal space mass may displace the tonsil fossa medially.

A full neurologic examination should be performed to include testing of gait and dysmetria. Long tract signs and proprioception can be affected in cases with compression of the brainstem compression and other sensations, including light touch and pinprick in the face, trunk, and extremities, may also be abnormal; the pattern of its loss may localize to the lateral medulla.

**INDICATIONS**

The indications for a medial EEA to the jugular foramen are limited. Many jugular foramen tumors (e.g., paragangliomas) originate or are primarily based lateral to the pars nervosa (which is medial to the pars venosum), placing the lower cranial nerves between the surgeon and the tumor with an endonasal approach. However, there are tumors that originate in the midline or paramedian skull base that extend out to the jugular foramen. Chordomas, chondrosarcomas, and some petroclival meningiomas can all be approached endonasally and often extend out toward the jugular foramen and/or occipital condyle. The primary limitation of an infrapetrous approach is the horizontal petrous segment of the internal carotid artery (ICA) and foramen lacerum superiorly and the hypoglossal nerve inferolaterally.

There are occasional small meningiomas that arise from the jugular tubercle, medial to the lower cranial nerves that are ideal for EES (Fig. 28.1). These can be completely resected with no manipulation of the nerves, something that is impossible with any transcranial approach. Some cholesterol granulomas of the petrous apex do not extend medial to the paracavial (vertical petrous) ICA and therefore have to be drained through an infrapetrous approach.

Malignancies of the nasopharynx are usually advanced at the time of presentation and are treated primarily with radiation therapy. The primary role of surgery is biopsy for diagnosis and debulking of tumor to relieve symptoms prior to radiation therapy. Exceptions include small tumors that can be completely resected with adequate margins. For adenoid cystic carcinoma, the goal of surgery is maximal removal with minimal morbidity, followed by radiation therapy. It is not possible to achieve clear resection margins with adenoid cystic carcinoma of the skull base due to perineural spread, and the extent of surgery is limited by the surrounding neural and vascular structures. Surgical salvage of residual tumor following radiation therapy is of potential value for local control and should be considered based on posttreatment functional imaging with PET–CT or the results of biopsies. Understanding the paramedian anatomy below the petrous ICA is critical for safely expanding the above indications.

**CONTRAINDICATIONS**

There are no absolute contraindications to an endonasal approach as long as the tumor is medial to the lower cranial nerves. Occlusion of the contralateral ICA warrants consideration of a posterolateral approach that would avoid any potential risk to the patent ICA. Extensive tumor (benign or malignant) with encasement of the...
ICA limits the goals of surgery, and complete resection is not possible without sacrifice of the ICA. Depending on the surgeon’s experience and available resources for dealing with an injury to the ICA, an open approach with better proximal and distal control of the ICA may be preferred. Any sinus infection would need to be properly treated before intradural surgery is performed, but sinusitis can usually be cleared within a week or two with antibiotics, drainage, or a combination of therapies.

**PREOPERATIVE PLANNING**

This region is difficult to image due to the dense bone and closely associated mucosal surfaces, muscles, vessels, and nerves. As a result, MRI and CT are complementary imaging modalities, and often both are needed to establish a differential diagnosis and determine extent of disease. Fine-cut T2-weighted MRI or FIESTA sequences can be critical in determining the relationship of the lower cranial nerves to any lesion in the infrapetrous space. Postcontrast T1-weighted images can help to reveal the vascularity of a tumor or the presence of a dural tail. CT is critical, especially for small lesions of the petrous bone that can be quite heterogeneous on MRI. Even asymptomatic petrous pneumatization can be deceiving until evaluation with CT. The addition of CT angiography is important to define the vascular relationships and involvement, especially of the ipsilateral ICA and vertebral artery. Combined PET–CT scan imaging is helpful in differentiating cancer from radiation changes in patients with recurrent or residual sinonasal malignancy.

A full swallowing evaluation is necessary to identify cranial nerve deficits and assess the risk of perioperative complications related to airway obstruction or aspiration. Complete vocal cord paralysis or significant aspiration may require prophylactic tracheostomy to prevent aspiration in the perioperative period. The detection of cranial nerve dysfunction by physical examination or electromyography can provide prognostic information regarding the potential for additional nerve injury or recovery.

**SURGICAL TECHNIQUE (VIDEO 28.1)**

All EES is best performed by a team of two surgeons, composed of otolaryngology and neurosurgery specialties. Patients are positioned supine and preferably in head pin fixation with the head in slight extension and laterally flexed to point the chin at the surgeons, both of whom stand on the patient’s right side (right-handed surgeons). Oxymetazoline (0.05%)-soaked pledgets are placed in the nose, image guidance is registered, and the midface and abdomen are prepped and draped. Antiseptics are not used intranasally except for the nasal vestibule.

Intradural cases or those with significant ICA exposure should have a vascularized nasal septal flap (see Chapter 42) harvested from the side contralateral to the infrapetrous approach at the beginning of the operation. The right middle turbinate is frequently resected to allow working room for the endoscope, and the sphenoid sinus is opened widely, fully exposing the lateral recess on the operative side. The key to accessing the infrapetrous region is a medial maxillary antrostomy and transpterygoid approach.

A maxillary antrostomy is performed on the same side as the lesion. The sphenopalatine artery is sacrificed, and the sphenopalatine foramen is enlarged with a 1-mm Kerrison rongeur. The bone of the posterior wall of the maxillary sinus is removed to fully expose the contents of the pterygopalatine space. Within the sinus, the infraorbital nerve (branch of the maxillary nerve) is identified along the floor of the orbit as it courses medially toward the foramen rotundum. Medially, at the inferior margin of the sphenoidotomy, the palatophyseal (palatovaginal) vessel is sacrificed, and the soft tissues of the pterygopalatine space are elevated from the underlying bone to identify the vidian canal within the base of the pterygoid bone. It is difficult to identify the canal without first sacrificing the terminal branches of the internal maxillary artery.

The vidian nerve and its canal are a key anatomic landmark for this approach. The pterygopalatine contents should be carefully retracted laterally to identify the vidian nerve as it enters the bony canal within the pterygoid base. The vidian canal angles posterolaterally toward the anterior genu of the petrous ICA. However, the vidian nerve crosses over the petrous ICA lateral to the genu to originate from the greater superficial petrosal nerve on the floor of the middle fossa. The pterygoid base must be drilled to define the course of the petrous ICA and provide localization of the anterior genu of the carotid and foramen lacerum (Table 28.1). The pterygoid/vidian canal serves as a good guide during this drilling, especially if the lateral recess of the sphenoid is poorly pneumatized. Drilling the bone of the “pterygoid wedge” (the medial extension of the pterygoid base onto the sphenoid floor) along the path of the vidian nerve will lead to the ICA genu (Figs. 28.2 and 28.3), but it is critical to understand that the vidian nerve crosses the ICA immediately lateral to the genu. Lateral exposure is limited by the vidian nerve and descending palatine branch of the second division of the trigeminal nerve. Both nerves can be skeletonized with careful drilling and released from their respective canals with an attempt at preservation of function. Greater exposure of the ICA, however, usually requires sacrifice of the vidian nerve.

The second key anatomic landmark is the eustachian tube (ET) and its attachment to foramen lacerum. The ET can be easily identified as the lateral boundary of the nasopharynx (Fig. 28.3). The nasopharyngeal
mucosa should be dissected from the floor of the sphenoid along the medial pterygoid plate just above the ET. This region is the epicenter of the exposure, and drilling this bone will lead directly to the cartilage of foramen lacerum that is contiguous with the ET cartilage. This cartilage is attached firmly to the inferior aspect of the ICA genu and cannot be easily dissected from the ICA. Careful removal of the majority of this cartilage with a “thru-cut” instrument can expand the superior access to the petroclival junction but must be done with extreme care given the proximity and high risk of injury to the ICA. Further dissection of the ET laterally to the junction of the cartilaginous and bony ET leads to the skull base adjacent to the entrance of the parapharyngeal ICA into the petrous bone. Dissection of soft tissues in this region must be done very carefully since the parapharyngeal ICA can be very tortuous and does not have reliable landmarks. A micro-Doppler probe can be used to explore the soft tissues to identify the ICA, but this may provide a false sense of security given the precise placement required for accurate sonography.

The final key anatomic point is the supracondylar groove (Fig. 28.4). This paramedian osseous landmark provides the common attachment region of the capsule joint, the atlanto-occipital membrane as well as the rectus capitis anterior muscle and accurately estimates the position of the hypoglossal canal. In fact, drilling over this region will expose the anterior cortical bone of the hypoglossal canal, which divides the inferolateral area of the clivus into two compartments: superior (jugular tubercle) and inferior (occipital condyle). By resecting the overlying mucosa and musculature with a needle tip monopolar cautery (with caution, depending on the proximity of the parapharyngeal ICA) or straight and angled thru-cutting rongeurs, these landmarks and structures can be carefully but reliably exposed.

Tumors that originate from or extend into these paramedian structures, displacing the lower cranial nerves laterally, can generally be safely accessed by removing the bone of the medial jugular tubercle and occipital condyle with a high-speed electric drill and cutting diamond burr. When drilling, care must be taken to preserve the dural sheath around the hypoglossal nerve. Often, this can be ensured by leaving the inner cortical bone of the hypoglossal canal intact.

The majority of the surgery is performed with a 0-degree endoscope. Angled endoscopes are needed to resect lateral extension of the tumor into the petroclival synchondrosis or medial jugular tubercle and occipital condyle. Similarly, angled instruments are used in these regions to safely resect tumor. Care should be taken to ensure that injury to the parapharyngeal and petrous ICA does not occur when resecting tumor deep to them. If there is extensive involvement of the ICA in these regions, exposure through the neck for proximal control should be considered.

Further lateral resection is generally limited by neurovascular structures; in this case, the parapharyngeal ICA and lower cranial nerves. Removal of bone laterally in the jugular tubercle leads to the inferior petrosal sinus, which lies immediately medial to the pars nervosa. Dissection should not proceed lateral to this to avoid injury to these nerves. There can be significant venous bleeding from the inferior petrosal sinus, but this can be

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<th>TABLE 28.1 Segments of the Cranial Base Internal Carotid Artery and Associated Endonasal Anatomic Landmarks for Localization</th>
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<tr>
<td><strong>ICA Segment</strong></td>
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<td>Anterior genu</td>
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<td>Horizontal petrous</td>
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<td>Ascending/parapharyngeal</td>
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FIGURE 28.2 Intraoperative, endoscopic endonasal view of the right vidian neurovascular bundle (VN) entering the vidian canal (VC), which has been drilled to the anterior genu of the petrous internal carotid artery (ICA). Note that the vidian nerve runs lateral to the genu (just deep to the drill in this image), which lies just superior to the oramen lacerum (FL). (CR, clival recess.)
controlled by packing with morselized, flowable Gelfoam (Surgifoam, Surgiflo, Floseal). When resecting the condyle, the joint capsule should be preserved when possible. Based on our experience and recent biomechanical data, the medial half of the condyle can be resected without overt instability, as long as the joint capsule is not disrupted or the condyle disconnected from the skull base.

Resection of intradural tumors in these regions should proceed similarly, from medial to lateral, with care to identify the relevant intradural structures: the vertebral artery with hypoglossal nerve lying immediately dorsal to it as it exits into its canal and the glossopharyngeal and vagal nerves just below the foramen lacerum (Fig. 28.5). Resection of the lateral margins should be performed or confirmed with angled endoscopy and often requires angled instruments. This should be done with care and cognizance of the location of the parapharyngeal ICA to prevent inadvertent injury to its deep surface. Similarly, the horizontal petrous ICA and lacerum segment should be well localized superiorly. Often, the ICA in both locations can be located with a long Doppler probe. Confirmation of location with ultrasound is reassuring, but lack of localization is not, given the fickle nature of the directional tip of the device.
Reconstruction of the dural defect is undertaken with an inlay graft of DuraGen or other collagen allograft or dural substitute. This is usually done to replace or reinforce the arachnoid layer. The dura can be reconstructed primarily with a vascularized nasal septal flap (see Chapter 42). A wider flap is harvested that includes the mucosa of the nasal floor. This allows simultaneous reconstruction of the dural defect and coverage of the ICA. A deep clival defect may require augmentation with an adipose tissue graft placed between the dural graft and the mucosal flap. In either technique, care must be taken to ensure that the flap is in contact with bone or dura circumferentially. There should not be mucosa deep to the flap, and its pedicle must also be in contact with bone or other tissue across its entire length to prevent retraction of the pedicle and subsequent flap displacement. Surgicel, tissue glue, and Gelfoam packing then follow, held in place with either a Foley catheter balloon or Merocel tampons, depending upon the size and shape of the defect.

POSTOPERATIVE MANAGEMENT

Packing is maintained for 5 to 7 days when there is a dural defect (depending on size, extent, and quality of reconstruction). Patients are kept on antibiotics while packing is in place (intravenous for 24 to 48 hours, then oral, broad-spectrum cephalosporin or equivalent). The use of perioperative lumbar drainage has not been well studied, but it does reduce cerebrospinal fluid (CSF) pressure during the initial period of healing, and it is our current practice to maintain drainage for 3 postoperative days in cases of large clival or paraclival defects, especially with extensive arachnoid dissection.

After the nasal packing is removed, patients should be observed closely for signs of a CSF leak. With low paraclival defects, this may present as postnasal, pharyngeal drainage with frequent coughing. Patients should be questioned about this and checked for clear nasal drainage. It may be more difficult to detect leaks in this location, and bedside endoscopy should be performed if there is any question. Patients are started on saline nasal spray QID and PRN postoperatively. They are cautioned to avoid activities that increase intracranial pressure and stress the repair. After 3 weeks, saline irrigations are started for more effective cleaning of the nasal cavity. Nasal endoscopy with gentle debridement is performed every few weeks until healing is complete. Silastic nasal splints are removed at 3 weeks if a nasoseptal flap has been used and at 1 to 2 weeks if not.

Lower cranial nerve function should be assessed in the postoperative period prior to allowing oral intake. If suspicion of injury is low, this can consist merely of bedside observation of intake of fluids with varied consistency. Otherwise, a formal evaluation, often including fiberoptic endoscopic evaluation, may be necessary.

Any patient with tumor resection involving the condyle should have ongoing evaluation to ensure they do not develop instability. This consists of evaluation of neck pain, range of motion, and flexion/extension radiographs. If there is new or increasing mechanical neck pain or radiographic evidence of listhesis or other instability, CT and MRI should be performed to assess the cranio cervical junction and evaluate the need for fixation.

COMPLICATIONS

The close anatomical relationships and potential tumor involvement of the petrous and parapharyngeal segments of the ICA place these structures at greater risk with the infrapetrous approach. The lack of reliable landmarks outside the skull base and the difficulty of dissecting around the foramen lacerum further increase the risk. Proximal control of the ICA is a challenge, and balloon test occlusion and neck dissection for proximal control should be considered as needed. Currently, there are not good techniques for suturing endonasally,
leaving only clip reconstruction or packing for repair of a vessel. Any injury should be evaluated as soon as possible with formal digital subtraction angiography to evaluate for active extravasation, pseudoaneurysm, thromboembolus, dissection, or occlusion. As a general rule, extensive tumor resection should not proceed following such an injury. It is important that the surgical team be prepared to handle such an emergency, and simulation training is recommended.

Lower cranial neuropathy can have a devastating effect on patient quality of life and should be avoided when feasible, even if this means choosing treatment modalities other than complete resection. As a result, resection lateral to the inferior petrosal sinus should generally be avoided.

CSF leak is a potentially challenging complication, regardless of approach. Caudal, paramedian dural defects are at the limit of coverage for vascularized flaps such as the nasoseptal flap but can often be successfully managed with inlay and onlay allo- or autografts with an overlay of adipose tissue grafts deep to the flap. If a leak is suspected, it should be evaluated efficiently, even if this requires reexploration under anesthesia to confirm healing. If a secondary repair is performed, a lumbar spinal drain is placed at the same time.

RESULTS

The infrapetrous approach has been used with great success for complete removal of meningiomas and chondrosarcomas of the medial jugular tubercle and petroclival meningiomas. An understanding of the inferior and lateral extension of a transclival approach is critical for achieving maximal resection of tumors of midline or paramedian origin. This is demonstrated by the learning curve for clival chordoma. In our first 60 chordoma cases, the midclival resection rate was 100%, while the inferior clivus was only 47.6%; midline resection rates were 76.7% while lateralized tumor had only 56.7% of their volume resected. Gaining an understanding of the anatomy and technique of the infrapetrous approach is a key part of the learning curve, demonstrated by a sequential increase in gross total resection rates from 36.4% in early years to 88.9% in the last 15 cases.

PEARLS

● Dynamic endoscopy and an experienced surgical team (two surgeons, three or four hands) are critical for paramedian, “coronal plane” approaches.
● Proximal ICA control may require a small incision in the neck.
● The supracocondylar groove, an important point for muscle and capsule attachment, lies at the precise level of the hypoglossal canal and, as such, provides an important anatomic landmark.
● Paramedian and caudal CSF leaks can present as nasopharyngeal drainage, rather than nasal dripping. This requires close patient questioning and often presents as excessive secretions when supine.

PITFALLS

● The vidian nerve crosses the petrous ICA lateral to the genu of the ICA at foramen lacerum and does not accurately predict the medial margin of the genu.
● Dissection lateral to the ET should be done with caution to avoid injury to the parapharyngeal ICA. Preoperative radiographs should be reviewed to identify a tortuous ICA that projects medially.
● Bleeding from the inferior petrosal sinus marks the lateral extent of resection of a “far medial” or infrapetrous approach; extension beyond this requires dissection into the pars nervosa of the jugular foramen with attendant lower cranial neuropathy.

INSTRUMENTS TO HAVE AVAILABLE

In addition to the standard endoscopic sinus surgery instruments, it is helpful to have the following instruments:

● Angled endoscopes
● Angled thru-cutting instruments
● Malleable suction tip
● Extendable, endoscopic dissection instruments (KLS Martin)
● Angled, Fisch dissectors
● 4-mm coarse diamond bit for drill
● Pistol grip, endoscopic bipolar electrocautery
● Micro-Doppler probe
● Nerve stimulation probe (Kartush)/insulated dissector tip
● Aneurysm clips (available) and pistol grip applier.
SUGGESTED READING


INTRODUCTION

Angiofibroma is a rare benign tumor making up only 0.05% of tumors of the head and neck. It typically affects young males, between 10 and 24 years of age, with an incidence between 1:5,000 and 1:60,000. First described by Chaveau in 1906, angiofibromas originate from the sphenopalatine foramen and may occupy the pterygopalatine space and the infratemporal fossa. As the tumor enlarges, it may extend to the middle fossa via various neurovascular foramina (i.e., the carotid canal, jugular foramen, foramen spinosum, foramen ovale, and foramen lacerum) and extend to the orbit via the inferior orbital fissure.

Histologic studies revealed myofibroblasts as the cells of origin. Fibrous connective tissue with abundant endothelium-lined vascular spaces, a pseudocapsule of fibrous tissue and blood vessels lacking a complete muscular layer are other histologic features. Although benign and slow growing, these tumors are locally aggressive and cause symptoms of nasal obstruction and epistaxis in 63% of patients.

Surgery following embolization is the standard treatment of angiofibroma. Depending upon the size, extension, and structures involved, the tumor can be removed by either an open or endoscopic approach (Fig. 29.1).

Until the 1980s, the surgical technique for removal of tumors involving the infratemporal fossa involved only external (preauricular, postauricular (transtemporal), anterior transfacial, transorbital) approaches.

With the improvement in endoscopic techniques and angiography with embolization, a large number of angiofibromas, especially the early stages, are being removed endoscopically.

HISTORY

The main clinical presentation is unilateral nasal obstruction in 91% and epistaxis in 63% of patients. Headaches and facial pain may be present secondary to the blockage of the paranasal sinuses. Compression of the Eustachian tube orifice in the fossa of Rosenmüller produces middle ear effusion with a conductive hearing loss. Other related symptoms include facial deformity and ocular symptoms of proptosis, diplopia, and, less often, visual loss.

PHYSICAL EXAMINATION

Nasal endoscopy reveals a smooth lobulated mass in the nasopharynx or lateral nasal wall: pale, purplish, red-gray, or beefy red (Fig. 29.2). Although compressible, it is important to avoid manipulating the tumor, due to the high risk of bleeding. Patients in more advanced stages may have proptosis, diplopia, and facial deformity.

The author has nothing to disclose.
INDICATIONS

Surgical excision, with or without preoperative embolization, is the primary treatment option for angiofibromas. Before choosing the approach, the tumor must be evaluated based on the classification proposed by Andrews and modified by Fisch (Table 29.1).

Lesion Grades I, II, IIIA, and IIIB can be resected through an endoscopic transnasal approach. This technique in experienced hands has the advantage of decreasing intraoperative blood loss, reducing hospital stay, and producing equal or reduced recurrence rates compared with open approaches. The use of the endoscope may be difficult depending on the lateral extension, mainly to soft tissues of the zygomatic region and cheek.

The open surgical treatment is most frequently reserved for grade IV angiofibroma. A great number of open approaches have been described (transpalatal, lateral rhinotomy, midface degloving, medial maxillectomy, transantral, infratemporal fossa, and frontotemporal craniotomy). I often use the midface degloving approach under microscopic visualization since it does not produce external scars.

CONTRAINDICATIONS

In patients who present with encasement of the internal carotid artery or cavernous sinus extension and blood supply from branches of the ICA, a gross total removal by the endoscopic and even the open approach may be more difficult.
CHAPTER 29 Surgery for Angiofibroma

**PREOPERATIVE PLANNING**

Preoperative imaging includes CT and MRI scans. The bone window of the CT scan without contrast shows classic signs such as enlargement of the anteroposterior diameter of the sphenopalatine fissure, anterior bowing of the posterior maxillary wall (Holman-Miller Sign), and erosion of the basisphenoid in the axial view and provides the bony landmarks for the surgery. Soft tissue window with contrast demonstrates a lesion with homogeneous enhancement (Fig. 29.3). CT scans are also commonly used for intraoperative navigation to confirm the extent and resection of tumor. MRI with gadolinium is important in assessing tumor enhancement, intrallesional features, and the relation of the tumor to critical structures such as the internal carotid artery, cavernous sinus, periorbita, dura mater, and pituitary gland and its extension. Moreover, it helps in differentiating tumor from secondary chronic rhinosinusitis.

The diagnosis is made on clinical grounds of history, physical diagnosis, and imaging studies. Preoperative biopsy is unnecessary and not recommended due to the risk of catastrophic hemorrhage. Laboratory investigation including blood typing and preparation of fresh blood for transfusion is always indicated.

Because it is a highly vascular tumor, the embolization is indicated between 24 and 48 hours before surgery. Several materials may be used such as Gelfoam, Polyvinyl alcohol, or Onyx, a liquid embolic agent that allows deep penetration into the lesion, producing extensive tumor infarction. Embolization significantly reduces intraoperative blood loss and consequently minimizes the need for blood transfusion. Furthermore, the radioactive isotope Iodine-125 is occasionally used with embolization to cause necrosis of the tumor.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Tumor limited to the nasal cavity and nasopharynx</td>
</tr>
<tr>
<td>II</td>
<td>Tumor extension into the pterygopalatine fossa, maxillary, sphenoid, or ethmoid sinuses</td>
</tr>
<tr>
<td>III A</td>
<td>Extension into orbit or infratemporal fossa without intracranial extension</td>
</tr>
<tr>
<td>III B</td>
<td>Stage IIA with small extradural intracranial (parasellar) involvement</td>
</tr>
<tr>
<td>IV A</td>
<td>Large extradural intracranial or intradural extension</td>
</tr>
<tr>
<td>IV B</td>
<td>Extension into cavernous sinus, pituitary, or optic chiasm</td>
</tr>
</tbody>
</table>

**TABLE 29.1 Andrews’ Classification (Modified Fisch) of Angiofibromas**

**FIGURE 29.3**

CT scan with contrast.  
A. Axial scan showing a heterogeneous tumor (T) enlarging the pterygopalatine fossa (Holman-Miller Sign) (arrow).  
B. Postoperative axial view.  
C. Coronal scan with tumor (T) protruding into the right sphenoid sinus.  
D. Postoperative coronal showing no residual tumor.
endoscopic visualization is improved, providing more complete tumor removal. The maxillary and the ascending pharyngeal arteries are the most frequent vessels embolized (Fig. 29.4). Depending on the location, especially in advanced grades with intracranial and cavernous sinus involvement, branches from the internal carotid artery can provide high blood flow to the tumor. The embolization of these vessels can be dangerous, and in the majority of the cases is contraindicated.

**SURGICAL TECHNIQUE**

**Microscopic Midface Degloving**

Under general anesthesia, with the patient in the supine position the procedure begins with a bilateral incision in the gingival sulcus, as in a conventional Caldwell-Luc procedure. A complete transfixion incision of the membranous septum extended around the piriform aperture to the space between the superior and inferior lateral cartilages is made. The soft tissues of the nasal dorsum are then elevated in a subperichondrial and subperiosteal plane by using an elevator and Metzenbaum scissors. The remaining connections between the columella and the anterior nasal spine are dissected transnasally, joining the nasal cavity to the sublabial incision. The periosteum is then elevated, exposing the anterior maxillary wall, the ascending branch of the maxilla and the piriform fossa. The degloving approach is then completed by elevating the soft tissue of the upper lip, nasal dorsum, and superior maxillary region, thus exposing the bony structures of the middle third of the face (up to the infraorbital foramen leaving the infra orbital nerve intact and the infraorbital rim) (Fig. 29.5).

An ipsilateral wide resection of the anterior wall of the antrum is performed, leaving the infraorbital opening and its contents in place. The next step is the opening of the posterior wall of the maxillary sinus. Depending on the size of the tumor, the wall has the consistency of an eggshell, and, in the other cases, it may not be present.

The surgical microscope is then brought into the field in order to facilitate the ligation and section of the vascular pedicle of the tumor in the pterygomaxillary fossa. It is important to not touch the tumor until all the exposure is completed. The entire medial nasal wall is opened through a posterior and inferior detachment of

![FIGURE 29.4](image-url)

A. Angiography with the guide catheter inserted in the right maxillary artery showing a characteristic tumor blush. B. Postembolization with considerable reduction of tumor blood supply. The arrow indicates the occluded vessel.
the inferior turbinate that can be kept anterior until the end of the procedure or totally resected. The middle turbinate is displaced superiorly, increasing the visualization of the tumor.

An ethmoidectomy is done and the sphenoid sinus is opened, taking care to expose and resect the sphenoid rostrum, to allow visualization of the basisphenoid bone, which is one of the most important areas of the tumor’s origin. After an entire exposure, using forceps, suction tubes, and bipolar electrocautery, the tumor is dissected free from the mucosa of the posterior wall of the nasopharynx, the mucosa of the posterior third of the nasal septum, the dura mater (if involved), and the basisphenoidal area of origin. The tumor is removed, and a final look is done in order to avoid leaving some tumor remnants. It is important to drill the infiltrated surface of the basisphenoid bone with a diamond burr. Finally, after hemostasis, the middle and inferior turbinates are sutured to the periosteum of the inferior orbital border (Fig. 29.6). The sublabial incision is sutured, and the surgical cavity is carefully packed. In Figure 29.7, is an example of a stage IVA angiofibroma resected by microscopic midfacial degloving.

FIGURE 29.6
Postoperative axial CT view. Note the inferior right turbinate sutured to the orbital border (arrow).

FIGURE 29.7 A and B. Coronal CT and MRI scans showing a stage IVA angiofibroma. C and D. Postoperative scans with complete resection using microscopic midface degloving approach.
PART III
Middle Cranial Fossa

Transnasal Endoscopic

The surgery is performed under hypotensive general anesthesia. The patient is placed in a supine position on the operating table, with the head elevated 30 degrees and with the neck slightly flexed and the head turned toward the surgeon. High concentration adrenaline-soaked cottonoids (1:1,000) are placed in the nasal cavity and over the tumor for 10 minutes before the surgical procedure begins.

The procedure begins with a wide middle meatus antrostomy to give maximal exposure of the posterior wall of the maxillary sinus. Then an anterior and posterior ethmoidectomy is performed. To avoid bleeding during the exposure and access, it is important not to inadvertently touch the tumor. The bone of the posterior wall of the maxillary sinus is removed, exposing the pterygopalatine fossa, which is enlarged by the tumor, enabling the surgeon to control the internal maxillary artery which can be coagulated with bipolar forceps or clipped (Fig. 29.8A and B).

An anterior mucosal septal incision contralateral to the side of the tumor and another more posterior ipsilateral incision can be done allowing a binostril technique for four hands. At the end of the procedure, the tumor in the pterygopalatine fossa, is dissected using blunt instruments and bipolar cautery. To increase the mobilization of the tumor and free it from the pterygoid muscles and the infratemporal fossa adipose tissue, the base of the pterygoid bone must be drilled out. The tumor is mobilized by separating it from the choana and posterior septum, then the nasopharyngeal portion is removed using bipolar cautery and surgical scissors, freeing it from the posterior pharyngeal wall and the prevertebral muscles (i.e., the longus capitis and longus colli muscles). If there is invasion of the basisphenoid and sphenoid sinus, a wide sphenoidotomy is performed, and the floor of the sinus is drilled with a diamond burr, removing the tumor (Fig. 29.8C).

For larger tumors with lateral extension, the procedure may include a medial maxillectomy with removal of the inferior turbinate, entirely resecting the medial wall of the maxillary sinus to obtain adequate exposure of the posterior and posterolateral wall of the sinus or endoscopic-assisted approach (combined and open procedures) (Fig. 29.9). Finally, careful hemostasis is provided with hemostatic agents and bipolar cautery, and the entire surgical cavity is packed with rayon gauze soaked with antibiotic and supported by a Rapid Rhino pack.

POSTOPERATIVE MANAGEMENT

Care on the 1st postoperative day is commonly done in the intensive care unit. It is not mandatory, but due to the blood lost, it is safer. Patients are given systemic, broad-spectrum antibiotics for 1 week or more, depending on the duration of packing.
The inferior nasal packing (Rapid Rhino) is often removed in the hospital on the 3rd day. Patients are usually discharged within 3 to 5 days after surgery. The rayon gauze is removed after 7 days in the office. After removal of the pack, the patient receives saline nasal douches, and postoperative care is done every 2 weeks with nasal endoscopy in order to keep the nasal cavity without crusts in order to prevent scarring.

Frequent follow-up after surgery is necessary. MR scans with gadolinium or CT scans with contrast are performed after the re-epithelialization of the operative region and when the endoscopic examination does not show mucosal edema due to inflammation (Fig. 29.10). It avoids false-positive results in the radiologic study. Often the imaging is done in the 3rd month and then at 6 and 12 months.

**FIGURE 29.9** Intraoperative navigation of a stage IIIB angiofibroma using an endoscopic-assisted approach.

**FIGURE 29.10** Postoperative endoscopic view at 3 months of right nasal cavity after endoscopic transnasal tumor removal. (M, maxillary sinus; S, sphenoid sinus, and N, nasopharynx.)
COMPLICATIONS

Complications of surgical management of angiofibromas are related to two circumstances, embolization and surgical procedure. The first may have some important thromboembolic complications such as vasospasm that can impair the continuation of the examination or more rarely, vessel injury such as dissection or laceration. The formation of an embolus can occur and lead to deficits after the angiography, such as hemifacial and parotid swelling, necrosis of facial skin (lip, zygomatic area), and chemosis or, more important, decreased visual acuity due to central retinal artery occlusion.

Intraoperative hemorrhage is the most common complication during the surgical procedure for both open and endoscopic approaches. Branches from the internal maxillary artery and cavernous sinus are usually implicated. ICA damage during drilling of the pterygoid–infratemporal region can lead to catastrophic bleeding.

Nerve injury can occur during the external approach, especially to the second branch of the trigeminal nerve, causing infraorbital nerve dysesthesia. If the cavernous sinus is involved, during the tumor resection, cranial nerves III, IV, and VI can be injured causing a “frozen eye.” Finally, depending on the orbital involvement, an optic nerve or medial rectus muscle injury can occur, but this is transient in the majority of the cases.

In cases of dural defects due to the lesion or the procedure, the CSF leak needs to be repaired with multilayer-free grafts or pedicled flaps during the surgery.

RESULTS

The endoscopic endonasal approach to excise angiofibromas (stages I, II, and IIIA, B) has shown good results. Large angiofibromas can be treated by this approach but requires an experienced surgeon. Sometimes, the use of endoscope-assisted and external approaches with the microscope can achieve better results for stage IV tumors.

Recurrence rates are low and appear to be similar in endoscopic and open approaches. Even with large angiofibromas, radiation therapy or chemotherapy is rarely used.

PEARLS

- The preoperative image evaluation includes CT and MR scans.
- Preoperative biopsy is unnecessary and not recommended due to the risk of severe bleeding.
- Preoperative embolization of the lesion, usually performed 24 to 48 hours before surgery, enables better results.
- The current concept of surgical cure does not require en bloc resection. A piecemeal resection seems to facilitate exposure of difficult anatomic locations.
- Follow-up includes periodic MR or CT scans in addition to routine endoscopic examinations.

PITFALLS

- Some tumor extensions can be hidden into the pterygoid and prevertebral muscles and fascia. Exploration of these regions is important to avoid residual tumor.
- In order to avoid leaving some residual tumor, it is important to drill the infiltrated surface of the basisphenoid bone with a diamond burr.

INSTRUMENTS TO HAVE AVAILABLE

- High definition video camera
- Surgical microscope
- Cutting forceps and endoscopic scissors
- Bipolar electrocautery
- Long-handled drill with cutting and diamond burrs

ACKNOWLEDGMENT

The author would like to thank the contribution of Leonardo Balsalobre, MD, MPH.
SUGGESTED READING


INTRODUCTION

The major principle of intracranial skull base surgery is to provide access to the pathology at hand with minimal brain manipulation. When the lesion is extradural, the craniotomy should be tailored to the area of interest. Extradural brain retraction is usually well tolerated. However, intradural brain retraction is not and should be minimized. If the lesion is intradural, the surgeon should make every effort to carefully dissect the cerebrospinal cisterns and drain cerebral spinal fluid (CSF) to minimize brain retraction.

The modified orbitozygomatic (OZ) craniotomy is the cranial base approach used most frequently for surgical exposure of the anterior fossa, middle fossa, and orbit. The craniotomy incorporates the frontal bone, temporal bone, orbital rim, and a portion of the zygoma. This cranial bone flap usually is made in one piece unless the roof of the orbit is involved with the pathology. This versatile craniotomy provides access to vascular lesions and tumors of the basal frontal lobe, floor of the anterior cranial fossa, suprasellar and parasellar regions, anterior third ventricle, orbit, cavernous sinus, and floor of the middle fossa. Removal of the orbital rim and zygoma provides the surgeon with wider exposure and minimizes brain retraction when compared to the traditional pterional craniotomy.

HISTORY

The presentation of lesions that can be addressed with a modified OZ craniotomy is wide ranging and may include headache, vision loss, hydrocephalus, subarachnoid hemorrhage, upper cranial nerve palsies, proptosis, seizure, and even coma. The wide and varied regions for which this approach provides access make the possible presentations endless. A careful history should be taken focusing on visual complaints and upper cranial nerve symptoms.

PHYSICAL EXAMINATION

A complete neurologic examination should be carried out and tailored to the region of interest. Ophthalmologic evaluation for papilledema or oculomotor palsies is paramount. Trigeminal function should also be thoroughly investigated, especially in cases with involvement of Meckel’s cave or the cavernous sinus. Other signs should be sought based on the location of the specific lesion and are too numerous to detail here, given the wide range and flexibility provided by the modified OZ.

INDICATIONS

The OZ craniotomy is one of the most versatile approaches in skull base surgery. It can be used for any anterolateral pathology such as meningiomas of the sphenoid wing or lateral orbital tumors or for deep pathologies.
such as high-riding basilar aneurysms. It provides access to the suprasellar space and even the third ventricle for tumors such as craniopharyngiomas as well as the superior aspect of the clivus for some chordomas and any clinoidal process. The OZ approach may be ideal for anterior middle fossa and cavernous sinus pathologies such as meningiomas and schwannomas. Virtually any pathology in the anterior supratentorial space can be a potential indication for this modification.

**CONTRAINDICATIONS**

There are no absolute contraindications to an OZ craniotomy. Orbital manipulation should be avoided when possible in cases where there is preexisting contralateral loss of vision as the rare orbital complications become much more concerning in this setting.

**PREOPERATIVE PLANNING**

Magnetic resonance imaging is standard for planning any supratentorial tumor surgery. T2-weighted imaging can help to predict the consistency of the tumor, and T1-weighted imaging without and with contrast helps determine the differential diagnosis as well as vascularity of a tumor. Fine-cut computed tomography (CT) should be added for bone tumors or to determine the degree of bony involvement, hypertostosis, or erosion. MR or CT angiography can often provide adequate detail about arterial involvement or encasement, and computed tomographic angiography (CTA) can even provide useful details of venous involvement. Magnetic resonance angiography is routinely used for screening for unruptured aneurysms, and CTA can be used in subarachnoid hemorrhage. Digital subtraction angiography remains the gold standard for the detection of aneurysms and provides the greatest detail about venous drainage. Embolization can be performed to limit blood loss, but the modified OZ provides access to the accessible blood supply of most tumors.

The anesthesiologist and surgeon should attempt to maximize brain relaxation at the beginning of the procedure. Brain relaxation will prevent inadvertent dural tears when turning the bone flap and will improve exposure. The anesthesiologist should attempt to hyperventilate the patient to an end-tidal carbon dioxide level of 25. Intravenous infusion of 25 to 50 g of mannitol is also frequently performed to maximize brain relaxation. Frequently, the neurosurgeon will augment relaxation by insertion of a lumbar drain prior to scalp incision. The anesthesiologist can then slowly drain 30 to 40 mL of CSF at the time of the skin incision. If the surgical lesion is intradural and a wide Sylvian fissure dissection is planned, the lumbar drain is not inserted. Sylvian fissure dissection is easier when it is full of CSF.

**SURGICAL TECHNIQUE**

**Positioning**

After intubation and insertion of appropriate lines for venous access and monitoring of arterial blood pressure, the patient is positioned supine with the head in three-point fixation. The three-point fixation involves two pins inserted on the ipsilateral side of the planned craniotomy behind the ear in the parietal occipital bone. The third pin is placed in the contralateral frontal area. To avoid slippage in adults, the skull three-point fixation device is tightened until the pressure gauge measures 60 lbs/in². The head is then turned 15 to 45 degrees toward the contralateral side depending upon the desired target. This three-point fixation device is then fastened to the operating table to prevent head movement during the surgical procedure. The head of the table is then elevated approximately 15 degrees above the level of the patient’s heart to facilitate venous drainage and reduce intracranial pressure.

**Scalp Incision**

The skin incision begins anterior to the tragus at the level of the zygoma. It extends cephalad in the hairline and crosses midline to the contralateral midpupillary line (Fig. 30.1A). It is important not to place the incision too far anterior to the auricle so as to avoid injury to the superficial temporal artery and frontal branch of the facial nerve. This long incision allows the surgeon to turn a skin flap down to the orbital rim without tension. The scalp flap is dissected in the subgaleal plane leaving the pericranium intact. A vascularized pericranial graft based upon the supraorbital artery is then harvested separately down to the orbital rim. This pericranial flap can be used upon closure to repair skull base defects, such as the frontal sinus, at time of closure. As the pericranial flap is defined, the dissection continues over the orbital rim and exposes
the periorbita. The supraorbital nerve is identified, and all attempts are made to preserve its integrity. If the nerve is in a notch, it is reflected down with the periorbita. If the nerve is in a foramen, then a drill with a side-cutting bit or osteotome is used to open the foramen and displace the nerve forward with the periorbita. The ipsilateral temporalis muscle is also dissected free from the skull in the subperiosteal plane and reflected forward with the scalp flap. A small cuff of temporalis fascia is left attached to the skull near the superior temporal line. The fascial cuff will be used at closure to reapproximate the temporalis muscle and secure it with suture. The orbital rim and the zygoma at the level of the frontozygomatic suture are dissected free.

**Burr Holes**

The McCarty burr hole is essential in performing the one-piece modified OZ craniotomy (Fig. 30.1B). The burr hole is placed over the frontosphenoidal suture 1 cm posterior to the frontozygomatic suture. This burr hole exposes the periorbita and dura of the frontal lobe. Two additional burr holes are made. One is placed in the posterior frontal region near the superior temporal line and the other is in the temporal squamosa area just above the root of the zygoma.
Creating the Bone Flap

Using a high-speed drill with a footplate attachment, the first cut is made from the temporal burr hole to the posterior frontal burr hole in the extradural plane. The cut is then extended forward to the level of the supraorbital notch or foramen. The second cut is made from the McCarty burr hole down to the sphenoid wing. The third cut is then made from the temporal burr hole forward and up to the sphenoid wing. A side-cutting bit on the high-speed drill is then used to cut the bone of the zygoma near the frontozygomatic suture down to the McCarty burr hole. This side-cutting bit drill is also used to weaken the orbital rim at the supraorbital notch or foramen. Using an osteotome, the attachment of the sphenoid wing is loosened (Fig. 30.1C). The osteotome is then used along the orbital rim to propagate a fracture line in the anterior roof of the orbit. The modified OZ flap is then cracked forward and separated from the dura and periorbita in one piece. The bone flap should be harvested easily, and the “crack” should not be forced. Upon removal of the bone flap, the anterior contents of the orbit and the frontal and temporal dura are exposed. A small rongeur can then be used to remove additional bone from the roof of the orbit and the sphenoid wing (Fig. 30.2A and B). The surgeon should remove this bone leaving the periorbita intact. Upon removal of the roof and wing, the surgeon will encounter the superior orbital fissure. Bone lateral to the superior orbital fissure down to the foramen rotundum can be removed easily with a rongeur. By removing bone over the superior orbital fissure, the temporal–orbital band is fully exposed.

Extradural Dissection

Extradural access to the optic foramen, anterior clinoid, and cavernous sinus is restricted by the temporal–orbital band (Fig. 30.2C). This temporal–orbital band is the dura along the superior temporal lobe that extends into the superior orbital fissure and is contiguous with the periorbita. The temporal–orbital band is comprised of two...
layers of dura. The outer layer is thick and continuous, and the inner layer is thin and not contiguous. Cutting the dural band with micro-scissors allows the surgeon to separate the layers of dura and reflect the temporal lobe posteriorly. As the temporal lobe is retracted, the wall of the cavernous sinus is peeled away with cranial nerves three, four, V1, and V2 exposed (Fig. 30.2D). In addition, the anterior clinoid and optic foramen are easily visualized.

Extradural Clinoidectomy and Optic Nerve Decompression

The optic canal is carefully thinned with a high-speed drill using a diamond burr. Copious irrigation is used during drilling. The bone is “eggshelled” over the foramen and then carefully removed with microcurettes. The clinoid can then be removed using a diamond drill bit. The center of the clinoid is drilled and the optic strut weakened until the bone can be easily removed with a curette.

Exposure

This craniotomy with extradural dissection provides a panoramic view of the orbit and access to the floor of the anterior and middle fossa and the cavernous sinus. If necessary, additional exposure can be obtained by opening the dura.

Bone Flap Reconstruction

The modified OZ bone flap can be placed back into position at time of closure. If the frontal sinus was violated, then a pericranial graft can be placed between its opening and the bone flap. The bone flap is secured with small cranial titanium plates. During this process, it is important to secure the orbital rim to the zygoma with a titanium “dog bone” plate. Reconstruction of the posterior roof of the orbit is not necessary.

POSTOPERATIVE MANAGEMENT

Patients should be kept overnight in an intensive care unit with frequent neurologic checks. The orbit should be checked for sign of muscle entrapment that, if noted early, can be corrected without long-term sequelae. Often the eyelid is so swollen that it must be opened by the examiner in order to check eye movements. When drains are used, they are kept until the edema has begun to resolve or their output has significantly decreased. The head of the bed should be kept elevated to facilitate cerebral venous drainage and minimize subcutaneous swelling. Intravenous steroids are administered briefly for neuroprotection.

COMPLICATIONS

In addition to the usual complications such as stroke or cranial neuropathy associated with any skull base approach, orbital entrapment is the most feared approach-related complication. Care should be taken to examine the orbit and periorbita following replacement of the orbital rim. If muscle entrapment has occurred postoperatively and is verified by the inability to move the eye in a given direction, fine-cut CT can confirm the location and source of entrapment. If identified early, the patient can be returned to the operating room for correction without long-term sequelae. Other orbital complications, such as ptosis, are usually transient.

Frontalis palsy can occur with any frontotemporal craniotomy, but zygoma dissection provides yet another opportunity for injury to or traction on this branch.

RESULTS

The results and efficacy of the OZ craniotomy for many pathologies, ranging from meningiomas to aneurysms, are well known and well reported. It remains a popular approach to the skull base and the gold standard for many anterior and anterolateral pathologies. When performed with proper knowledge and care, this modification to a frontotemporal craniotomy adds little morbidity and can provide profound improvement in access.

PEARLS

- Harvest the pericranial graft at the skin incision in case the frontal sinus is entered or the dura is difficult to close.
- A one-piece modified OZ craniotomy requires an osteotome to weaken the sphenoid wing and roof of the orbit to “crack” bone flap forward.
- Open the superior orbital fissure widely.
- Cut the temporal–orbital band to expose the anterior clinoid, optic foramen, and cavernous sinus extradurally.
PITFALLS

- A one-piece modified OZ craniotomy should not be attempted with hyperostosis of the roof of the orbit or sphenoid wing.
- Never force the cracking of the sphenoid wing or orbital roof.

INSTRUMENTS TO HAVE AVAILABLE

- Standard neurosurgical tray
- High-speed drill with side-cutting bit
- Osteotome

SUGGESTED READING

INTRODUCTION

The infratemporal fossa (ITF) is a deep space located below the lateral skull base. It is bordered anteriorly by the pterygomaxillary space, posteriorly by the carotid space, inferiorly by the masticatory space, and medially by the parapharyngeal space (Fig. 31.1). The medial pterygoid muscle attached to the mandible delineates its inferior border. Its other boundaries are anterior—infratemporal surface of the maxilla and the ridge that descends from its zygomatic process; posterior—temporal bone (articular tubercle) and the sphenoid bone (spinal angularis); medial—the lateral pterygoid plate, and lateral—ramus of mandible and the zygomatic arch. The ITF contains many important anatomical structures including the third division of the trigeminal nerve (transmitted through the foramen ovale), the middle meningeal artery (transmitted through the foramen spinosum), the internal maxillary artery, and the pterygoid venous plexus. Other nerves located in the ITF are the lingual and buccal nerves, the chorda tympani, and the otic ganglion. The temporalis muscle and the lateral and medial pterygoid muscles are also contained within the ITF.

Less than 1% of all head and neck neoplasms originate in the ITF. These can be either primary tumors or secondary tumors that invade or metastasize to the ITF. Primary ITF tumors can originate from any tissue within this compartment: nerve, vessels, muscle, bone, cartilage or connective tissue. These tumors may go undetected for a long period of time, after which they usually present as a symptomatic mass in the temporal area. Primary benign tumors that may involve the ITF include meningioma, juvenile angiofibroma, neurofibroma, schwannoma, fibroma, osteoma, and fibrous dysplasia. Malignant tumors include chordoma, soft tissue sarcomas, nasopharyngeal carcinoma, and sinonasal carcinomas. Tumors that may invade this space include carcinomas of the skin, sinonasal mucosa, or minor salivary glands.

The complex anatomy of the ITF accounts for the diversity of surgical approaches used to remove tumors from this anatomic area. The surgical approach is tailored according to the anatomical extent of the tumor, its histologic type (benign or malignant), and the patient’s past medical history (previous surgery or radiation treatment).

Large tumors that involve the ITF can be approached extracranially and intracranially depending on the primary origin of the tumor and its extensions. The contemporary surgical technique for resection of tumors arising in the ITF is based on the classical approach developed by Fisch and Mattox that involved a retroauricular incision and transposition of the entire facial nerve. The classical type-C Fisch ITF approach provides access from the sigmoid sinus to the parasellar region, cavernous sinus, and Meckel’s cave. The main limitation of this approach is that it imminently leads to conductive hearing loss and facial nerve neuropraxia, which are rarely encountered in the modern approach. Other variations of the Fisch approach are the lateral facial and lateral transtemporal sphenoid approaches, which allow limited superior access to the middle cranial fossa. The lateral facial approach provides access to small tumors of the middle fossa and is limited by the inferior displacement of the zygomatic arch and temporalis muscle (Fig. 31.2). Removal of the zygomatic arch in the lateral temporal sphenoid approach allows wider exposure of the subtemporal region and allows extracranial and intracranial removal of the tumor without rerouting the facial nerve.
The more common subtemporal–preauricular infratemporal fossa approach developed by Sekhar, Janecka, and Schramm is a combination of the lateral transtemporal sphenoid approach and the transparotid approach to the parapharyngeal space, in addition to temporal craniotomy (Fig. 31.3). It is also known as the lateral transtemporal infratemporal fossa approach. This approach affords wide exposure to the structures of the middle cranial base using a combination of transparotid, lateral transtemporal sphenoid, and temporal craniotomy approaches. This approach allows access to various anatomical areas including the temporal and

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FIGURE 31.2  Lateral facial approach to the cranial base. This approach allows limited access to the subtemporal area without removal of the zygoma.  
A. A question mark incision is used to expose the temporalis muscle and the lateral orbit (ribbon retractor).  
B. A pterional craniotomy is performed. Retraction of the temporal lobe dura reveals branches of the trigeminal nerve and attachment of the pterygoid plate at the base of the sphenoid bone.

FIGURE 31.3  Subtemporal–preauricular and infratemporal approach to the cranial base as described by Sekhar and Janecka.  
A. Initial exposure is similar to the lateral facial approach shown in Figure 31.2. The caudal exposure is extended by removal of the zygomatic arch.

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infratemporal fossa, temporal lobe, parasellar region, retro-orbital region, nasopharynx, retromaxillary space, pterygopalatine space, masticatory space, retromaxillary fissure and pterygoid plates, sphenoid ridge, and trigeminal nerve. The main advantages of this technique are excellent exposure of the middle cranial fossa and infratemporal compartments and minimal sensory–motor morbidity. This chapter describes the technique of the preauricular ITF approach and its combination with various other important techniques used in surgery of the cranial base.

HISTORY

The clinical presentation of ITF tumors varies greatly and relates directly to the location and rate of growth of the lesion. A thorough history of the present illness as well as past medical and surgical histories are obtained. In addition to the relevant risk factors, the patient is questioned regarding symptoms of cranial nerve dysfunction, head and ear aches, trismus, bleeding from the ear, and otorrhea. Signs and symptoms can often be misleading and may initially be interpreted as being infectious and benign diseases. Common symptoms and signs suggestive of tumors of the ITF include the following: (1) facial swelling and asymmetry that can result from tissue destruction and advancement of the tumor into the soft tissues of the head and neck; (2) palpable metastatic adenopathy, a possible indication of advanced disease; (3) hearing loss usually resulting from extension of the tumor and obstruction of the eustachian tube or middle or inner ear, (4) numbness of the face or pain as a manifestation of tumor invasion into various branches of the trigeminal nerve; and (5) neurologic or ocular manifestations, such as diplopia, exophthalmos, and multiple cranial nerve palsies, that suggest invasion of the nerves at the skull base or cavernous sinus. Pain is a significant adverse symptom suggestive of a malignant tumor. The classical triad of signs of cancer of the temporal bone includes otorrhea, pain, and bleeding. The usual comorbidities should be identified in addition to mental disorders and active alcohol, drug, or tobacco abuse. In addition to the above criteria, potential candidates must be well-informed about surgery, must be motivated, and should be prepared to accept long-term postsurgical follow-up.
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PHYSICAL EXAMINATION

Physical examination should include a meticulous survey of the temporal area and auricular and preauricular skin. The neck and parotid gland are palpated in search of lymph node metastases. The function of the facial and other cranial nerves is evaluated. Otoscopy is used to define the extent of the tumor in the external auditory canal. If the tympanic membrane can be seen, its integrity is verified. Jaw movement and trismus are examined as a potential sign of extension of the tumor into the temporomandibular joint (TMJ). Cranial nerve function is evaluated.

The comprehensive physical examination should always include an endoscopic evaluation of the nose, sinuses, nasopharynx, and oropharynx. Masses should be examined for friability, vascularity, bleeding, and signs of necrosis, possibly suggesting malignancy and necessitating additional investigation. Different entities may display specific and pathognomonic findings on physical examination, for example a vascular mass arising from the hypotympanum on otoscopic examination. However, most tumors are similar in their initial and late symptoms and demand a high level of suspicion in order to reach the correct final diagnosis. This type of tumor will silently advance in size and extent until it has infiltrated a cranial nerve or grown sufficiently to obstruct the nasopharynx. The most common findings on physical examination include the following: (1) nasal, paranasal, or nasopharyngeal mass. (2) Proptosis, the mild protrusion of the eye, may be consistent with tumor compression of the periorbita without frank invasion. (3) Cranial nerve deficits are always considered to be indicators of advanced disease and a poor prognosis. For example, invasion of the cavernous sinus by cancer, as can be suspected from signs of involvement of the abducens nerve, can be an absolute contraindication for surgery. (4) Any abnormal findings on the neurologic examination should raise the suspicion of involvement of the dura and brain. (5) A suspicious mass in the neck suggests the presence of a malignant tumor that has already undergone regional lymph node metastasis. (6) Unilateral middle ear effusion is an uncommon finding that mandates a thorough examination of the nasopharynx to rule out eustachian tube obstruction. Fiberoptic evaluation of the upper aerodigestive tract is an integral part of the physical examination. Sites of potential donor tissue to be used for reconstruction are examined.

INDICATIONS

Indications for surgery include extirpation of benign and malignant tumors that originate in the ITF or that invade this compartment from neighboring structures. Rarely, this approach is performed for treatment of infectious diseases including local abscess or necrotizing fascitis. Tailored treatment should take into consideration the fact that survival after recurrent or residual disease, as well as prior radiotherapy, is lower compared to primary treatment, and that the main cause of death is local recurrence rather than regional or distant metastases. For these reasons, an aggressive effort toward complete extirpation should be made whenever cure is the goal of the treatment or for palliation of intractable pain. Cosmesis and function are addressed by an adequate reconstruction plan.

When contemplating treatment of a specific patient, the following key questions need to be addressed: What is the goal of the treatment? What is the appropriate extent and nature of surgical resection? Is postoperative adjuvant therapy with radiation or chemoradiation anticipated? And finally, what reconstruction techniques will be employed?

CONTRAINDICATIONS

Contraindications for surgery include the diagnosis of tumors amenable to chemoradiation therapy (lymphoma, carcinomas of oropharyngeal or nasopharyngeal origin) and evidence of distant metastases. An exception is adenoid cystic carcinoma or single metastases of specific tumors (e.g., melanoma and sarcomas) that are amenable to excision. Cancer invasion of the prevertebral fascia, encasement of the carotid artery, invasion of the cavernous sinus, and considerable brain involvement are also considered contraindications for surgery. Stable small paragangliomas or schwannomas can be followed radiographically with magnetic resonance imaging (MRI). Severe comorbidities, marked debilitated status, or demented patients are considered to be potential contraindications for surgery.

PREOPERATIVE PLANNING

Imaging Studies

Imaging should always be used prior to surgery since it can influence decision making. A contrast computerized tomographic (CT) scan and a basic MRI study with fat suppression should be used for preoperative evaluation and decision making regarding treatment. A T2-weighted MRI study with fat suppression is usually
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Middle Cranial Fossa

added (Fig. 31.4). Visualization of a vascular flow void on an MRI study is usually sufficient for the diagnosis of a vascular tumor such as a paraganglioma, but magnetic resonance angiography may be added for a more precise diagnosis. Malignant tumors usually demonstrate a soft tissue mass invading intracranial or adjacent spaces, accompanied by bone destruction. The CT may show mild enhancement, and T1-weighted MRI may demonstrate strong postcontrast enhancement. Application of a fat suppression technique, such as short tau inversion recovery and frequency-selected fat suppression, eliminates strong signals from adipose tissue. In addition, the definition of normal anatomic structures is significantly improved, enhancing lesions become clearer, and the margins of a lesion are better defined when suppression of fat is used in combination with contrast enhancement. MRI 3D reconstruction enables multiplanar imaging of tumor extension and vessel encasement. These features can be established in tumors as small as 10 mm in diameter. If a malignant tumor is suspected, radiologic staging of the patients is completed by using a positron emission tomography–CT hybrid for assessing the presence of regional and distant metastases. Most of the malignant tumors arising in the ITF can invade the intracranial compartment, maxilla, mandible or TMJ, orbit and auditory canal, or skin. Other routes of spread include hematogenous, lymphatic, or perineural invasion along cranial nerves. Perineural invasion is common in adenoid cystic carcinoma and is the pathway to the intracranial space so that imaging studies should be directed toward the foramen ovale and rotundum, the cavernous sinus, orbital apex, trigeminal ganglion, and dura. In addition, the radiologic evaluation must include the neck in any case of suspected malignancy to evaluate for lymph node metastasis. Patients with suspected paragangliomas will require preoperative embolization a few days prior to surgery.

Tissue Diagnosis

Tissue diagnosis should be an integral part of preoperative evaluation. Although radiologic imaging could provide indications regarding the type of neoplasm, tissue diagnosis is sensitive to differences between benign and malignant lesions. Fine needle aspiration (FNA) biopsy can be performed via ultrasound but frequently will require CT-guided FNA, which is technically challenging. Radiologic imaging should precede FNA if a vascular tumor is suspected to avoid potential bleeding. Some exceptions to preoperative biopsy include juvenile angiofibroma and paragangliomas.

SURGICAL TECHNIQUE

The patient is placed in a supine position without shaving the hair at the surgical site. Tracheostomy usually is not performed. A lumbar spine catheter is inserted for a period of 3 days for CSF drainage when dural resection is expected, to reduce the risk of postoperative CSF leak. I do not recommend routine administration of prophylactic antibiotics in clean operations. First-generation cephalosporins and metronidazole are routinely used if the operation includes dissection in the oral cavity or pharynx. Surgery is performed under general anesthesia.
without muscle relaxants. This allows for monitoring of the spinal accessory, hypoglossal, phrenic, and marginal mandibular nerves and brachial plexus, during dissection with electrocautery. Monitoring of facial nerve integrity is used when preservation of the nerve is a goal.

Various surgical approaches for the resection of ITF tumors are used. In this chapter, I describe the preauricular approach that is the most acceptable contemporary technique for resection of neoplasms of the ITF.

**Description of the Technique**

After the induction of anesthesia, an oral endotracheal tube is inserted and secured contralateral to the surgical site. The patient is prepped and draped with the hemiface and calvarium exposed. Ointment is placed in both eyes, and the eyelids contralateral to the surgical site are taped shut. The patient’s hair is shampooed vigorously with 4% w/v chlorhexidine (Septal Scrub), parted with a sterile comb along the proposed incision line, and tied in tufts with rubber bands. The head is stabilized with a soft donut holder, and then the entire operating table is tilted at an angle with the head up in order to minimize bleeding. The operative field is scrubbed with surgical sponges containing chlorhexidine solution (0.05% w/v) and draped with sterile towels that were held in place with 2-0 silk sutures and surgical staples.

**Skin Incision**

The preauricular ITF approach combines three common incisions: hemicoronal or question mark scalp incision, preauricular modified Blair incision, and apron incision (Fig. 31.5). Any variation of these can be used according to tumor histology and location. Marking the incision is preferably performed with the neck slightly flexed in order to identify the lines of relaxed skin tension. The incision normally extends from the mastoid tip to the cricoid arch, 2 to 3 fingers below the ramus of the mandible along a transverse skin crease in the lower neck. After marking the incision, a roll is placed under the shoulders to hyperextend the neck, and the head is rotated toward the contralateral side. The skin is incised with a no. 15 blade, and subsequent dissection of the subcutaneous tissue and the platysma is carried out with an electrocautery instrument at the lowest effective setting.

**Exposure of the Neck and Vascular Control**

Tumors located close to the internal or external carotid arteries or adjacent to the jugular foramen require control of the large vessels, prior to resection of the tumor. Similarly, I advise exposure and identification of cranial nerves that are at risk of injury during the operation. These include the hypoglossal, spinal accessory, and facial nerves. In order to achieve identification and preservation of these neurovascular structures, I recommend beginning this procedure with a transcervical approach (Fig. 31.5B). If a neck dissection is indicated or if

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**FIGURE 31.5** Elevation of superior and inferior platysmal flaps. A. The ITF approach combines three common incisions: hemicoronal or question mark scalp incision, preauricular modified Blair incision, and apron incision. B. The skin is incised with a no. 15 blade, and subsequent dissection of the subcutaneous tissue and the platysma is carried out with an electrocautery at the lowest effective setting. Subplatysmal and subgaleal flaps are elevated superiorly and inferiorly.
If a free flap reconstruction is anticipated, the neck dissection would serve the goal of both removing lymph node metastases and exposing the blood vessels for anastomosis. The detailed surgical technique of neck dissection is not included in the scope of this chapter.

**Elevation of the Scalp Flap and Exposure of the Zygoma**

A routine superficial parotidectomy is performed if indicated with dissection of all facial branches, and the various branches are then sharply dissected away from the deep lobe of the parotid. If the facial nerve is infiltrated by the tumor, a total parotidectomy is performed and the facial nerve is sacrificed. If the tumor grossly extends toward the skull base, the posterior belly of the digastric muscle can be retracted cephalad, or transected exposing the tumor at the base of the skull. The stylohyoid muscle and stylomandibular ligament may be also divided to allow a wider approach to the inner middle of the parotid. This maneuver could also prevent accidental injury to the internal jugular vein at the jugular foramen, which would be difficult to control and hemostasis would require ligating the vein.

Elevation of the scalp flap is continued down to the level of the adipose tissue pad overlying the zygoma, above the temporalis fascia. On the ipsilateral side, the remainder of the dissection dips below the level of the temporalis fascia and continues as a fasciofascial flap.

It is important to recognize the anatomy of the structures below the temporalis line. The temporal adipose tissue pad lies lateral to the temporalis muscle (Fig. 31.6). Above the zygoma the superficial temporal fascia splits to envelop the superficial adipose tissue pad. The frontal branches of the facial nerve run lateral to the superficial adipose tissue pad. In order to preserve these branches, dissection below the temporal line must continue along the deep layer of the temporalis muscle fascia, deep to the superficial temporal adipose tissue pad. At this level, the sharp dissection is performed with a scalpel and Freer dissector until the superior edge of the zygomatic bone is exposed. The superficial temporal adipose tissue pad and the zygomatic branches of the facial nerve are preserved and carefully elevated with the galeal layer. Next, the zygomatic bone and the lateral and upper walls of the orbit are exposed and skeletonized (Fig. 31.7). The temporalis muscle is freed from the medial surface of the zygomatic arch and bone.

**Osteotomy of the Zygomatic Arch**

After the zygomatic arch and bone are exposed, the osteotomies are performed. Prior to the osteotomies, titanium mini plates are fixed and pre-bent to allow accurate repositioning of the bone. The anterior osteotomy is performed at the zygomatic process of the frontal bone, and the posterior osteotomy is performed anterior to the auricular tubercle in the posterior border of the arch (Figs. 31.7 and 31.8). The medial attachment of the zygomatic bone to the lateral wall of the orbit is also cut in order to complete separation of the bone. Here the osteotomy is performed medial to the zygomatic bone along the zygomatic and frontal process of the lateral orbital wall. Following the osteotomies, the bone is gently elevated and separated from its medial attachments to the temporalis muscle fascia. The bone segment is then stored in saline during the length of the operation.
Exposure of the ITF

After the zygomatic process and arch are removed, the temporalis muscle is reflected downward, exposing the greater wing of the sphenoid bone and squamosa of the temporal bone (Fig. 31.8). Electrocautery is used here to reduce blood loss. The extracranial content of the ITF including the lateral pterygoid plate, the styloid process and its muscles, the lateral pterygoid muscles, the internal maxillary artery and its branches, and the branches of the mandibular nerve (V3) are now exposed. The condyle of the mandible may be retracted, or resected if indicated, to expose the spine of the sphenoid bone, the foramen ovale and V3, the middle meningeal artery, and the ICA at its entrance into the skull. If involved by the tumor, the sphenoid or maxillary sinuses are opened. The lateral wall of the sphenoid sinus is located between the maxillary nerves V2 and V3 and the base of the pterygoid plates.
Craniotomy and Exposure of the Middle Fossa

When the pterional area, the lateral orbital wall and orbital roof are exposed, care is taken to perform the craniotomy, which is tailored according to the intracranial and extracranial extension of the tumor. For tumors confined to Meckel’s cave, a pterional craniotomy is adequate. For more anterior tumors that involve the petrous apex and when exposure of the superior orbital fissure and cavernous sinus are indicated, an orbitozygomatic craniotomy is required (Fig. 31.9). A burr hole is placed beneath the temporalis muscle, and a curvilinear craniotomy is performed. The bone flap is extended down toward the base of the middle cranial fossa. After the osteotomy, the bone flap is elevated and carefully detached from the dura overlying the middle cranial fossa with a bone dissector. If not involved by the tumor, the bone segment is stored in saline for the duration of the operation. Gentle retraction of the dura superiorly offers exposure of the entire middle fossa including the greater sphenopalatine nerve (GSPN), the middle meningeal artery, and cranial nerve divisions of the trigeminal nerve (Fig. 31.10). Using the dissecting microscope, the divisions of V3 and V2 are unroofed by drilling out the greater wing of the sphenoid. The superior orbital fissure and its neurovascular structures may be exposed in the same manner. Rarely, exposure of the intrapetrous part of the internal carotid artery is also indicated. This can be achieved by first dividing the middle meningeal artery and the GSPN and then removing the anterior clinoid process and the surrounding bone. Next, careful drilling along the external opening of the carotid canal may be performed to complete the approach.
Extensions of the ITF Approach

The ITF approach can be combined with other approaches according to the anatomical area and histology of the tumor. Table 31.1 indicates the different combined approaches and their indications.

**Combined Transcervical ITF Approach**

The combined transcervical ITF approach is indicated for benign tumors involving the parapharyngeal space that extends to ITF. This approach is most frequently used for large schwannomas and pleomorphic adenomas in this area. The transcervical approach is extended by dividing the posterior belly of the digastric muscle and the stylohyoid and stylomastoid muscles. The stylo mandibular ligament is also divided, allowing anterior retraction of the mandible. The submandibular gland is dissected out and retracted anteriorly. The tumor is now identified, and its association with the cranial nerves should be explored. The tumor can now be separated from the surrounding tissue, and here it is advisable to use meticulous dissection with a thin hemostat in order to prevent injury to the great vessels and cranial nerves. Care is taken to prevent accidental injury to the internal jugular vein at the jugular foramen. Bleeding in this area may be difficult to control, and hemostasis may require tying off the vein. In large ITF tumors that extend to the neck, removal of the submandibular gland can improve exposure and facilitate finger dissection in this area. Once the specimen is completely freed from its surrounding tissue, its proximal and distal margins are clamped and tied with a 3-0 silk suture, and the tumor is then removed.

**Combined Transmandibular ITF Approach**

This approach is suitable for patients with extremely large benign tumors, malignant tumors, and for highly vascular lesions. There are two options for this approach: (1) a lateral approach using a segmental mandibulectomy and (2) a mandibulotomy using a lip split incision. The first approach is indicated as part of a composite resection involving the ramus of the mandible (Fig. 31.11). The second is indicated when the mandible is not involved.

**Combined Transtemporal ITF Approach**

For malignant tumors extending posterior to the ITF, a combined lateral temporal bone resection is the foundation of the treatment. This is usually accompanied by a segmental resection of the ramus of the mandible and its coronoid and condylar processes along with en bloc removal of the mandibular fossa, auditory canal, and mastoid portion of the temporal bone. The extent of the excision may also involve the auricle, adjacent skin,

<table>
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<tr>
<th>Surgical Approach</th>
<th>Indication</th>
<th>Limitations</th>
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<tr>
<td>Type-C Fisch ITF approach</td>
<td>Large glomus tumors extending from the sigmoid sinus to the paraseellar region, cavernous sinus and Meckel’s cave</td>
<td>Facial nerve rerouting causes facial nerve neuropraxia. Limited access to the retromaxillary area.</td>
</tr>
<tr>
<td>Lateral facial approach</td>
<td>Small middle fossa lesions</td>
<td>Limited by the inferior displacement of the zygomatic arch and temporalis muscle</td>
</tr>
<tr>
<td>Subtemporal–preauricular ITF approach</td>
<td>Tumor extending to the subtemporal region and retromaxillary space</td>
<td>May cause injury to the zygomatic branch of the facial nerve</td>
</tr>
<tr>
<td>Combined transcervical ITF approach</td>
<td>Tumor extending to the parapharyngeal space</td>
<td>A limited approach, used mainly for noninfiltrating benign tumors</td>
</tr>
<tr>
<td>Combined transmandibular ITF approach</td>
<td>Malignant tumors extending into the parapharyngeal space</td>
<td>A very extensive approach that may be associated with cosmetic and functional morbidity</td>
</tr>
<tr>
<td>Combined transtemporal ITF approach</td>
<td>Malignant tumors extending posteriorly to the temporal bone</td>
<td>Risk of conductive hearing loss and facial nerve injury</td>
</tr>
<tr>
<td>Combined craniofacial ITF approach</td>
<td>Tumors extending to the anterior skull base and sinuses</td>
<td>Requires meticulous reconstruction of the dura</td>
</tr>
<tr>
<td>Combined ITF transorbital approach</td>
<td>Tumors invading the orbit or orbital apex</td>
<td>Associated with extensive resection requiring microvascular reconstruction</td>
</tr>
<tr>
<td>Combined ITF posterior fossa approach</td>
<td>Giant glomus jugulare tumors or chondrosarcomas with posterior fossa extension</td>
<td>Surgical morbidity consists of facial nerve weakness</td>
</tr>
</tbody>
</table>

ITF, infratemporal fossa.
and adjacent structures according to the specific tumor and patient’s characteristics (Fig. 31.12). Most commonly, this approach would be part of a more comprehensive surgery that may include parotidectomy and neck dissection.

If the auricle or parts of it are to be preserved, considerations for the blood supply must be a part of planning of the skin incision. Here, skin incisions and soft tissue approach are similar to those described above for the ITF. A temporal extension of the approach is achieved by elevation of the posterior retroauricular flap that includes the auricle. The flap is elevated posteriorly over the mastoid process and occipital bone (Fig. 31.12). A retroauricular skin incision may be used as an alternative. However, this incision puts the blood supply to the auricle at risk, especially in previously irradiated patients or if a previous preauricular incision was performed. Skin incisions should also accommodate reconstructive efforts, allowing access to local flaps as required. For tumors involving the external auditory meatus, a circular area of auricle engulfing the meatus is incorporated with the specimen. Bone work commences with a complete canal wall up mastoidectomy, and decortication is

**FIGURE 31.11**
Combined transmandibular ITF approach. A patient with high-grade mucoepidermoid carcinoma. The composite resection included preauricular ITF approach, radical parotidectomy, and segmental mandibulectomy. **A.** Marking the incision. **B.** The tumor was resected, and reconstruction was performed with an anterolateral thigh free flap.

**FIGURE 31.12**
Combined transtemporal ITF approach. A patient with adenoid cystic carcinoma of the parotid and long-standing facial nerve paralysis. The composite resection included preauricular ITF approach, segmental mandibulectomy, radical parotidectomy, and lateral temporal bone resection. **A.** The main tumor resection was performed via the ITF approach and pterional craniotomy. **B.** The lateral temporal bone resection was performed through a posterior occipitotemporal flap.
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extended toward the mandibular fossa and includes the entire mastoid tip. A middle fossa craniotomy is necessary to separate the specimen in en bloc fashion. Eventually, the temporal fossa is reached, and the dissection is continued in the space between the annulus and the jugular bulb. If a segmental mandibulectomy is indicated, the TMJ is included along with the specimen. At this stage, the residual attachments of the specimen are connected to the posterior aspect of the TMJ capsule and adjacent bone. The bone can be disrupted by anterior fracturing of the specimen or with the aid of an osteotome, passed from the mastoid through the facial recess.

Combined Transfacial ITF Approach

Although the ITF approach permits complete tumor resection in the majority of cases, there could be situations in which the anterior aspects of the tumor are not adequately exposed. These include neoplasms that extend to the hard palate, orbit, nasopharynx, paranasal sinuses, and anterior skull base. Such cases require a combination of the ITF approach with a standard transfacial approach, to allow proper exposure and tumor extirpation. These combined approaches require additional incisions and osteotomies according to type and extent of the tumor.

The question mark incision is extended with a coronal incision, and the skin flap elevation continues down to the level of the adipose tissue pad overlying the zygoma, above the temporalis fascia. The ITF approach is performed as described above. The next stage includes osteotomies in both the frontal and pterional regions. The standard frontal osteotomy is modified by its lateral extension to include a portion of the orbital roof and temporal bone. A lateral rhinotomy or Weber-Ferguson incision is performed and a maxillectomy with or without orbital exenteration is achieved via the transfacial approach (Fig. 31.13).

Combined ITF–Transorbital Approach

A combined ITF–transorbital approach is used for malignant tumors that penetrate the bone of the orbit and periostium, and infiltrate the anterior orbital contents or orbital apex. The skin flap is performed as described above in the ITF approach. The superior and lateral walls of the orbit are exposed and the periostium stripped from the bone. If the skin is not involved by the tumor, the upper and lower lids may be spared, allowing for future insertion of an orbital implant and improved cosmetic results. For advanced skin cancers, the exenteration can involve the eyelids, scalp, and skin overlying the temporal region. In this case, a circular skin incision is performed along the superior and inferior orbital rims, and the skin of the lids is left on the main specimen (Fig. 31.14). Usually, this approach involves composite resection of the skin, zygomatic bone and arch, and the lateral orbital wall along with the orbital contents (Fig. 31.15).

Reconstructive Considerations and Wound Closure

The specimen is oriented and submitted separately for analysis to the pathology laboratory. The wound is copiously irrigated and inspected. Systolic blood pressure should be above 120 mm Hg to allow hemostasis. Any communication between the upper aerodigestive tract and the intracranial compartment should be closed. In case of dural resection, I prefer using double-layer fascia lata free graft, sutured to the edge of the resected dura with a continuous nonabsorbable suture. The eustachian tube should be plugged with a strip of fascia to prevent CSF leak. Any opening to the sphenoid or maxillary sinuses or to the nasopharynx should be eliminated. This is most commonly achieved by a free tissue transfer or temporalis muscle rotational flap. If exposed, the internal carotid
artery should be covered with vascularized tissue to prevent carotid blowout. I do not recommend the use of nonvascularized free muscle graft for any reconstruction purpose, since it completely disintegrates within a few days after surgery. Primary closure of the surgical defect should be done when possible. When the facial nerve is sacrificed, a reconstructive procedure is required, and in such cases, an interposition sural nerve graft is used during the same procedure. Larger defects require regional flaps (temporalis muscle flap) or free flaps (radial forearm or anterolateral thigh free flaps). Finally, the previously removed zygomatic bone and the temporal bone segments, if not involved by tumor, are repositioned and secured with titanium mini plates and craniofix screws, respectively. If the temporalis muscle has been preserved, it is repositioned and sutured to the pericranium. Two No. 7 Jackson-Pratt drains are placed into the neck and ITF compartments.

POSTOPERATIVE MANAGEMENT

After the operation, the patient is extubated and immediately transferred to the postsurgery care unit for monitoring before transfer to the wards. The wound is kept clean by saline rinsing three times a day, and covered with antibiotic ointment after each cleansing. The drains are removed either 3 days after the operation or when the drainage is less than 20 to 30 mL in 24 hours. Prophylactic antibiotic treatment is not indicated in the postoperative period. For pain control, patients are treated with nonsteroidal anti-inflammatory drugs (diclofenac 75 mg...
intramuscularly or orally) once daily, or with tramadol 40 to 100 mg if requested by the patient or considered necessary by the nurses. If a free flap is also performed, selective COX-2 inhibitors should be avoided. CSF drainage is indicated after large dural resections. A lumbar drain is inserted prior to surgery and left for 3 days, while draining 5 to 10 mL of CSF per hour. In such cases we usually administer postoperative broad antibiotic therapy until the drain is removed.

COMPLICATIONS

Surgery in this area is dangerous and requires experience in skull base and head and neck techniques. Major morbidity and mortality may be associated with tumor extirpation in this area, mainly due to the potential injury to neurovascular structures. Complications of the various surgical approaches to the ITF are similar and are listed in Table 31.2. The most common perioperative complication is injury to the cranial nerves. Temporary injury to the facial nerve will occur in 10% to 20% of the patients. Most cranial nerve injuries are temporary, and recovery can be expected within 6 months. Wound infection and meningitis may occur in up to 10% of the patients. CSF leak is rare but may occur through a defect in the dura and/or in the maxillary or sphenoid sinuses or the eustachian tube. Other significant potential complications include thrombosis of the jugular vein or sigmoid sinus.

RESULTS

The overall 5-year survival of patients with malignant tumors of the anterior skull base is 50%. Their prognosis depends above all on histology and margin status. Other factors having an impact on survival are staging and invasion of the orbit, dura, or brain. Most patients with tumor recurrence die of local tumor recurrence followed by distant metastases. Consequently adjuvant postoperative radiation therapy is recommended for malignant tumors of the ITF.

PEARLS

- The operation is performed without muscle relaxation in order to monitor the cranial nerves.
- Frontal branches of the facial nerve are preserved by dissecting along the deep layer of the temporalis muscle fascia.
- Meticulous reconstruction of the dura and plugging of the eustachian tube is required to prevent CSF leak and meningitis.
- Immediate extubation is required to allow continuous neurologic monitoring.
- Early reinstatement of TMJ and jaw physiotherapy should be used to prevent trismus.

PITFALLS

- Exposure of the zygomatic arch from its lateral border may lead to permanent injury of the facial nerve.
- Removal of a small segment of the zygoma will limit exposure of the ITF.
- A small or misplaced craniotomy will make access to the middle fossa difficult.
- Failure to plug the eustachian tube may lead to a CSF leak.

<table>
<thead>
<tr>
<th>TABLE 31.2 Complications Associated with the ITF Approach</th>
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<tbody>
<tr>
<td>Anesthesia in the periauricular area²</td>
</tr>
<tr>
<td>Bleeding</td>
</tr>
<tr>
<td>Conductive or sensorineural hearing loss</td>
</tr>
<tr>
<td>Cranial nerve paralysis: trigeminal or facial nerves, ophthalmoplegia</td>
</tr>
<tr>
<td>First bite syndrome</td>
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<tr>
<td>Seroma</td>
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<td>Sigmoid vein thrombosis in perioperative radiotherapy treatment</td>
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<tr>
<td>Trismus</td>
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<tr>
<td>Wound infection</td>
</tr>
</tbody>
</table>

²A direct consequence of surgery rather than a complication.
INSTRUMENTS TO HAVE AVAILABLE

- Navigation system
- Dissecting microscope
- Nerve monitor
- Skull pin frame
- Bovie set including monopolar and bipolar electrocautery
- Electrical drill and saw
- Micro air drill
- Craniofacial tray
- Craniotomy tray
- Basic neuro tray
- Micro neuro tray
- Craniotome tray
- Malleable suction tray
- Kerrisons tray
- Rongeurs tray
- Neuro curettes
- Basic neck dissection tray
- Basic plastic tray (for fascia lata harvesting)
- Microvascular reconstruction tray (for free flap reconstruction)
- Surgicel
- Gelfoam size 100
- Neurosurgical patties
- Vascular clips—small and medium size
- Dural substitution

ACKNOWLEDGMENT

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SUGGESTED READING

INTRODUCTION

This is an approach that permits access to extraaxial intradural and extradural lesions primarily based in the middle cranial fossa, the parasellar region, the petrous apex, and the upper clivus. Extensions into the infratemporal fossa can be accessed by extending the approach inferiorly by unroofing the entire petrous segment of the internal carotid artery (ICA) and displacing it laterally. Knowledge of the surgical anatomy of the petrous temporal bone and the sphenoid bone from a lateral perspective is essential (Fig. 32.1) for the approach. The main advantage of this approach in comparison with a suboccipital approach is that it provides an anterolateral access to the tumor located in front of the brain stem and, with the exception of the trigeminal nerve and ganglion, it allows the surgeon to work anterior to most of the cranial nerves.

HISTORY

Since many of these tumors are slow growing, there is paucity of signs and symptoms in most patients. Headache may be the only problem they are experiencing. Cranial nerve dysfunction of the 3rd, 4th, 5th and 6th nerves can produce diplopia, facial pain, and facial numbness. Compression of the brain stem can lead to difficulty with balance and incoordination. Contralateral weakness or hemiparesis can be seen in large tumors.

PHYSICAL EXAMINATION

The location and size of a tumor can be inferred from the physical examination. Common findings are deficits of cranial nerves. The physical examination should include a complete ophthalmologic assessment including visual acuity and ocular motility. A palsy of the 6th (abducens) cranial nerve is most frequent, probably a reflection of its long course. The 6th cranial nerve may be involved at the brain stem, at the petrous apex (Dorello’s canal), or in the superior orbital fissure. Deficits of multiple cranial nerves (III, IV, and VI) suggest tumor involvement of the superior orbital fissure. Evaluation of trigeminal nerve function includes an assessment of sensory and motor function of all three branches. Decreased motor function of the third division is evidenced by decreased muscle contraction by palpation, facial asymmetry due to muscle wasting, and drift of the mandible with opening the mouth. Involvement of multiple branches suggests tumor involvement of Meckel’s cave or the proximal nerve trunk.
PART III Middle Cranial Fossa

INDICATIONS

This approach is useful for a variety of tumors that can be found here that include intradural tumors such as meningioma, trigeminal schwannoma, and epidermoid tumors. Extradural tumors that may also have intradural extension include chordoma, chondrosarcoma, and cholesterol granuloma. The approach allows access to a very specific area of the skull base, and the surgeon should carefully evaluate the preoperative imaging studies to ascertain the adequacy of the approach to the lesion at hand. It is suited for tumors in the middle cranial fossa that spill over the petrous apex and upper clivus into the posterior fossa, usually on the ipsilateral side of the midline. The inferior most reach of the approach is the level of the internal auditory canal.

CONTRAINDICATIONS

There are no absolute contraindications. A relative contraindication is a lesion that has eroded through the clival bone and has a significant component in the sphenoid sinus. Dural repair after removing such a tumor will be quite difficult, resulting in a high risk for developing a cerebrospinal fluid fistula.

PREOPERATIVE PLANNING

MRI scans before and after administration of gadolinium are the essential diagnostic as well as surgical planning tool. Thin-slice scans of the posterior fossa in the axial and coronal planes are performed and also a CISS (constructive interference in steady state) sequence that allows better visualization of the relationship of the tumor to the surrounding neurovascular structures. Meningiomas are dural based while schwannomas are found along the course of the cranial nerves, most commonly the trigeminal nerve. Both of them enhance vividly with gadolinium. Epidermoids do not enhance with contrast and may be difficult to differentiate from cerebrospinal fluid signal. They are best seen in the diffusion-weighted sequence of the MRI. The narrow signal inside the petrous bone and clivus may be altered in chordomas and chondrosarcomas. These tumors have a mixed signal characteristic but are mostly hyperintense on T2-weighted images. They enhance to a variable extent with contrast. CT scan performed in thin axial slices provides information regarding the relationship of the tumor to the bony anatomy at the skull base. Irregular bone destruction is the hallmark of chordomas and chondrosarcomas, whereas schwannomas will produce smooth bone remodeling along the course of the nerve.

SURGICAL TECHNIQUE

Anesthesia, Intraoperative Neurophysiologic Monitoring and Positioning

The patient is operated under general anesthesia. Sequential compression stockings are applied to the lower extremities for prevention of deep vein thrombosis, and the patient is given steroids and broad-spectrum antibiotics. Intraoperative neurophysiology is used in the majority of instances in order to monitor cranial nerve and brain stem functions. The electrodes are applied for continuous somatosensory and transcranial motor evoked potential monitoring. Since the geniculate ganglion of the facial nerve is in the path of the approach, direct facial nerve stimulation as well as transcranial facial nerve stimulation and responses are monitored. Thus, muscle relaxation is avoided during these procedures.
The patient lies supine, and the head is positioned rotated 60 degrees to the side opposite the tumor and the vertex is turned slightly down to the floor and fixed in a three-point pin fixation (Fig. 32.2A and B). The body of the patient is adequately padded and secured with multiple straps to the operating table. This is important because the table is often rotated side to side during the operation to facilitate the exposure and visualization.

**Incision and Soft Tissue Exposures and Craniotomy**

A question mark incision is made starting immediately anterior to the external auditory canal, curving upward, above the ear and towards the hairline (Fig. 32.3). The scalp flap is raised using a subfascial dissection plane (to protect the frontalis branch of the facial nerve) above the temporalis muscle, exposing the zygomatic arch and lateral rim of the orbit. The temporalis muscle is elevated from the side of the head. Removal of the zygomatic arch allows the temporalis muscle to be fully depressed below the working angle of the surgeon. The zygomatic osteotomy is made by making a cut with the reciprocating saw at the root of the zygoma, staying anterior to the temporomandibular joint and another one at the junction of the zygoma with the lateral rim of the orbit. The zygomatic bone segment is left attached to the temporalis and the masseter muscles and the entire complex is retracted inferiorly. Two burr holes are now made: One of them is located at the “keyhole” (behind the frontozygomatic suture, where the burr hole would straddle the floor of the frontal fossa and the roof of the orbit), and the other one is at the root of the zygoma above the external auditory canal. A frontotemporal bone flap is now raised with a high-speed drill.

**Extradural Dissection and Elevation of the Temporal Lobe**

A substantial amount of extradural dissection is performed to elevate the temporal lobe from the sphenoid wing anteriorly to the petrous ridge posteriorly (Fig. 32.4A). It is important for the brain to be relaxed with either a lumbar spinal drain that is placed after the patient is anesthetized or administration of mannitol, in order to...
facilitate this dissection. The floor of the middle cranial fossa is drilled down along with the sphenoid wing to provide a flat and low approach. The dura is elevated systematically starting posteriorly over the petrous ridge of the temporal bone and then progressing anteriorly. The posterior petrous ridge and the arcuate eminence are identified. Immediately anterior to the arcuate eminence is the recess in the bone through which the greater superficial petrosal nerve (GSPN) emerges after originating from the geniculate ganglion of the facial nerve. The foramen spinosum and foramen ovale are seen transmitting the middle meningeal artery and the mandibular branch of the trigeminal nerve respectively. Further anteriorly the foramen rotundum is seen, through which the maxillary branch travels to the pterygopalatine fossa.

Using a diamond burr on a high-speed drill, the foramen spinosum, ovale, and rotundum are unroofed. The middle meningeal artery is coagulated and divided. Under high magnification, the GSPN is followed anteriorly along its course as it travels between the two layers of the dura under the temporal lobe. The periosteal layer of dura is sharply incised in a direction parallel to the course of the nerve. This allows the temporal lobe dura to be elevated leaving the nerve traveling along the bony floor medial and deep to the foramen ovale. Thus, traction on the nerve, which can produce facial paralysis, is avoided. The GSPN closely follows the course of the horizontal segment of the petrous ICA. The artery is exposed by unroofing it with a small (3 mm) diamond drill. If only a limited exposure of the ICA is needed, the GSPN can be left in place and the drilling is done just lateral to it. If the vessel needs to be fully unroofed, the GSPN is divided at a distance from the geniculate ganglion.

**FIGURE 32.4** A. The temporal lobe is elevated extradurally, and the middle meningeal artery is exposed in the foramen spinosum, coagulated, and divided. The GSPN has also been exposed and divided to facilitate identification of the horizontal segment of the petrous ICA. In most situations, it is not necessary to divide the nerve. It can be preserved by leaving the outer layer of the temporal dura along with the nerve and elevating the temporal lobe without putting traction on the nerve. (V2, foramen rotundum; V3, foramen ovale; MM, middle meningeal artery; ICA, horizontal petrous internal carotid artery.) B. The outer layer of the dura that forms the lateral wall of the Meckel’s cave has been peeled away exposing the trigeminal ganglion and the three divisions. The dura posteriorly is incised to follow the trigeminal root. The petrous apex medial to the petrous ICA has been drilled away to expose the posterior fossa dura (arrowheads). (GG, gasserian ganglion.)
ganglion to avoid traction. The bony eustachian tube is located immediately lateral to the artery, separated from the vessel with a very thin layer of bone. While drilling lateral to the ICA, one has to be careful not to open into the eustachian tube. The tensor tympani muscle travels on the superior surface of the eustachian tube and is usually exposed first before opening into the actual eustachian tube. Inadvertently opening this with the drill should be avoided; otherwise, a cerebrospinal fluid fistula can result. It must be recognized and dealt with by opening it sufficiently and packing it thoroughly with a plug of muscle.

Further dissection varies according to the nature and location of the tumor, whether extra- or intradural.

Extradural Tumors

The usual extradural tumors are chondrosarcomas, chordomas, and cholesterol granulomas. The superoinferior extension as well as the medial–lateral extension of the tumor must be carefully assessed on the preoperative images (CT and MRI). The soft tissue extension, the area of bone destruction, and the relation to the foramina at the skull base and the petrous carotid artery are noted. Based on these assessments, the area and size of the exposure at the skull base is determined. The horizontal segment of the petrous ICA is unroofed using a diamond drill after dividing the GSPN as described above. The artery is unroofed from the posterior genu of the petrous segment up to the precavernous segment as it turns upward deep to the mandibular nerve. An incision is carefully made in the subtemporal dura immediately lateral to the point of exit of the mandibular and maxillary divisions under the temporal lobe. The temporal dura is bluntly dissected away from the lateral surface of the trigeminal ganglion, thus exposing the trigeminal ganglion and the three branches arising from it (Fig. 32.4B). The ganglion is covered by a thin arachnoid layer. This dural incision is extended posteriorly to expose a small portion of the trigeminal root behind the ganglion. Prior to drilling the petrous apex, it is important to be aware of the location of the cochlea, geniculate ganglion, and the internal auditory canal (Fig. 32.1). The geniculate ganglion is immediately posterior to the facial hiatus (emergence of the GSPN). There is a thin layer of bone that separates the ganglion from the subtemporal dura, and on occasion, it is not covered by any bone. The cochlea is located just posterior to the genu of the ICA, where the vertical segment of the petrous ICA turns into the horizontal segment. The internal auditory canal is located along a line bisecting the angle sustained by the junction of the arcuate eminence and the course of the GSPN. The bone medial to the horizontal petrous ICA and posterior to the trigeminal ganglion is gradually drilled down with a diamond burr. This bone is drilled in a quadrangular area with the petrous ridge behind, the trigeminal root superiorly, the trigeminal ganglion anteriorly, and the horizontal petrous ICA laterally. There may be some air cells that are unroofed in the process. The dura in front of the brain stem is thus exposed. The bone drilling can be carried out laterally in the temporal bone, to unroof the internal auditory canal. This marks the posterior limit of the exposure. Bone drilling in the vicinity of these structures needs to be done carefully and with neurophysiologic monitoring of the facial nerve.

Tumor Removal

Chondrosarcomas and chordomas are extradural tumors, and are usually encountered by the time the petrous apex is being drilled (Fig. 32.5A and B). These tumors are usually gray and gelatinous and soft with areas of calcification. Small ring curettes and suction are used to remove the tumor in a systematic manner clearing out all extensions of the tumor. The carotid artery is carefully protected while drilling out additional bone, until

**FIGURE 32.5** A. Axial T2-weighted image of a low-grade chondrosarcoma of the right petrous apex that has a high signal intensity in this sequence (arrowheads). B. Axial MRI T1 with contrast shows that the tumor has irregular enhancement with areas of low intensity corresponding to calcifications (arrowheads).
normal bone is encountered. Since the majority of these tumors are extradural, the posterior fossa dura in front of the brain stem and the dura inferior to the trigeminal ganglion and root are the limits of the tumor resection. If the approach is used for a cholesterol granuloma, the cyst wall is usually visible and the cyst contents can be drained. The cyst wall is then carefully dissected free from the surrounding bone and removed in a piecemeal manner.

**Intradural Tumors**

Intradural tumors located in the middle cranial fossa, the anterior portion of the tentorium and incisura, and the anterolateral portion of the clivus (ipsilateral to the side of the exposure) are accessible by this approach. These include meningiomas (Fig. 32.6A and B; Fig. 32.7A and B), trigeminal nerve schwannomas (Fig. 32.8A and B), and epidermoid tumors. Although an excellent exposure of the middle cranial fossa is achieved by this approach, the posterior fossa exposure is limited to a specific anatomical region. This region is defined by the bony window into the posterior fossa: superiorly, the posterior clinoid process and inferiorly, the internal auditory canal and the horizontal segment of the petrous ICA. This area can also be accessed through a retrosigmoid approach or a presigmoid retrolabyrinthine approach, but the main advantage of using the anterior transpetrosal approach is that it allows the surgeon a direct route to the lesion and to work anterior to the VII and VIII cranial nerves, instead of across them.

The temporal dura is elevated from the petrous ridge posteriorly to the lesser wing of sphenoid, anteriorly. The GSPN is isolated and divided to allow further elevation of the subtemporal dura. Meckel’s cave and the trigeminal ganglion are exposed by incising the dura lateral to the maxillary and mandibular divisions and peeling away the dura of the lateral wall (Fig. 32.9A and B). The horizontal petrous ICA is exposed from its genu posteriorly to its precavernous segment under the trigeminal ganglion. The bone medial to the petrous...
ICA is drilled away with a diamond burr (3 or 4 mm) thus exposing the dura ventral to the brain stem and inferior to the trigeminal root (Fig. 32.9C). The posterior and inferior limit of the bone drilling is the internal auditory canal. The subtemporal dura is incised posteriorly along the trigeminal root until the superior petrosal sinus. The superior petrosal sinus runs at the junction of the subtemporal dura with the prepontine dura and marks the attachment of the tentorium. The incision of the subtemporal dura is carried posteriorly parallel to and above the superior petrosal sinus, and another incision is made below the superior petrosal sinus in the dura ventral to the brain stem. The sinus is then thoroughly coagulated with the bipolar and divided. The temporal

**FIGURE 32.8** A. Axial MRI scan with gadolinium as well as a T2-weighted image showing a dumbbell-shaped trigeminal schwannoma occupying Meckel’s cave and extending into the posterior fossa. Since the petrous apex is partially eroded by the tumor (arrowheads), it is ideally approached by the anterior transpetrosal approach. B. The T2-weighted image shows that the tumor extends down to the level of the internal auditory canal (arrowhead).

ICA is drilled away with a diamond burr (3 or 4 mm) thus exposing the dura ventral to the brain stem and inferior to the trigeminal root (Fig. 32.9C). The posterior and inferior limit of the bone drilling is the internal auditory canal. The subtemporal dura is incised posteriorly along the trigeminal root until the superior petrosal sinus. The superior petrosal sinus runs at the junction of the subtemporal dura with the prepontine dura and marks the attachment of the tentorium. The incision of the subtemporal dura is carried posteriorly parallel to and above the superior petrosal sinus, and another incision is made below the superior petrosal sinus in the dura ventral to the brain stem. The sinus is then thoroughly coagulated with the bipolar and divided. The temporal

**FIGURE 32.9** A. Intraoperative photo of meningioma shown in Figure 32.6. The patient’s vertex is downward, and the nose is to the reader’s right. Left-sided extradural subtemporal dissection shows that the middle meningeal artery has been divided at the foramen spinosum (arrowhead). Foramen ovale (FO) and foramen rotundum (FR) are exposed where the V3 and V2 trigeminal branches are exiting. (TL, temporal lobe dura.) B. The dura of the lateral wall of Meckel’s cave has been incised and peeled away showing the nerve fascicles of V3. The horizontal segment of the petrous ICA is exposed (arrowhead). C. The left petrous apex has been drilled medial to the petrous ICA (arrowheads). The dura anterior to the brain stem has been exposed (BS).
lobe is elevated, and the tentorium is incised to the incisura (Fig. 32.10A and B). The prepontine dura is incised inferiorly as far as the bony opening permits, to visualize the caudal pole of the tumor.

The tumor is visualized and progressively debulked. It is then dissected free from the surrounding cranial nerves, brain stem, and vascular structures (Fig. 32.11A and B).

**Closure and Reconstruction**

The floor of the middle cranial fossa is carefully inspected under the microscope for any breaches into air cells. These are carefully occluded with bone wax. Dural closure is achieved by placing a piece of dural substitute over the dural defect and is secured to the surrounding dura with a few sutures in order to prevent it from migrating. Fibrin glue is used along the edges to further secure it. A small adipose tissue graft harvested from the abdomen is placed on top of the dural repair to bolster it (Fig. 32.11C). The bone flap is secured with miniplates. If there is a substantial gap in the bone at the inferior edge of the craniotomy where the bone was drilled away, a small cranioplasty is performed with titanium mesh to minimize any unsightly indentations. The temporalis muscle is secured back into place by resuspending it with sutures passed through small drill holes in the bone. The zygomatic arch is secured with miniplates, and a subgaleal drain is left in place; brought out through a separate stab wound. This is not connected to a suction bulb but is instead attached to a gravity drainage bag. The drain is used routinely because there is always a subcutaneous CSF collection that accumulates and by providing a temporary drainage system, it allows the scalp and the muscle to stick down and minimizes the possibility of a pseudomeningocele formation.

**FIGURE 32.10**  
A. Tumor (T) is exposed in this area after the tentorium has been incised (arrowheads). B. An axial diagram shows the location of the tumor relative to the surgical approach and its relation to the surrounding structures. The lower limit of the tumor that is accessible by this approach is the level of the internal auditory canal (arrowhead). (V2, maxillary nerve; V3, mandibular nerve.)

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POSTOPERATIVE MANAGEMENT

The patient is maintained in the neurosurgical intensive care unit to watch for delayed temporal lobe swelling or bleeding. Since seizures can occur from temporal lobe retraction or contusion, the patients are routinely placed on anticonvulsant prophylaxis. A CT scan without contrast is performed the day after the operation to check for hematoma and brain edema.

COMPLICATIONS

1. Cranial nerve problems: The cranial nerves that are exposed to risk are the 3rd to the 6th on the side of the approach. Although the inferior limit of the approach is at the level of the internal auditory canal, if there is any significant level of 7th and 8th cranial nerve involvement or extension into the internal auditory canal, this is not a preferred approach for such a tumor. The approach is performed by elevating the dura covering the middle fossa floor and dividing the tentorium posteriorly. This allows the cranial nerves to be exposed from their origin at the brain stem to the cavernous sinus and parasellar region. Since the trigeminal nerve is entirely within the field of the exposure, it can be easily traumatized. Impairment of the trigeminal nerve is especially important because of the corneal anesthesia that can result and jeopardize the eye. Careful vigilance is required to detect and treat trophic ulcers.

2. Brain stem problems: Preoperative evaluation of the MRI scan is important in anticipating potential brain stem problems. When the T2-weighted and FLAIR sequences show brain stem edema, it is a poor prognosticator. It indicates that the tumor has violated the arachnoid and pial membranes and will have no clear plane to allow separation of the tumor from the brain stem. There is a high potential for injuring the brain stem in such a situation, and it is usually advisable to leave a small residue of tumor against the brain stem to avoid the devastating complication of a brain stem injury.

3. Arterial injury: These tumors often are intimately related to the basilar artery and its branches. If more than 180 degrees of the circumference of the vessel is surrounded by the tumor, there is a substantial risk of injuring the main vessel or its perforating branches if the tumor is found to be adherent and aggressive attempts are made at separating it from the vessel. The usual mechanism of injury is from avulsion of perforators at the origin from the main vessel. The bleeding can be controlled by accurately coagulating the site with a bipolar or sometimes may require placing a suture such as 8-0 nylon. The most severe consequence of an
arterial or perforator injury leading to a brain stem stroke is devastating and is best avoided by meticulous technique and careful surgical judgment.

4. **Temporal lobe problems:** Excessive and prolonged retraction is the common reason for temporal lobe contusion and edema, and occasionally a hematoma can result. Aggressive drilling of the middle fossa floor during the opening allows the surgeon to angle the microscope to visualize the top of the tumor instead of retracting the temporal lobe. When the portion of the tumor that is in the posterior fossa is being accessed, cutting the tentorium and drilling the petrous apex are important maneuvers to minimize temporal lobe retraction.

**RESULTS**

The approach provides excellent access to selected tumors in this area. Although complete tumor removal is the goal, the degree of resection is usually determined by the biologic behavior of the tumor such as its invasiveness into neurovascular structures. Temporary cranial nerve palsies can result from their manipulation, as described below.

**PEARLS**

- The preoperative imaging studies must be carefully evaluated to determine if the anatomical access provided by the approach is adequate.
- The FLAIR and T2 sequence must be checked to see if there is hyperintense signal in the brain stem indicating pial invasion. This indicates that the tumor will not be safely separable from the brain stem.

**PITFALLS**

- While drilling the bone of the petrous apex, the air cells must be carefully waxed to prevent cerebrospinal fluid fistula formation.
- During the elevation of the temporal lobe from the floor of the middle cranial fossa, care must be taken not to injure the geniculate ganglion that may be devoid of bony cover.
- Traction on the GSPN must be avoided to prevent facial palsy.

**INSTRUMENTS TO HAVE AVAILABLE**

- High-speed drill with assorted cutting and diamond burrs with irrigation
- Microsurgical instruments
- Nerve integrity monitor for facial nerve stimulation

**SUGGESTED READING**


INTRODUCTION

A variety of benign and malignant neoplasms arise in the complex neurovascular terrain of the lateral and infratemporal skull base. These neoplasms may originate in the jugular foramen, petrous apex, temporal bone, or nasopharynx. In addition, advanced malignant tumors of the parotid gland, neuromas of the extracranial lower cranial nerve, and paragangliomas of the parapharyngeal space can involve the infratemporal fossa. The postauricular approach to this region offers a wide lateral access with preresection exposure of the internal carotid artery, the internal jugular vein (IJV), the lower cranial nerves, the facial nerve, and the jugular foramen. Transcranial, dumbbell-shaped neoplasms can also be removed in a single procedure with the addition of presigmoid dural resection for posterior fossa exposure. This approach is the most popular for most lesions of the lateral skull base and infratemporal fossa.

HISTORY

The most common symptoms associated with jugular foramen tumors presenting in the middle ear are hearing loss and pulsatile tinnitus. Lower cranial nerve neuropathies are often compensated and asymptomatic, but some patients do admit to subtle difficulties with speech, swallowing, or chronic cough. Numbness of the face may occur as a result of trigeminal nerve involvement, and temporomandibular joint invasion can lead to progressive trismus. Nonvascular tumors, such as neuromas of the jugular foramen, may cause few, if any, symptoms and can be incidental radiographic findings in patients with other, unrelated manifestations such as headache or imbalance.

PHYSICAL EXAMINATION

Any patient with a suspected tumor of the infratemporal fossa must undergo a complete head and neck examination, cranial nerve evaluation, and microscopic otoscopy. Neck and bimanual parotid palpation will assess high cervical and/or parapharyngeal space involvement. Tongue movement, vocal cord function, and shoulder strength must be documented as well as facial animation and temporomandibular joint function. Microscopic otoscopy will identify tumors of the hypotympanum or mesotympanum disease, the color of the tumor, and any pulsatile quality of the neoplasm. Basic tuning fork testing (Weber and Rinne) will help determine the type and degree of hearing loss.
INDICATIONS

The postauricular infratemporal fossa approach is most often utilized for tumors of the jugular foramen, petrous apex, clivus, or the infratemporal fossa. These lesions include paragangliomas, neuromas, meningiomas, chordomas, epidermoids, epithelial malignancies, and salivary gland tumors. This approach may also be combined with various neurosurgical techniques for the extirpation of transcranial tumors (Table 33.1).

CONTRAINDICATIONS

Surgical resection is not necessary in elderly patients due to the slow growth of the benign tumors occurring in this region. Surgical contraindications may include tumor invasion of the carotid and vertebral arteries, brainstem invasion, radiation failures with malignant tumor histology, and selected cases of familial, hereditary, bilateral, and multifocal disease.

PREOPERATIVE PLANNING

All patients must undergo a thorough medical history and a complete head and neck examination. This includes an assessment of all cranial nerves and close inspection of the presurgical vocal cord and pharyngeal function.

Basic pure-tone and speech discrimination audiometry is obtained for both ears, and patients must be counseled regarding the inevitable postoperative hearing loss.

Contrast-enhanced MRI and CT scanning are obtained in most patients to determine the soft tissue and bony involvement, respectively. Cerebral angiography is used to assess the arterial and venous anatomy and to perform preoperative tumor embolization if necessary.

Balloon test occlusion with cerebral blood flow monitoring is performed in patients with recurrent tumor, a history of radiation therapy, or tumors with encasement of the internal carotid artery. Patients with paragangliomas undergo serum and urine catecholamine screening to assess for secreting status of the tumor. Those who show evidence of catecholamine elevation must be treated with beta-blockers (Inderal) to prevent hypertensive crisis during embolization and surgical manipulation. Biopsy of these tumors is usually not indicated.

SURGICAL TECHNIQUE

The patient is secured in a supine position with the head turned contralateral to the tumor. Three-point pin fixation is used, and the lateral skull, face, neck, and ipsilateral abdomen are included in the sterilized field. Intraoperative electromyographic monitoring of the facial nerve and any preoperatively intact lower cranial nerves can be performed. Somatosensory monitoring of the brachial plexus is also used in selected cases according to patient body habitus or cervical spine immobility. General endotracheal anesthesia is maintained without paralytic agents.

A post-auricular reverse S-shaped incision begins in the supra-auricular temporal scalp and extends behind the ear and into a cervical skin crease at least two-finger widths below the mandible (Fig. 33.1). The entire auriculoparotid flap is elevated from posterior to anterior with preservation of the temporalis fascia above and the platysma muscle below. The cartilaginous external auditory meatus is transected and oversewn with a two-layer, blind sac closure technique. An anterior to posterior incision is made below the temporal line to allow superior reflection of a temporoparietal flap and postero inferior elevation of the sternocleidomastoid muscle and surrounding peristeum.

The skin of the external auditory canal is removed including the tympanic membrane, the malleus, and the incus.

<table>
<thead>
<tr>
<th>TABLE 33.1 Tumors of the Infratemporal Fossa</th>
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<tbody>
<tr>
<td>Chondrosarcoma</td>
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<td>Chordoma</td>
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<tr>
<td>Glomus jugulare</td>
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<tr>
<td>Glomus vagale</td>
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<tr>
<td>Meningioma</td>
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CHAPTER 33 Postauricular Approach to the Infratemporal Skull Base

Subtotal Petrosectomy

A canal wall-up mastoidectomy is performed with early identification of the sigmoid sinus and the temporal dura. At least 3 cm of bone is removed posterior and inferior to the sigmoid sinus to allow prereseption ligation of the vessel. The mastoid antrum is identified along with the lateral semicircular canal in order to safely open the facial recess. The bony canal wall can be removed with a rongeur or by drill curettage. The entire mastoid tip is removed with a rongeur, up to the level of the digastric groove and the stylomastoid foramen.

Under microscopic guidance, the facial nerve is skeletonized from the geniculate ganglion to the stylo-mastoid foramen. This facial bridge is left intact if tumor can be resected by dissecting both anterior and posterior to the nerve. Anterior transposition requires complete bone removal along the course of the nerve as well as transection of the greater superficial petrosal nerve. Retrofacial bone removal below the posterior semicircular canal and above the jugular bulb provides access to the posterior pole of the tumor (Fig. 33.2).

A labyrinthectomy can be performed to enhance posterosuperior exposure in patients with significant preoperative sensorineural hearing loss. Removing the anterior bony ear canal allows exposure of the temporomandibular joint and anterior retraction of the surrounding soft tissue. Anteromedial bone removal from the glenoid fossa and the styloid base provides exposure of the vertical segment of the petrous carotid canal and the eustachian tube orifice.

Neck Dissection

Following posterior sternocleidomastoid muscle reflection, the spinal accessory nerve and the IJV are identified. The IJV is circumferentially dissected, and cranial nerves IX, X, and XII are visualized. Anteromedial reflection of the digastic muscle allows superior dissection of the internal carotid artery. Vessel loops are placed around the great vessels. The facial nerve is viewed at the stylomastoid foramen, and a superficial parotidectomy is performed. If neural translocation is planned, peripheral branch dissection will reduce neural stretching and possible postoperative facial weakness.

Tumor Resection

The middle ear component of the tumor is coagulated with bipolar cautery and resected in piecemeal fashion until the bone of the promontory, the carotid canal, and the ampullated end of the superior semicircular canal.
are encountered. The posterior and posteroinferior margins are likewise managed, and the tumor is reduced to a relatively devascularized remnant in the jugular foramen.

The sigmoid sinus is doubly ligated inferior to the transverse sinus and below the mastoid emissary vein. The IJV is then tied in the superior aspect of the neck, below any intraluminal tumor extension.

The remaining extradural tumor is mobilized from superior to inferior, parallel to the posterior wall of the vertical petrous carotid artery. The lateral wall of the sigmoid sinus is opened, and the tumor is dissected anteriorly, toward the jugular bulb. The medial wall of the sigmoid sinus is left intact, unless there is intradural posterior fossa tumor. As the tumor is delivered inferiorly, toward the ligated jugular vein, vigorous bleeding may be encountered from the inferior petrosal sinus. This structure must be gently packed in order to avoid injury to cranial nerves IX and X.

Posterior intradural tumor can be removed by carefully excising the posteromedial wall of the jugular bulb or the medial dural wall of the inferior sigmoid sinus. Extension of the tumor to the clivus can be addressed by drill curettage of the cochlea and the petrous apex, medial and anteromedial to the horizontal petrous carotid artery. Extension of the tumor into the middle cranial fossa can also be managed following ligation of the middle meningeal artery, transection of the mandibular division of the trigeminal nerve, ligation of the cartilaginous eustachian tube, and inferior retraction of the mandibular condyle.

**Wound Closure**

Adipose tissue harvested from the abdomen is used to obliterate the bony defect or to repair limited dural defects in the jugular bulb or presigmoid region. The temporoparietal flap is rotated to cover the adipose tissue and is sutured to the remaining parotid gland anteriorly and the sternocleidomastoid muscle posteroinferiorly (Fig. 33.3). Microvascular free muscle transfer is used in patients with large dural defects, prior radiotherapy, and revision surgical procedures. Two suction drains are positioned deep and superficial to the muscle closure, respectively. A compressive mastoid dressing is used for 3 to 4 days.
POSTOPERATIVE MANAGEMENT

Patients who have undergone a postauricular infratemporal approach are usually extubated in the operating room and are monitored in the recovery room for 1–2 hours. They are then sent to the Neurosurgery or ENT intensive care unit for 1 or 2 days. A temporary nasogastric feeding tube is left in place until a bedside swallowing examination can be performed. Multiple lower cranial nerve deficits may prolong swallowing rehabilitation, but rarely are patients in need of home external feedings.

These patients are usually transferred to the ward on the second or third postoperative day where assisted speech, swallowing, and ambulation therapy are initiated. Suction drains are generally removed by the third postoperative day, and most patients are discharged by the fifth day.

The patients are seen one month later and usually return to work and normal activities at that time. The standard long-term surveillance includes MRI studies at 1 year, 4 years, and 9 years following the procedure. Additional surgical interventions for facial paralysis, voice, and swallowing difficulties are used according to the patient’s progress in these areas.

COMPLICATIONS (TABLE 33.2)

Minor wound complications include seroma, hematoma, salivary fistula, partial loss of skin, or cerebrospinal fluid (CSF) wound collection. These can all be managed with fluid aspiration, antibiotics, and compressive dressings. CSF cutaneous fistula, or CSF rhinorrhea likely requires revision of the defect site. Lumbar drainage of the CSF may result in cessation of the leak, but it may also lead to meningitis in cases of CSF rhinorrhea.

Facial nerve weakness is transient in cases where facial nerve transposition was necessary and rarely occurs when the nerve is left in its bony “bridge.” Appropriate eye care with artificial tears, ophthalmic lubricants, and nightly taping will reduce the risk of corneal damage. Excellent facial recovery with minimal synkinesis should be expected 3 to 6 months following the procedure.

Combined lower cranial nerve injury due to stretching or transection is to be expected in most patients with large tumors of the jugular foramen and infratemporal fossa. The quality and strength of the voice can be improved with temporary vocal cord injection or permanent medialization procedures. Swallowing therapy is
initiated as soon as possible while nutrition can be maintained via nasogastric or directed gastrointestinal feedings. Airway protection and postoperative dysphagia are difficult challenges for the patient and surgeon alike. Proper radiographic and angiographic assessment of the venous and arterial anatomy should markedly reduce the risk of major or catastrophic neurovascular complications such as cerebral edema, hemorrhage, or stroke. Neurosurgical intensive care unit monitoring is mandatory for resection of large tumors in order to identify such complications as early as possible so immediate and perhaps lifesaving measures can be instituted.

RESULTS

The postauricular infratemporal fossa approach has been used in the surgical treatment of jugular foramen, temporal bone, parapharyngeal space, and clival tumors. It is usually possible to anatomically and/or physiologically preserve the lower cranial nerves (IX to XII) if these nerves were preoperatively functional. This results in either normal postoperative speech and swallowing or a transient weakness of the involved nerves. The facial nerve is only temporarily paretic if the nerve is anteriorly transposed for enhanced tumor exposure.

Venous congestion or infarction is extremely rare, as most patients demonstrate collateral contralateral venous flow on magnetic resonance venography or preoperative cerebral angiography. Inadvertent carotid injury could lead to hemorrhage, stroke, or death. I have not experienced these complications in performing over 1,200 lateral skull base procedures in large part due to leaving some tumor on the weakened wall of the petrous portion of the carotid artery.

The average hospital stay is 3 to 5 days, and most patients return to work within 1 month. Longer hospitalization and overall recovery will occur if speech and swallowing are adversely affected or if patients develop wound complications or CSF leakage.

The postauricular infratemporal fossa approach is a versatile option for lateral access to any tumor of the jugular foramen, clivus, deep parapharyngeal space, or nasopharynx. This technique allows identification and protection of all the surrounding neurovascular structures prior to tumor resection. Proper patient selection, based on detailed clinicoradiographic assessment, will minimize the risk of serious complications and maximize the opportunity for safe and complete tumor resection.

PEARLS

- A detailed history of the presenting symptoms with a thorough head, neck, and cranial nerve examination is mandatory.
- Use the combination of high-resolution temporal bone CT scan and MRI of the internal auditory canals to determine the size, location, and type of tumor.
- Consider nonsurgical options in elderly or medically compromised patients due to the high likelihood of airway, speech, and swallowing complications following surgery.
- Avoid the start of tumor resection before definitive identification and protection of cranial nerves VII and IX–XII, the internal carotid artery, and the sigmoid sinus–jugular bulb–IJV are carried out.
- Consider microvascular free muscle flap in previously irradiated or operated patients or in patients with extensive dural defects.

PITFALLS

- Selecting this surgical option in patients who are poor candidates for aerodigestive rehabilitation will lead to untoward or difficult recovery.
- Inadvertent permanent lower cranial nerve injury in patients with preoperatively functioning nerves.

| TABLE 33.2 Complications Following Postauricular Infratemporal Skull Base Surgery |
|---------------------------------|-----------------|-----------------|
| Wound                          | Cranial nerve   | Neurovascular   |
| Seroma                         | Facial nerve    | Cerebral edema  |
| Hematoma                       | IX–XII          | Hemorrhage      |
| Salivary fistula               | Airway          | Stroke          |
| Skin necrosis                  | Voice           | Death           |
| CSF collection                 | Swallowing      |                 |
| CSF rhinorrhea                 |                 |                 |

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● Inadequate wound closure resulting in CSF leak and possible meningitis
● Injury to the carotid artery or failure to identify inadequate venous return based on angiographic assessment

INSTRUMENTS TO HAVE AVAILABLE

● Otology tray
● Head and neck tray
● Craniotomy tray
● Surgical drill
● Ultrasonic aspirator
● Microscope
● Intraoperative navigational system

SUGGESTED READING

INTRODUCTION

There are numerous effective and safe open surgical approaches to the middle cranial fossa (MCF). These include, but are not restricted to, the pterional, orbitozygomatic, frontotemporal, and temporal approaches. These approaches are very effective, offering ample exposure with a high degree of safety. However, there are some drawbacks to each of these procedures. The commonly cited and recognized drawbacks or risks include morbidity related to a large scalp incision, atrophy of the temporalis muscle, damage to the frontal branch of the facial nerve, and postoperative cerebral edema that occurs as a result of retraction of the brain required for access to the lesion.

The same surgical interests that have inspired and accelerated the development of endoscopic approaches to the anterior cranial fossa (ACF) have pushed forward research in minimally disruptive approaches to the MCF. Transnasal approaches to the medial MCF (parasellar region and medial aspect of the cavernous sinus) have been described and are effective. Extended endoscopic approaches to the anterior base of the MCF have also been developed and have been evolving in clinical practice. Admittedly, extension laterally and superiorly beyond these regions is more challenging. The challenge to develop safe and effective minimally invasive endoscopic approaches to the MCF is, in part, a result of the significant length of the surgical pathway and surgical obstacles such as the orbital contents and the optic nerve.

As a means of circumventing these obstacles, while providing short, direct pathways to lesions in the MCF, we developed a system of transorbital endoscopic approaches that is unique but effective in treating lesions in this region. The surgical trajectory through the orbit is based on an orbital quadrant system, as discussed in Chapter 15 (Fig. 34.1). This system divides the orbit into distinct approach quadrants based on common target regions adjacent to and beyond the orbit, as well as anatomic structures related to the orbit that should not be disturbed. These include the superior orbitotomy through a superior lid crease (SLC) incision and medial orbitotomy through a precaruncular (PC) incision to the ACF (see Chapter 16). Access to the MCF is available through a lateral orbitotomy using a lateral retrocanthal (LRC) approach, an inferior orbitotomy through an inferior transconjunctival (ITC) approach (Fig. 34.2), and a medial orbitotomy through the contralateral orbit using a contralateral precaruncular (CPC) approach (see Chapter 15 and below). These approaches are in common use for the repair of orbital trauma and treating orbital and intracranial complications of sinogenic abscesses. We have reported on the safety and efficacy of the use of these techniques in a large series of cases. These approaches can be used alone in monoportal technique or combined with contralateral transorbital, transnasal, or transmaxillary approaches for multiportal access.

The choice of pathway and number of portals is made with a preoperative computerized approach analysis using a surgical navigation system and includes a full 360-degree evaluation of the anatomy involved in and adjacent to the pathology, as well as the anatomic structures that are displaced or traversed by the potential endoscopic pathways to the target. The pathway(s) are chosen to provide the most efficacious and least morbid approach. The goal of surgery is to achieve the best possible angle(s) for the
FIGURE 34.1 The four quadrants of the right orbit. The surgical approach is chosen by the quadrant of the orbit that is most involved by the underlying pathology. The superior quadrant is accessed by the SLC approach (see Chapter 15); the medial quadrant is entered through a PC incision; the inferior quadrant approach is made through an ITC incision; and the lateral quadrant is reached through an LRC portal. (SLC, superior lid crease; PC, precaruncular; ITC, inferior transconjunctival; LRC, lateral retrocanthal.)

FIGURE 34.2 A. Surgical anatomy of the right orbit. 1, frontozygomatic suture; 2, sphenozygomatic suture; 3, superior orbital fissure; 4, optic canal; 5, inferior orbital fissure; 6, foramen of infraorbital nerve. B. Outline of bone removed through lateral orbitotomy: A, approach to MCF through greater wing of sphenoid bone; B, approach to infratemporal fossa. C. Region of approach through inferior orbitotomy. (MCF, middle cranial fossa.)
CHAPTER 34 Transorbital Endoscopic Approaches to the Middle Cranial Fossa

endoscopic treatment of the pathology and ultimately to lessen the morbidity by avoiding an open cranial microsurgical approach (Fig. 34.3).

While the LRC approach provides retro-orbital access to regions of the MCF that cannot be safely achieved transnasally, the ITC and CPC portals provide access that can also be obtained through transnasal or transmaxillary approaches. The angles of approach that they provide to a target are quite different; the distances may be significantly shorter than transnasal approaches, and as such, the portals can be complementary. At times, however, pathology may involve the floor of the orbit (e.g., metastatic tumor) or a portion of the orbit that would be resected with the pathology. In these situations, a transorbital portal can provide a clearly advantageous surgical visualization of the orbit, particularly if orbital reconstruction will be required. As experience with all of these approaches grows, the indications and contraindications to the use of each portal will be further delineated.

This chapter provides a discussion of the transorbital endoscopic approaches that we use for access to the MCF, including the LRC, ITC, and CPC portals. Though our approach for sellar and parasellar pathology is most commonly performed through transnasal portals, a description of these is beyond the scope of this discussion.

HISTORY

The presentation and history of patients with MCF lesions are highly variable, depending on the location, type, and stage of the underlying pathology. Tumors in this region are often silent until they invade and travel along nerves, at which time they may cause facial numbness or pain. Progression within the brain may cause symptoms depending on the region involved. Tumor involvement in the infratemporal or pterygo-palatine fossae may cause interference or pain with mastication. Spread anteriorly with the orbit may cause diplopia, proptosis, and progressive loss of vision.

FIGURE 34.3
Example of preoperative computer analysis of possible endoscopic pathways to right cavernous sinus, superior view, CT scan. Lateral (red), inferior (blue) contralateral PC (green) approaches. MCF and adjacent sphenoid regions are highlighted in yellow. (PC, preauricular; MCF, middle cranial fossa.)
PHYSICAL EXAMINATION

Any patient presenting with symptoms consistent with pathology involving the MCF should have a complete examination of the head and neck, as well as a thorough neurologic evaluation including all of the cranial nerves. Evaluation of facial sensation in all branches of the trigeminal nerves is important. Nasal and pharyngeal endoscopy should be performed to evaluate involvement of the medial orbit, interorbital skull base and, sphenoid and clival regions.

Imaging is then performed based on the history and physical examination, with computerized tomographic (CT) scans and magnetic resonance imaging (MRI) being the most frequently indicated studies alone or as complementary evaluations. Angiography may be indicated for examination of vascular involvement or for preoperative embolization to make surgery safer.

INDICATIONS

A wide range of pathology can involve the MCF as a primary site, through metastasis from a distant site, or through local extension from an adjacent structure. Tumors arising within the MCF are usually benign and include pituitary adenoma, meningioma, and trigeminal schwannoma. (Temporal bone pathology is excluded from this chapter.) Malignancies arising in this area include chordoma, chondrosarcoma, and osteosarcoma; perineural invasion from squamous cell carcinoma or adenoid cystic carcinoma. Local invasion and hematologic metastases are also common.

The most common open procedures to access these regions are the pterional, orbitopterional, orbitozygomatic, and transzygomatic/infratemporal fossa approaches. The open microvascular procedures, although effective, can be morbidity due to brain retraction, cerebral edema, and disruption of normal structures associated with large, potentially visible scars. Furthermore, open procedures through the frontotemporal regions require displacement of the temporalis muscle that may cause significant visible hollowing of the temporal contour. In addition, the frontal branch of the facial nerve is at risk for injury during the creation of these surgical pathways. Though paralysis of this nerve is not common, when it does occur, it has a significant negative impact on a patient’s appearance and may cause blockage of the superior visual field. Removal of a large cranial bone flap also carries the risk of infection of the flap and added recovery time for the patient.

For reasons of safety, better visualization of the pathology and improved healing time, transnasal endoscopic approaches have been described and investigated for access to the parasellar regions, petrous apex, and medial aspect of the cavernous sinus. These approaches offer excellent access through a natural corridor. There are times, however, when an additional access portal to these regions may be beneficial to improve the angles of visualization of the pathology or to provide increased working space between the surgeons’ hands or instruments.

Transnasal approaches may also be limited in their ability to provide visualization and endoscopic access to the lateral aspect of the cavernous sinus/parasellar regions and locations lateral to the trigeminal ganglion, and when these regions can be reached, this endoscopic route may be at the upper limits of their effective range.

Another region of limited access transnasally is the superior infratemporal fossa and the anterior—superior MCF. These regions are within the orbital “shadow effect” of a transnasal approach, making these areas challenging to access without endangering critical neurovascular structures.

Transorbital approaches can be used to access these areas that are either difficult or dangerous to reach through the nose or to provide multiportal corridors in addition to transnasal approaches. The indications for these approaches are similar to those for transnasal portals and are expanding with growing familiarity of the anatomic perspectives and technical demands. Transorbital endoscopic approaches to the MCF are currently indicated for benign and localized malignancies involving the ventral aspects of the MCF along the inferior, medial, lateral, and anterior borders. The primary transorbital approaches to these regions are the LRC, ITC, and the CPC portals as described above.

The indications and applications of these approaches are continuing to expand and will likely further develop as advanced instrumentation becomes available. The lateral orbitotomy (LRC approach) provides access to the infratemporal fossa, the greater wing of the sphenoid, and adjacent regions of the MCF. Its applications include trauma and CSF leak repair, and resection of tumors. This pathway can be used for access to the lateral aspect of the cavernous sinus and trigeminal ganglion, with a relatively short intracranial component (Fig. 34.4). There is considerable flexibility in the placement of the entry portal in the coronal plane, and the choice of entry is made by vector analysis with regard to the surgical target.

The ITC approach can be used for targets at the inferior anterior aspect of the MCF, such as the region of the foramen rotundum (Fig. 34.5). It also offers a potential pathway to the inferior lateral aspect of the cavernous sinus following a trajectory inferior to the optic nerve. This approach is particularly useful for pathology that involves the inferior orbit and maxilla, such as tumors in the infraorbital nerve.
CHAPTER 34  Transorbital Endoscopic Approaches to the Middle Cranial Fossa

The CPC approach is indicated for pathology in the medial aspect of the cavernous sinus, optic nerve, and selected sellar and suprasellar lesions (Fig. 34.6). Pathology of the optic nerve and chiasm as well as the resection of encephaloceles are strong indications for inclusion of this portal in the surgical plan.

CONTRAINDICATIONS

As for the transorbital approaches to the ACF (see Chapter 16), the primary contraindication to transorbital approaches to the MCF appears to be a recent history of severe orbital trauma. A history of LASIK surgery, though not a contraindication to surgery, should caution the surgeon to treat the cornea with great care and follow the patient closely postoperatively for any corneal complications (see Complications section). These patients may have partial corneal anesthesia and may be at higher risk for corneal ulceration or exposure damage. Patients with primary orbital pathology, particularly those with corneal anesthesia, should be evaluated preoperatively by an ophthalmologist and receive joint follow-up postoperatively.

FIGURE 34.4  A. Surgical planning view, LRC approach. B. Enlargement demonstrating trajectory of LRC approach. C. Access to lateral MCF. Note proximity of infratemporal fossa that can easily be entered as needed. (LRC, lateral retrocanthal; MCF, middle cranial fossa.)
**FIGURE 34.5** ITC approach. A. Preoperative pathway analysis with vector from entry portal to the surgical target. B. Enlarged parasagittal view demonstrating pathway inferior to the globe, leaving the orbit posteriorly, where the orbital floor rises, to enter the MCF. C. ITC approach to foramen rotundum with CPC approach (green) to lateral sphenoid. (ITC, inferior transconjunctival; MCF, middle cranial fossa; CPC, contralateral precaruncular.)

**FIGURE 34.6**
A. Left CPC approach to right MCF (Sternberg’s) encephalocele (yellow). B. Magnified segment of (A), with virtual endoscopy demonstrating favorable approach for viewing and instrumentation. (CPC, contralateral precaruncular; MCF, middle cranial fossa.)
The pathology must be of a suitable extent, location, and character for resection with endoscopic visualization and the instrumentation at the surgeon’s disposal. Care should be taken to ensure that the lesion is a solitary lesion in cases of metastatic disease.

Surgeons should receive adequate training and/or mentoring in these approaches before using them clinically. Each patient’s pathology should be evaluated individually with preoperative CT and MRI analysis to be certain that an endoscopic approach of any type is appropriate and to determine which type of monoportal or multiportal surgical approach will be optimal.

**PREOPERATIVE PLANNING**

As for any complex surgical procedure, transorbital endoscopic approaches to the MCF should be considered only after comprehensive evaluation of the patient including comprehensive imaging and consultation with all of the members of the skull base team who will be involved. When possible, it is optimal for the patients to be seen by the treating physicians synchronously to provide a comprehensive evaluation. Tumor cases should be presented and discussed at a multidisciplinary skull base tumor board involving skull base surgeons from the fields of neurologic surgery and otolaryngology as well as neuroradiologists, neuropathologists, medical oncologists, and radiation oncologists.

Approaches to the MCF are planned in the same manner as described in Chapter 16 for the ACF. Suitability of the pathology for an endoscopic approach must be considered, and the ability to successfully treat the surgical target with available instrumentation should be confirmed.

Preoperative computer analysis should be undertaken to determine the optimal surgical approach or approaches. This is performed on a planning station, using uploaded CT and/or MRI images (Fig. 34.3). The target is highlighted (Fig. 34.7), and the three-dimensional image is examined circumferentially to familiarize the surgeon with the structures that are involved with or adjacent to the pathology. The potential pathway vectors under consideration are then diagrammed and analyzed with respect to the following:

- The pathway should not cross critical neurovascular structures.
- Creation of the pathway must be technically feasible.
- Reconstruction of any portion of the pathway, if necessary, must be within the skills of the surgeon.
- The pathway should be short and direct to minimize collateral damage.
- The view of the target provided through the pathway should be unobstructed by tissue or instruments.

**FIGURE 34.7**

Preoperative approach planning. Lesion within bone of left greater wing of the sphenoid, segmented yellow. LRC (green) approach is shortest, most direct, and requires less adjacent tissue retraction. A. Possible entry points (inferior orbitotomy, red; lateral orbitotomy, green). B. Approaches with surgical target segmented. C. Lateral monoportal approach is able to access entire lesion. Approaches and target are evaluated circumferentially. (LRC, lateral retrocanthal.)
The angle of manipulation of the pathology provided by the endoscopic pathway should be adequate to complete all surgical tasks. Until the advent of flexible endoscopic surgery, the pathway must be linear, and direct virtual endoscopy can be performed to evaluate the structures involved with and encountered along the proposed surgical pathway. Adequacy of visualization of the target can be similarly analyzed, and mock instruments can be placed in multiportal fashion to determine if their approach angle is adequate and removed from the viewing trajectory of the endoscope.

As described in Chapter 16, the choice of the orbital region for the surgical approach is based on a division of the orbit into four quadrants (superior, medial, inferior, and lateral; Fig. 34.1). The quadrant that is directly involved by the pathology or is within the chosen surgical pathway is employed. The primary endoscopic transorbital approaches to the MCF are the LRC, ITC, and CPC. The ipsilateral PC approach to the medial quadrant and the transpalpebral SLC approach to the superior quadrant are described in Chapter 16, on transorbital approaches to the ACF.

The inferior quadrant is bounded medially by the lamina papyracea and laterally by the inferior orbital fissure and its anterior extension toward the orbital rim. The entry portal is through an ITC preseptal or inferior fornix incision. There is no medial anatomic boundary of this incision as it can be continued into a PC incision. Likewise, there is no lateral anatomical boundary to the incision as it can be extended into a LRC incision.

The lateral quadrant is bounded superiorly by the superior orbital fissure and its anterior extension to the orbital rim and inferiorly by the inferior orbital fissure and an anterior extension to the orbital rim. The portal of entry is through the LRC approach. The superior limit of the incision is the lateral horn of the levator aponeurosis and muscle. There is no inferior limit to this incision since it can be continued inferomedially into an IT incision.

As noted above, the PC, ITC, and LRC approaches can all be combined as they are transconjunctival, and the incisions do not cross anatomic structures. The SLC incision is transcutaneous and, as such, is not typically connected with transconjunctival incisions. The use of an adjacent transcutaneous and transconjunctival portal would be possible, as would joining the incisions laterally through the lateral canthus, but this is rarely necessary due to the ample surgical pathways that can be created by each of these independently.

The medial quadrant boundaries include the ethmoid arteries superiorly and the junction of the lamina papyracea and orbital floor inferiorly. Entry to this quadrant is achieved through the PC transconjunctival portal (see Chapter 15). Superiorly, the incision can extend up to the medial horn of the levator aponeurosis. Inferiorly, the incision and approach can be extended into an IT incision through the conjunctiva of the lower eyelid.

Preoperative approach analysis is essential for these surgical procedures and should be performed with a detailed study of the anatomic structures that involve or are adjacent to the surgical target. A surgical plan is formulated, including the choice of monoportal versus multiportal technique. The entry portals are then chosen based on the criteria described above. This evaluation should be done preoperatively so that the possible surgical routes can be discussed with the patient, bringing the patient’s desires into the decision-making process, and enabling a detailed informed consent process. A detailed surgical plan should be made, including the planned method of any reconstruction that might be required. As these procedures are technology intensive, the nursing staff must know ahead of time which powered and manual instruments and materials will be required to avoid intraoperative delays.

**SURGICAL TECHNIQUE**

As described in Chapter 16 in detail, the patient is placed in the supine position on the operating table and general anesthetic is administered. A lumbar drain is then placed if desired, and the bed is rotated 180 degrees with the foot toward the anesthesiology equipment. A circular gel headrest is used, or the patient’s head may be placed in pin fixation. The patient’s head is retroflexed 15 degrees to allow relaxation of the brain away from the skull base to minimize the need for brain retraction during the procedure. The head of the bed is elevated slightly to improve the intraoperative hemostasis; a small amount of local 1% lidocaine with epinephrine 1:100,000 (0.1 mL) is infiltrated into the planned conjunctival incision sites. The pupils are checked for symmetry before anesthetic injection as the local anesthetic may cause dilation of the pupil.

The surgical navigation system of choice is used, registration is performed, and the accuracy is confirmed (applying the navigation probe to the occlusal surface of the central upper incisors is an effective point to check). Using the navigation probe, a final check of the approach vector is made to confirm the choice and precise location of the surgical portal. The patient’s face is then prepared and draped in the usual sterile fashion. If an optical navigation system is used, a colorless preparation solution should be used to avoid system malfunction, and care must be taken to avoid covering the infrared light-emitting diodes with the drapes.

Three primary transorbital approaches are used to access the MCF: the LRC, ITC, and CPC. These are described below. The SLC and PC approaches are described in Chapter 16. Though the ipsilateral PC approach can be used to access the medial aspect of the cavernous sinus, access to targets lateral to this is obstructed by the orbit and optic nerve.

Orbital endoscopy is carried out in a similar fashion to that of sinus surgery, with standard 4-mm endoscopes with 0- and 30-degree lenses. An irrigating system may be used, but there is often less blood and secretions than experienced with transnasal portals, and this may be unnecessary. To create an optical cavity, malleable ribbon...
retractors are used to gently retract the orbital contents or brain as needed. Minimal pressure is exerted against the globe, and the pupil is regularly checked. If the pupil begins to dilate relative to the contralateral side, all instruments and retractors are removed until symmetry returns. Creation of a pathway within the orbit occurs between the orbital bone and periorbita (periosteum). The plane is dissected with the aid of a Freer suction elevator. The elevator is attached to a soft suction extender rather than directly to the relatively stiff standard suction tubing.

Our preference for creation of the pathway is for the surgeon to hold the endoscope and dissecting instrument; the assistant holds the malleable retractor in one hand and a small skin retractor in the other hand to hold open the portal (Chapter 16, Fig. 16.10). When the target has been reached, the surgeon may wish to operate with bimanual microsurgical technique as described elsewhere (see Suggested Reading).

The technique for creation of the endoscopic transorbital craniectomy depends on the characteristic of the bone, particularly its thickness. For the thin bone of the orbit, a periosteal elevator may be used to gently fracture the bone and then remove the fragments as needed. For thicker bone, such as that of the greater wing of the sphenoid, a drill or ultrasonic bone aspirator is used. We prefer the latter, as the bone aspirator irrigates, ablates bone, and aspirates with one instrument. Furthermore, the tip of the instrument has no tendency to skip off the bone and injure adjacent structures. In addition, it is our impression that the ultrasonic aspirator is less damaging to the underlying dura if the bone is directly transgressed. Our practice is to thin the bone to the point of eggshell thickness, then gently fracture and excise the elements remaining on the dura.

**Medial Quadrant: Contralateral Precaruncular Approach**

The PC approach may be used to access the ipsilateral ACF, the contralateral ACF, and the contralateral MCF. There are times when a CPC approach to the target is preferred, to optimize the angle of target approach for improved visualization and efficacy of manipulation.

This may be the case for lesions involving the cavernous sinus, lateral wall of the sphenoid, optic nerve, and suprasellar regions (e.g., craniopharyngioma). An example of this is shown in Figure 34.6: a meningoencephalocele of the anterolateral sphenoid (Sternberg canal) was treated through a contralateral PC approach when preoperative navigation analysis and virtual endoscopy demonstrated the excellent working and visualization angles of the approach.

The CPC approach is undertaken with the same technique as a PC approach, as described in Chapter 16 (Fig. 34.8). In brief, a PC approach is created in the contralateral orbit. The bone of the medial wall of the...
orbit is removed by ultrasonic aspiration or other technique at the site determined by navigation. The extent of bone removal is dictated by the instrumentation that will be used, creating the smallest necessary corridor. The pathway is then continued through the ethmoid cells crossing posteriorly to the sphenoid sinus adjacent to the pathology. A sphenoidotomy is created, providing access to the appropriate region of the MCF.

Lateral Quadrant: Lateral Retrocanthal Approach

Access to the lateral orbit, lateral ACF, anterior MCF, and infratemporal fossa can be obtained through the LRC approach (Figs. 34.2B, 34.4, 34.8, and 34.9). While numerous techniques of lateral orbitotomy have been described with excision of the lateral orbital rim, the LRC orbitotomy preserves the bone of the orbital rim, and thus does not require extended incisions. Furthermore, though a lateral canthotomy/cantholysis may be performed if the surgeon prefers, no skin incisions are required, and the functional integrity of the lateral canthus is maintained.

A lubricated corneal protector is placed, and the lateral canthus is retracted laterally with a small retractor. An incision is made through the conjunctiva adjacent to the lateral orbital rim (Fig. 34.9). The dissection then follows the posterior aspect of the lateral canthal tendon to its insertion on the medial face of the lateral orbital wall. The incision is extended superiorly as needed, dissecting between the bone and periorbita as described above. In doing so, the lacrimal gland and orbital contents are retracted medially. The incision can be extended as far inferiorly as needed and extended into an IT orbitotomy if desired. The periorbita is lifted off the entire orbital wall under endoscopic and navigation guidance, dissecting posteriorly until the superior and inferior orbital fissures are encountered (Fig. 34.2B). The optic nerve is medial to the confluence of these structures at the orbital apex and will not be visualized unless the contents of the superior fissure are transgressed.

The sphenofrontal suture can be visualized at the superior aspect of the lateral orbital wall. For lateral ACF targets, the craniectomy will be created above this line, as described in Chapter 16. For MCF targets, the craniectomy will be located below the suture. The entire section of greater wing of the sphenoid can be removed between the superior and inferior sutures as needed for access (Fig. 34.2B).
For access to the infratemporal fossa, the thin bone lateral to the sphenozygomatic suture, posterior to the lateral orbital rim is removed (Fig. 34.2B). Navigation is then used to direct the dissection, which occurs between the temporalis muscle and underlying bone.

**Inferior Quadrant: Inferior Transconjunctival Approach**

Access to the inferior orbit is obtained through an ITC approach with the same technique that is used for repair of a fracture of the orbital floor (Figs. 34.5 and 34.9). The approach can be extended laterally into an LRC or medially into a PC portal as needed.

The preseptal IT approach is advantageous in that, by preserving the orbital septum, there tends to be less prolapse of orbital fat into the surgical path. The deep fornix ITC approach has the benefit of leaving a small amount of fat on the lower eyelid and posterior aspect of the septum that may provide a protective layer that shields the lower eyelid. Either approach is effective, though we recommend the latter for less experienced surgeons.

The procedure is begun by placing a lubricated corneal protector. For a preseptal approach, an incision is made 2 to 3 mm inferior to the tarsus on the conjunctival surface of the lower eyelid (6 to 8 mm inferior to the eyelid margin) (Fig. 34.10D). The orbicularis oculi muscle will then be visible. Dissection continues inferiorly between the orbicularis and the septum until the inferior orbital rim is reached. The septum itself is quite thin and difficult to recognize—confirmation of the appropriate dissection plane is obtained by dissecting immediately deep to the orbicularis, and superficial to the orbital fat that is retained behind the septum. To perform an inferior fornix incision, the lower eyelid is retracted anteriorly, and the inferior orbital rim is palpated through the conjunctiva with a periosteal elevator or similar instrument. An incision is then made directly through the conjunctiva onto the orbital rim. This can be done with a scalpel, or a needle-tip Bovie cautery on a low setting.

**FIGURE 34.10** Inferior transconjunctival approach. 
A. supporting structures of the lower eyelid, skin, and orbicularis oculi muscle removed. 
B. Lower eyelid retracted anteriorly. 
C. Preseptal approach to inferior orbital rim. A direct inferior fornix approach (posterior to septum can also be used). 
D. Conjunctiva retracted, bone of inferior orbital rim exposed. Periosteum is incised, and periorbita is then elevated off the orbit floor.
When the orbital rim has been reached, a retaining suture is placed through the edge of the inferior conjunctival flap. This flap is then retracted superiorly over the corneal protector. The peristeum is then incised at the superior aspect of the inferior orbital rim, and a peristeal flap is raised posteriorly. This plane is then dissected posteriorly, and the orbit is entered. Dissection is continued posteriorly, lifting the peri orbital off the orbital floor. When a suitable optical cavity has been developed, a 4-mm 0-degree endoscope is brought into the field and the rest of the dissection is performed under endoscopic visualization. The orbital contents are gently displaced superiorly with a malleable brain elevator. The infraorbital nerve is visualized running through a canal in the orbital floor; there may be thin fascial attachments between the nerve and the overlying orbital contents that are sharply severed. Dissection continues to the orbital apex, bordered laterally by the inferior orbital fissure and medially by the lamina papyracea. To develop the path beyond the orbit to the point of the cranietomy, the orbital bone is removed in the location indicated by navigating along the chosen approach vector to the surgical target. The bone can be removed by gentle down-fracturing if it is appropriately thin. For regions with thicker bone, we use an ultrasonic bone aspirator. Alternatively a fine diamond drill can be used, but care must be taken not to damage adjacent tissue. Dissection then continues along the indicated trajectory to the MCF; the cranietomy is then performed at the appropriate point indicated by surgical navigation. To perform the cranietomy, we use ultrasonic aspiration, thinning the cranial bone to the point of transparency. The bone is then gently fractured and lifted off the subjacent dura. The target is then approached in an intracranial-subdural plane, or with intradural dissection according to the operative plan. The intracranial pathway is often quite short, measuring 3 cm or less. Endoscopic surgical treatment of the pathology is then undertaken always tracking the surgical relationship to the globe and brain.

Reconstruction
The need for reconstruction of the surgical pathway depends on the extent of orbital bone that has been removed, which in turn depends on the location and extent of the underlying pathology. For the lateral approach, the bone that is removed has little role in supporting the globe. If an infratemporal fossa approach is used and temporalis muscle fills the defect, there is no need for reconstruction. If a significant amount of the greater wing of the sphenoid has been removed, the orbital volume may have expanded enough to cause enophthalmos. In this case, a small abdominal adipose tissue graft can be placed within the bone. The bone defect can also be covered with titanium mesh, or a 0.25-mm thick sheet of PDS foil. If the lateral canthus has not been disturbed, we do not close the incision. If a canthotomy and cantholysis has been performed, the canthal tendon is repaired.

If an inferior approach has been used, the defect in the orbital floor is repaired. We typically use a titanium implant manufactured for orbital fracture repair, or PDS foil. If there is no pathology invading the orbital floor, we place and shape the implant to the existing floor before bone is removed so that we precisely match the original contour, then remove the implant until the end of the case. If this is not practical, we complete the reconstruction and then check the position of the implant against the configuration of the original floor using the navigation CT scan. We do not close the incision unless it has been extended into a medial or lateral approach, in which case one or two sutures are placed to align the conjunctiva using 6-0 resorbable suture with inverted technique.

If a contralateral medial orbital approach is used, the medial wall may require reconstruction if the defect is large enough to cause enophthalmos. If this occurs, we reconstruct the defect with a thin titanium fracture implant or PDS foil.

POSTOPERATIVE MANAGEMENT

The same considerations for the postoperative management of patients who have undergone transorbital surgery of the ACF (see Chapter 16) are given to patients who have had surgery of the MCF. The morbidity of the approach itself depends on the length of the procedure and extent of tissue disruption—for the lateral and inferior approaches, it is similar to the repair of an orbital fracture.

The postoperative care is dictated predominately by the treatment of the target pathology rather than the surgical approach itself. Postoperative treatment of the eye is directed at maintaining corneal hydration and minimizing conjunctival edema. Ophthalmologic lubrication is administered at least twice daily for 7 days after surgery. For patients who have had prolonged surgery, we often administer dexamethasone for the first 48 hours to minimize edema. If the procedure was performed for repair of a CSF leak, consideration is given to maintaining a lumbar drain in place if one was used for administration of fluorescein. The head of the bed is typically elevated 15 degrees for 48 hours.

COMPLICATIONS

The transorbital endoscopic approaches have been demonstrated to be safe in a large series of cases (see Suggested Reading). To date, the most significant complication we have experienced has been a corneal ulcer that apparently developed 2 weeks after surgery. The circumstances surrounding this are uncertain, but the patient had had previous LASIK surgery. LASIK surgery has been associated with dry eye and neurotrophic
epitheliopathy. It has been demonstrated to cause loss of corneal sensation, which places a patient at greater risk for corneal damage. We have subsequently performed transorbital endoscopic surgery in this setting, but with meticulous use of postoperative lubrication, we have not had this complication recur. We recommend that patients who have had LASIK be examined by an ophthalmologist before undergoing transorbital surgery.

Postoperative eyelid malposition is also a possible complication of these surgical approaches, as it is with orbitotomy in general. Though we have not had this complication occur in this patient population, we take great care to perform incisions precisely and do not use cautery near the margin of the eyelid. We avoid traction on the eyelids. As mentioned, the inferior fornix IT approach appears to be somewhat safer than the PS approach for the lower lid and should be used by less experienced surgeons.

Though none of our patients have suffered visual loss from transorbital endoscopic procedures, the pupil is regularly checked during surgery. If the pupil begins to dilate, the instruments should be removed from the orbit until the pupil returns to symmetry with the contralateral pupil. This typically occurs within several minutes. During surgery, the globe must remain well lubricated, and instruments should be passed in and out of the orbit carefully to protect adjacent structures.

Use of the ultrasonic bone aspirator carries a theoretical risk of thermal damage to the adjacent tissue. This risk appears to be mitigated by the continuous irrigation that is provided by the instrument, as well as the insulating sheath that covers the shaft of the instrument. The surgeon must be certain that the irrigation is sufficient and that the sheath is in place and intact at all times.

**RESULTS**

Transorbital approaches to the MCF are a recent development with applications that appear to be expanding, particularly with the advent of newer technologies such as ultrasonic bone aspiration. As instruments develop to allow the performance of multiple functions such as ablation, irrigation, and aspiration with a single apparatus, we have begun to move from the concept of “four-handed surgery” to “four-function surgery” and beyond. By empowering each surgeon to perform multiple functions synchronously, it is possible to diminish the number of instruments in each portal, and thereby decrease the cross-sectional area of each pathway. Decreasing the number of instruments in a given portal, each of which is transported to the target and back multiple times, it is also possible to diminish the amount of collateral trauma that occurs within and adjacent to the surgical pathway. The availability of flexible endoscopic surgical systems will be a critical advancement as we continue to strive toward minimally disruptive surgery.

The varied approaches described in this chapter can provide access to a large region of the base of the MCF, extending from the cavernous sinus to the infratemporal fossa. They can be used in a monoportal or multiportal strategy, depending on the location and characteristics of the target as well as the surgeon’s preference. Preoperative surgical planning is critical to assure the safety and success of the procedure.

As described above, appropriate care is taken to prevent injury to the globe and the brain. The transorbital pathways follow along natural planes of dissection within the orbit, between the periorbita and bone. The available trajectories parallel the bone of the orbit; intraorbital dissection is done to allow an optical cavity no greater than necessary for the introduction of a 4-mm endoscope, and the pressure needed to maintain this pathway with a ribbon retractor is minimal. Once the dissection passes beyond the orbit on the path to the pathology, no retraction on the orbital contents is required beyond the volume of the instruments themselves. Meticulous attention during intraoperative navigation keeps us cognizant of our relationship to critical structures of the cerebrum.

The skill set used in transorbital endoscopic surgery is a hybrid of the techniques used in endoscopic sinus surgery, open cranial base surgery, and orbital trauma surgery. Arguably, there are few residencies that currently provide training in all of these areas, the additional techniques can be learned during fellowship training or by individual study and by attending a cadaveric dissection course, depending on the surgeon’s background. Surgical teams should include members skilled in neurologic surgery, facial plastic/head and neck surgery, and ophthalmology. Cases should be presented for discussion at a multidisciplinary skull base tumor conference before and after surgery.

We have had favorable outcomes using these endoscopic routes for pathology ranging from malignant tumors to CSF leaks and fractures. We have not failed to reach the pathology and the access provided has allowed adequate and safe manipulation of the surgical targets. The postoperative recovery time has been rapid, with minimal pain; the scars are not visible. There is no subcutaneous hardware that can become palpable, visible, or painful over time.

**PEARLS**

- Complete preoperative analysis of the pathology, location, and the extent of disease is critical, including CT and MRI imaging and three-dimensional analysis on a navigation station. A metastatic evaluation may be required to confirm a solitary lesion prior to surgery.
Pathway planning is completed preoperatively, including the choice of monoportal or multiportal access, location of the surgical portals, and necessary instrumentation to complete the procedure. The method of reconstruction, if any, should be considered.

A detailed list of the necessary surgical instrumentation should be provided to the OR staff in advance of the operation. This should include all powered instrumentation, skull base, orbital and sinus instruments, adhesives such as fibrin glue, and reconstruction materials such as allografts and implants.

**PITFALLS**

- These procedures are complex and may involve skill sets that are new to a surgical team. If this is the case, the surgeons should attend an appropriate course or learn the techniques in a cadaver laboratory as needed.
- It is highly beneficial to have a dedicated team of operating room staff who consistently participate in these procedures. The team should understand the steps of the procedure and be familiar with the nomenclature, operation, and troubleshooting of all instruments. We aim to avoid turnover of staff during critical portions of the operation.
- Before performing new approaches, or if uncertain of the access provided by possible approaches to a particular location, the surgeon should perform the procedure in a cadaver laboratory preoperatively.

**INSTRUMENTS TO HAVE AVAILABLE**

- Complete endoscopic skull base instrument set with malleable suction cannulae, suction Freer elevators, malleable brain retractors, endoscopic bipolar cautery; soft suction extenders to attach to instruments
- Oculoplastic set with retractors, corneal protectors, lacrimal dilator, and probes
- High-quality endoscopes (0 and 30 degrees) with high-resolution monitors, preferably suspended from ceiling in ergonomic positions
- Endoscope irrigation system
- Endoscopic microdebrider
- Drill with diamond burr or, preferably, ultrasonic bone aspirator (Sonopet)
- Radiofrequency soft tissue aspirator (Coblator)
- Surgical navigation system with vector analysis and lesion highlighting (segmentation) software
- Intraoperative CT scanner (useful but not critical)
- Cranial bone drills and microsurgical sets (as back-up but not opened on the table)

**SUGGESTED READING**


INTRODUCTION

The clivus has traditionally been broken into “thirds,” segmented by neural foramina and requiring different open approaches or variations depending on tumor extension into each third. From an endonasal perspective, the upper third of the clivus includes the bone superior to the floor of the sella and extends from the posterior clinoids and dorsum sellae to the abducens nerve in Dorello’s canal. Traditionally, an orbitozygomatic or anterior transpetrosal or Kawase approach is required to access this region. Obviously, the pituitary gland is the critical structure associated with the upper clivus and must be handled carefully regardless of approach to avoid endocrine dysfunction. From an anterior, endonasal approach, this requires some degree of pituitary “transposition” depending upon extension of the tumor and the patient’s anatomy.

HISTORY

Tumors that involve or are associated with the upper clivus can cause a variety of symptoms or none at all. Diplopia from involvement of Dorello’s canal (abducens nerve) is a common presenting symptom for chondroid tumors (chordomas/chondrosarcomas); lateral extension of tumors such as petroclival meningiomas could also affect the oculomotor nerve. Facial numbness, paresthesias, or pain from involvement of the trigeminal nerve, though rare, can occur. Dural distension can lead to headache or retro-orbital pain. Mass effect upon the brain stem and midbrain from intradural extension can cause symptoms ranging from ataxia, quadriparesis, and dysphagia to decreased consciousness.

Despite its intimate association, most tumors treated with this approach do not present with pituitary dysfunction. The exception to this is the craniopharyngioma, which often presents with some degree of hypopituitarism or diabetes insipidus (DI), even if subtle. Careful questioning for symptoms such as increased urination, fatigue, decreased libido, and weight gain can usually reveal these deficits. Baseline testing of pituitary function is important even in the absence of symptoms. Tumors with significant suprasellar extension can cause vision loss, with a typical bitemporal pattern. Obstruction of the third ventricle outflow or even the foramina of Monroe can result in subacute hydrocephalus with associated symptoms of headache, visual loss, cognitive dysfunction, and ataxia.

PHYSICAL EXAMINATION

The upper cranial nerves should be thoroughly evaluated, especially function of the extraocular muscles. Facial sensation in each division of the trigeminal nerve including both pinprick/temperature and light touch can be
tested quickly and easily. Full neuro-ophthalmologic evaluation, including visual field and acuity testing can detect suprasellar extension with optic nerve or tract compression. Examination of the optic fundus can reveal papilledema associated with hydrocephalus; optic atrophy with pallor of the disk is a late finding of optic nerve compression or prolonged papilledema.

Full gait and reflex testing should be performed to pick up long tract signs in large tumors with brain stem compression. Hormonal effects can manifest as skin pallor, hair loss, and rarely galactorrhea.

**INDICATIONS**

Tumors that can be accessed employing this approach include bony neoplasms such as chordomas and chondrosarcomas, dural tumors with intradural extension such as clival or medial petroclival meningiomas, and intradural tumors such as craniopharyngiomas and granular cell tumors with retroinfundibular growth. Chondroid lesions tend to grow in the bone or interdural space into the upper clivus. Adding an extra- or interdural pituitary transposition to a transclival approach for meningioma will allow access to the superior aspect of tumors, which extend behind or even above the dorsum sellae (Fig. 35.1). Rare infundibular tumors with purely retroinfundibular extension can be accessed via an intradural transposition, though these tumors often have compromised pituitary function pre- or postoperatively due to the intrinsic involvement of the stalk. Sacrifice of the pituitary gland can be considered, especially with preexisting panhypopituitarism as this is very unlikely to recover.

Tumors that are intimately involved with the posterior cerebral arteries (PCAs) can be difficult to safely dissect without adequate exposure of the capsule of the tumor. Removal of the dorsum sellae or complete gland transposition provides excellent exposure and access to this region. Rare basilar or PCA aneurysms could be accessed as well (Fig. 35.2), though this requires significant experience and very careful patient selection.

**CONTRAINDICATIONS**

Sinus infection is a contraindication to endonasal intradural (or potentially intradural) tumor resection. However, this can usually be cleared in a short period of time, with antibiotics, surgical drainage, or a combination of therapies. Otherwise, there are no absolute contraindications, though care must be taken to evaluate the relationships of the upper cranial nerves to the mass, especially when it originates laterally such as a petroclival meningioma. If the majority of cranial nerves are displaced medially, a lateral or posterolateral approach is preferable.

Finally, the pituitary transposition approach requires the use of angled endoscopy and a comfort level with management of the cavernous and intercavernous sinuses, basilar venous plexus and the paraclival, and parasellar internal carotid artery (ICA) and its branches. This requires a surgical team with significant prior experience performing endoscopic skull base surgery.

**PREOPERATIVE PLANNING**

Both magnetic resonance imaging (MRI) and computed tomography angiography (CTA) are important in planning any clival approach. They provide complementary information: MRI shows specific tumor characteristics that may narrow the differential diagnosis and demonstrates the relationships of the nerves to the tumor
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(epecially with FIESTA or fine-cut T2 imaging); CTA reveals bone involvement in the form of erosion or hyperostosis and ICA and basilar artery relationships. It is especially critical to evaluate the size and height of the posterior clinoid processes (PCPs). If there is any sign of calcification of the dural ring or petroclinoidal ligament, dissection behind the ICA can result in potential disaster if this calcified spike is unknowingly manipulated into the artery.

Both MRI and computed tomography (CT) should also be closely examined for signs of sinus infection or other associated sinonasal pathology.

Hormonal evaluation with a full pituitary panel should be performed to document and treat preoperative dysfunction and provide baseline levels for comparison following surgical manipulation of the gland.

Preoperative treatment with corticosteroids is useful for patients with new or progressive neurologic deficits. A full course of antibiotic therapy with careful preoperative reevaluation for clearance of infection is important in patients with identified sinusitis.

SURGICAL TECHNIQUE (SEE VIDEO 35.1)

The superior clivus can be approached endonasally in one of the three ways: extradurally, interdurally, and intradurally. These approaches provide an increasing degree of access to the upper clivus as well as increasing risk of pituitary dysfunction. Both factors should be balanced for optimal tumor management. A purely extradural dissection has almost no risk of permanent pituitary failure but provides limited exposure in cases of extensive clinoid involvement or a “tall” dorsum sellae, whereas an intradural transposition allows complete, unencumbered access to the dorsum, clinoids, and perimesencephalic cistern but may carry a high risk of hypopituitarism from loss of venous drainage and manipulation of the gland.

As with any endoscopic endonasal approach, the surgery is performed by a surgical team consisting of an otolaryngologist and a neurosurgeon. The patient’s head is typically fixed in headpins to prevent inadvertent movement with the head slightly extended and rotated toward the surgeons. The nasal cavity is decongested with oxymetazoline-soaked pledgets immediately following induction. After image guidance is registered, the midface and abdomen (in the rare likelihood of needing an adipose tissue or muscle graft) are prepped and

FIGURE 35.2
A. Preoperative CTA showing a three-dimensional reconstruction view of a large PCA aneurysm causing an oculomotor nerve palsy. B. Intraoperative view of the aneurysm before clipping. C. Intraoperative view of the aneurysm after clipping. Intraoperative angiogram showing complete obliteration of the aneurysm and patency of normal basilar apex branches.
draped. A third- or fourth-generation cephalosporin or equivalent coverage for nasal flora with cerebrospinal fluid (CSF) penetration is given for antibiotic prophylaxis.

Reconstructive needs should be considered prior to the exposure. Reconstruction with a vascularized nasal septal flap must be decided upon and performed prior to a transclival approach as the flap pedicle overlies the sphenoid rostrum, which must be removed to access the midclivus. If there is risk of an intraoperative CSF leak or if there is need for ICA exposure, a flap should be harvested and placed either in the nasopharynx or in the maxillary sinus (if mid or lower clival exposure is needed). The exposure of the upper clivus is essentially identical to a pituitary/sellar exposure with wide sphenoidotomy, extending from the planum/tuberculum to the clival recess and wide opening of the lateral recesses of the sphenoid. In order to safely mobilize the gland superiorly, the entire face and floor of the sella as well as the tuberculum sellae must be removed to prevent compression of the gland when it is elevated. The sellar exposure should extend as far laterally as the medial cavernous sinus to allow adequate mobilization and access to the dura overlying these sinuses. In the case of an interdural or intradural transposition, exposure of the medial ICA should also be performed as the inferior hypophyseal artery will need to be controlled.

For tumors of the clivus with superior extension, the midclivus should generally be drilled prior to proceeding with pituitary transposition. An extradural transposition begins with careful dissection of the dura from the dorsum sella, starting in the midline at the floor of the sella (Fig. 35.3). Depending on the height of the dorsum, an extradural dissection will be adequate to reach the superior edge of the dorsum in the midline, typically the lowest point of the top of the clivus, which extends superiorly out to the PCPs. This area is generally thin and can be removed with a Kerrison rongeur as long as the deep plane with the dura is carefully respected. Inevitable bleeding from the inferior intercavernous sinus and basilar plexus can be controlled with embolization of morselized Gelfoam (Surgifoam, Floseal, Surgiflo, etc.), sometimes repeatedly. The dissection required for a transposition often requires visualization with an angled (45-degree) endoscope. This provides a better view while limiting the degree of gland manipulation.

As noted, the PCPs are generally slightly superior to the rostral dorsum sellae. In addition, the lateral attachment of the dura of the floor of the sella (the inferior leaf of the inferior intercavernous sinus) to the cavernous sinus takes a slight downturn. This combines to limit access to the tip of the PCP, where the dural ring extending around the ICA attaches. Extreme care must be taken in detaching this dural attachment. If the PCP is shallow and there is no calcification of the dural ring, the PCP can be peeled relatively easily from just behind the ICA without further exposure. However, in many cases, further exposure is necessary for safe removal. This can be accomplished with an interdural dissection (Fig. 35.4). The outer leaf of the inferior intercavernous sinus is opened at its point of attachment to the medial cavernous sinus. Once the venous bleeding is packed off, this triangular space, bounded medially by the wall of the medial cavernous sinus and laterally by the medial parasellar ICA, provides much wider access to the posterior clinoid. The inferior hypophyseal artery, which does not provide critical supply to the gland, crosses the mid portion of the PCP and should either be sacrificed or carefully dissected from the PCP and preserved. Preoperative identification of a calcified dural ring, petroclinoidal ligament, or dural attachment is critical to avoid manipulating this bony spike into the ICA, resulting in injury. If this spike is identified, it should be disconnected (with a Kerrison rongeur, drill, or ultrasonic bone aspirator).

The exposure provided by the interdural dissection allows careful protection of the ICA with a suction tip while the dural attachments to the PCP are dissected and the process removed either piecemeal or en bloc. This can be done with a Kerrison rongeur, drill, or ultrasonic bone aspirator. If an interdural transposition is performed bilaterally, the entire inferior intercavernous sinus and both medial cavernous sinuses are thrombosed, leaving the superior and lateral cavernous sinuses for drainage of the gland. In addition, the inner dural layer, composed of the inner leaf of the inferior intercavernous sinus and the medial wall of the cavernous sinus, provides protection to the adenohypophysis.

**FIGURE 35.3**
Endoscopic endonasal view showing the initial step of extradural pituitary transposition, elevation of the dura from the floor of the sella (S), and dorsum sellae.
By comparison, an intradural transposition (Fig. 35.5) requires sacrifice of both superior and inferior intercavernous sinuses as well as disconnection of the gland laterally from the medial cavernous sinuses and posteriorly from any drainage provided via the dural plexus overlying the dorsum sellae. This, in addition to the mobilization of the stalk and superior hypophyseal arteries, leads to a significant increase in the risk to the function of the adenohypophysis. With any type of transposition, care must be taken not to directly damage the neurohypophysis (posterior pituitary gland).

As previously noted, intradural transposition begins with ligation of the superior intercavernous sinus (SIS). The simplest method is to make a small horizontal incision above (suprasellar) and below (over the gland) the sinus and carefully coagulate across it before cutting it. Care should be taken not to inadvertently coagulate a superior hypophyseal artery. Once the SIS is cut, the incision can continue across the diaphragma up to the stalk, completely releasing it from its aperture in the diaphragma. At this point, the lateral gland can be dissected from the medial cavernous wall. Care should be taken to identify the fibrous capsule of the gland and sharply dissect it from the medial cavernous wall by cutting the fibrous bands connecting the two. Inevitably, cavernous bleeding will need to be packed off. The gland is usually relatively easily dissected from the dura on the floor of the sella, leaving only the dorsum dura to dissect before the gland can be lifted in entirety from the sella and placed either on the planum or in the suprasellar space. The opening of the diaphragma to the stalk must be completed to allow full mobilization.

Once the gland is fully mobilized or the dura of the dorsum is opened behind a partially mobilized gland, the intradural view is unparalleled (Fig. 35.6), revealing the mammillary bodies, basilar apex, oculomotor nerves, and deep surface of the stalk. This access allows safe dissection of the upper basilar artery and branches from the deep surface of tumors. In addition, resection of retroinfundibular or hypothalamic tumors can lead to entrance into the third ventricle.

Once tumor removal is complete, the gland should be replaced into its native position. Even if nonfunctioning, it does provide tissue to help seal a dural defect, and theoretically, the gland has a much better chance of normal function if residing in its “normal” location. Any clival dural defect should be repaired with a vascularized flap whenever possible.
POSTOPERATIVE MANAGEMENT

Naturally, pituitary function must be monitored following pituitary transposition. Even when the dissection is extradural, there is risk for transient DI from manipulation of the gland. If the patient is not on steroids, a cortisol level can be checked each morning to evaluate for adrenal insufficiency (AI). In the absence of DI or AI, other hormone dysfunction is unlikely. Nevertheless, delayed full hormone evaluation should be performed in all patients who undergo a transposition.

When there is a dural defect, packing is left in place for 5 to 7 days while the patient stays on antibiotics (broad-spectrum IV for 48 hours and then oral cephalosporin or equivalent). Upper clival defects carry a high risk of postoperative CSF leak due to significant dural defects associated with arachnoid cistern dissection or even entry into the ventricle. While the role of lumbar drainage is not well studied, these defects should be considered for short-term CSF diversion. As with any endonasal surgery, postoperative precautions such as orders forbidding nasal instrumentation, positive pressure ventilation, and nose blowing should be followed closely. In addition, head of bed elevation and stool softeners (to avoid straining) should be continued even after discharge. Nasal saline irrigation is used in the early postoperative period but should be temporarily discontinued if there is a question of a CSF leak.

COMPLICATIONS

The two major complications of pituitary transposition are pituitary dysfunction and CSF leak. The rates of both for this approach are not well documented and vary depending on degree of transposition and size of defect and extent of dissection, respectively.

The dissection of the ICA required for removal of the PCPs places the ICA at significant risk. Angled endoscopy can improve the view during this dissection, but constant care must be taken to avoid injury. Preoperative identification of a calcified dural ring or attachment to the PCP that could result in ICA puncture is critical to avoid this as a source of injury.

RESULTS

Pituitary transposition is not well studied. Kassam et al. presented the first 10 cases performed with reasonable results, but this was a mixture of intra- and extradural transpositions. This experience has been expanded, and it seems that extradural or interdural transpositions are very effective in achieving significant increase in exposure and access with negligible rates of hypopituitarism. By comparison, intradural transpositions carry a very high rate of pituitary dysfunction, though this is complicated by the fact that this approach is used almost exclusively for tumors that involve the pituitary stalk directly. Nevertheless, we use the intradural transposition very sparingly due to concern for loss of venous drainage and resultant dysfunction.

PEARLS

- The addition of a pituitary transposition is critical for access to areas behind the pituitary gland.
- Removal of the planum and tuberculum prevents compression of the gland during transposition.
- Reconstruction with a vascularized flap decreases the risk of a postoperative CSF leak.
- Use of an angled (30- or 45-degree) endoscope during dissection and dorsum sellae and posterior clinoid resection can increase safety and limit the amount of gland elevation.
CHAPTER 35 Endoscopic Endonasal Pituitary Transposition Approach to the Superior Clivus

PITFALLS

- Intradural transposition should be avoided when possible due to loss of pituitary function.
- Identification of a bony spike on the PCP as a result of calcification of the dural ring or attachment is critical to avoid ICA injury.

INSTRUMENTS TO HAVE AVAILABLE

- A full set of sinus instruments, high-speed drill, and 0- and 45-degree endoscopes are used for the exposure. A microdebrider may facilitate sphenoidotomy.
- Fine and angled-tip, pistol-grip bipolar (Storz) are critical for extra- and intradural hemostasis. Extended tips or Luer lock suctions (without holes) are needed to deliver morselized Gelfoam products (Surgifoam, Floseal, Surgiflo).
- Extendable tip neurodissectors (KLS Martin) and fine, pistol-grip microscissors (Storz) are critical for intradural tumor dissection.
- CUSA (Integra) and Sonopet (Stryker) ultrasonic aspirators both come with extended and bone cutting tips for endonasal use and can be invaluable for fibrous tumors and PCP removal.

SUGGESTED READING

INTRODUCTION

The clivus is the anterior portion of the occipital bone and adjoins the petrous and sphenoid bones via synchondroses that gradually ossify throughout childhood and early adulthood. The clivus is typically divided into thirds based on neural foramina, as these determine the surgical approach (orbitozygomatic vs. transpetrous vs. far lateral). Given its midline location, endonasal approaches provide seamless access to the entire clivus with their lateral extension determined by neural foramina. Typically, the superior clivus is separated from the mid and lower clivus by Dorello’s canal, which transmits the abducens nerves from the intradural space, dorsal to the paraclival internal carotid artery (ICA), into the lateral cavernous sinus. From an endonasal viewpoint, this occurs at approximately the level of the midpoint of the paraclival ICA, halfway between foramen lacerum and the sella. A more practical division for endonasal approaches is to define the middle clivus as the bone between the floor of the sella and the floor of the sphenoid sinus while the inferior clivus extends from the floor of the sphenoid (at the level of the pterygoid “wedge”) to the foramen magnum.

Regardless of classification, the clivus makes up the pure midline of the inferior skull base, and as such, lesions that arise from it or its adjacent tissues, such as nasopharyngeal mucosa and dura, are ideally suited for an anterior approach such as the endoscopic endonasal approach (EEA). The limitations of this approach are the surrounding neurovascular structures and the surgeons’ experience, anatomical knowledge, and resources.

HISTORY

Headache and diplopia are the two most common symptoms caused by tumors arising from the clivus. Since the clivus is part of the occipital bone, tumors involving this bone typically present with purely occipital pain, though the headaches can be generalized or frontal. Bone tumors classically cause pain that is worse at night, even awakening the patient from sleep. Lesions such as meningiomas that involve or distend the dura or arachnoid can also cause headache of variable character. However, one must be careful about attributing headache to clival tumors, especially if small or otherwise asymptomatic. Lateral extension to Meckel’s cave or distension of the cisternal segment of the trigeminal nerve can cause retro-orbital pain or trigeminal neuralgia/neuropathy, respectively.

An abducens palsy with variable degrees of subjective or objective diplopia is a classic presentation for chordoma or chondrosarcoma. These tumors grow within the bone or interdural space, compressing or filling Dorello’s canal and thus causing nerve dysfunction. Intradural extension of clival tumors with brain stem compression can lead to gait dysfunction, swallowing difficulties, and even decreased mental status and hydrocephalus. Hearing loss and facial palsy can be signs of lateral extension to the petrous bone. Origination from or extension to the nasopharynx can lead to nasal airway obstruction, hyponasal speech, and epistaxis.
PHYSICAL EXAMINATION

A complete examination of the cranial nerves is critical in patients with clival tumors since these tumors can affect practically every cranial nerve depending on their size and extension. It is especially important to examine eye movement (CN III, IV, and VI) and palatal (CN IX and X) and tongue function (CN XII). Gait and swallowing function should be closely assessed as these can significantly affect patient recovery. Laryngoscopy to identify vocal cord paresis as well as a barium swallow evaluation should be performed in patients with a history of dysphagia or voice changes. Nasal endoscopy can identify masses with significant sinonasal involvement and occasionally provide for biopsy in appropriate settings such as sinonasal malignancy. This should be avoided in excessively vascular tumors or chordomas that have a potential for seeding. All patients should receive a complete examination of the head and neck to palpate for signs of cervical metastases or cervical extension.

INDICATIONS

Any tumor whose epicenter or origin is the clivus or associated structures can be approached endonasally. Given a midline origin, these tumors will displace surrounding neurovascular structures laterally, allowing direct access to the tumor through the paranasal sinuses without manipulation of these critical structures.

Chordomas are one of the best examples of a tumor with a midline origin that are ideally suited for an endonasal approach, the vast majority of which can be completely removed endonasally. Chondrosarcomas often

FIGURE 36.1 A. T1-weighted postcontrast axial MRI. B. CT angiogram sagittal reconstruction demonstrating a primarily clival meningioma with midline origin and dural base. Following endoscopic endonasal resection, only a small, paramedian residual is left. C. Postcontrast axial. D. Sagittal T1-weighted MRI.
involve the midline clivus but with their typical paramedian origin at the petroclival synchondrosis, each must be individually assessed and may require a combination with another approach (retrosigmoid, transpetrous, or orbitofrontal) for complete removal. Similarly, petroclival meningiomas have very variable epicenters. Purely or mostly clival meningiomas can be addressed with endoscopic endonasal surgery (EES) (Figs. 36.1 and 36.2), whereas purely or mostly petrous tumors cannot. The majority fall somewhere in between, and their relationship to associated cranial nerves (best visualized with FIESTA MRI sequences) determines the best approach (or combination of approaches).

Care should be taken to properly define the differential diagnosis of clival lesions. The diagnosis of benign fibro-osseous lesions such as fibrous dysplasia can usually be made radiographically, with their classic “ground...

**FIGURE 36.2**

A. T1-weighted postcontrast sagittal. B. axial MRI demonstrating a primarily clival meningioma with midline origin and dural base. Following endoscopic endonasal resection, the clival location allows for complete resection demonstrated on (C) immediate postoperative postcontrast axial and (D) sagittal T1-weighted MRI. Note enhancing nasoseptal flap used for reconstruction (*dashed arrow*). E. T2-weighted, axial MRI showing the typical, hyperintense “bubbly” appearance of a clival chordoma (*arrow*).
glass” appearance, so that intervention can be avoided. Rare exceptions include progression with optic or cranial neuropathy, usually in children or adolescents and associated with cyst formation. Rarely, pituitary adenomas erode into and invade the clivus primarily, rather than extending into the suprasellar space. Extending a sellar exposure into the mid and even inferior clivus is required for complete removal of such tumors.

Nasopharyngeal cancers are usually advanced at the time of presentation and are treated primarily with radiation therapy. The primary role of surgery is biopsy for diagnosis and debulking of tumor to relieve symptoms prior to radiation therapy. Exceptions include small tumors that can be completely resected with adequate margins. For adenoid cystic carcinoma, the goal of surgery is maximal removal with minimal morbidity, followed by radiation therapy. It is not possible to achieve clear resection margins with adenoid cystic carcinoma of the skull base due to perineural spread, and the extent of surgery is limited by the surrounding neural and vascular structures. Surgical salvage of residual tumor following radiation therapy is of potential value for local control and should be considered based on posttreatment functional imaging with PET–CT or the results of biopsies.

**CONTRAINDICATIONS**

Tumors originating in the lateral skull base but extending medially will displace critical neurovascular structures medially, into the path of a midline approach such as an EEA. This remains the major contraindication to EES. Sinus infection is a transient contraindication to intradural (or potentially intradural) surgery that should be treated with antibiotics with or without surgical drainage as indicated before proceeding.

**PREOPERATIVE PLANNING**

Magnetic resonance imaging (MRI) and computed tomographic angiography (CTA) are complementary, and it is important to obtain both to help determine preoperative differential diagnosis. For example, MRI illustrates the typical heterogeneously hyperintense T2 “bubbles” of a chordoma or chondrosarcoma (Fig. 36.2), while CTA illustrates bony erosion, ICA stenosis, or occlusion and identifies benign fibro-osseous lesions such as fibrous dysplasia (that can appear very ominous on MRI). With meningiomas, MRI will show the dural tail while CTA illustrates the vascular relationships and degree of bony involvement or hyperostosis (Figs. 36.1 and 36.2).

**SURGICAL TECHNIQUE (VIDEO 36.1)**

All surgeries are performed by a team consisting of an otolaryngologist and a neurosurgeon performing a two-surgeon, three- or four-hand technique. This allows for appropriate care of both sinonasal and neural structures as well as critical dynamic endoscopy and bimanual microsurgical techniques. Additional benefits include improved problem solving (“copilot”) and efficiency.

Most patients are placed in three-pin head fixation with the head in a neutral or slightly extended position and rotated toward the side where the surgeons stand. This allows for precise positioning to optimize surgical ergonomics as well as prevent movement during critical portions of the operation. Registration of the navigation system is performed, and nasal decongestion with topical oxymetazoline (0.05%) is achieved. The external nose and nasal vestibule are prepped with an iodine solution, and perioperative antibiotic prophylaxis is provided with a third-generation cephalosporin.

Nasal endoscopy is performed with a 0-degree endoscope, and the turbinates are laterialized to provide greater access to the nasopharynx. The inferior portion of the middle turbinate is typically resected to provide room for endoscopy. If a dural defect is anticipated, a septal mucosal flap is elevated on the side contralateral to the bulk of the tumor and is placed into the maxillary sinus through a middle meatal antrostomy for storage during the surgery. The posterior septum is detached from the sphenoid rostrum, and the rostrum is resected to provide binarial access to the sphenoid sinus. The sphenoidotomy is maximized to provide full access from the sella to the floor of the sinus and lateral to both internal carotid arteries. Sphenoid septations are removed with bone rongeurs and drilling, and landmarks are identified with special attention to the course of the paracaval carotid arteries.

Fascia is elevated from the inferior margin of the sphenoidotomy, and the medial pterygoid plates are exposed bilaterally. The inferior portion of the clivus is exposed by resecting the nasopharyngeal mucosa and basopharyngeal fascia. This can be done either with a microdebrider or with monopolar electrosurgery (needle tip or suction). Care should be taken to evaluate the course of the parapharyngeal ICA as it can become ectatic and loop medially at its most inferior (proximal) aspect. This is rarely an issue, but when it is, dissection of the fascia from the bone should occur in the subperiosteal plane, deep to the artery. Laterally, the supracyclindylar groove should be identified. This is a ridge of bone to which the fascia of the rectus capitis anterior muscle attaches; it reliably predicts the location of the hypoglossal canal.
Once the basopharyngeal fascia has been removed from the sphenoid floor to the foramen magnum, drilling of the entire clivus can be performed. The floor of the sphenoid represents the most prominent portion of the clivus and should be drilled to the depth of the clival recess. The initial width of this bone removal should be limited to the paracloival ICAs to prevent inadvertent injury. These are usually easily identifiable in a well-pneumatized sinus by their bony protuberances (Fig. 36.3). If they are not, their location can be verified by dissecting in the extradural space along the floor of the sella laterally until the downturn of the ICA as it enters from the paracloival segment is visualized.

Once the floor of the sphenoid, the thickest portion of the clivus, has been drilled to the depth of the clival recess, the entire clivus is drilled to the depth of the inner cortex, which can be further thinned with the drill and removed with a Kerrison rongeur. The exposure should be extended as widely as possible to the paracloival ICA in the midclivus and to the medial eustachian tube in the lower clivus. The dura of the clivus has two layers (periosteal and meningeal) between which lies a very impressive venous plexus that must be managed before opening the inner layer. The bleeding can usually be packed off with flowable Gelfoam (e.g., Surgifoam, Floseal, Surgiflo) or other hemostatic materials. Careful stripping of the entire periosteal layer allows final packing of this plexus at its lateral margin and exposure of the inner, meningeal layer for more careful, controlled opening into the intradural space.

The vertebrabasilary system and abducens nerves are the key neurovascular structures associated with the mid and lower clivus and should be identified when possible with image guidance and electromyography, respectively (Fig. 36.4). The abducens nerve is at greatest risk with an endonasal approach and, because of its long course and association with multiple spaces, can have relationships with tumors that are difficult to predict. Chordomas typically displace the intradural segment posteriorly and laterally, but their tendency to invade the interdural space predisposes them to extend into Dorello’s canal. This can make identification of this portion of the nerve very challenging, and nerve involvement can make it impossible to preserve at times. Petroclival meningiomas can displace the abducens nerve in any direction, depending on their origin and growth pattern. Electromyographic stimulation of the overlying dura prior to opening into tumor can provide reassurance that the nerve is not interposed between the dura and tumor capsule and hopefully prevent nerve transection as part of the dural opening. If the origin of the nerve intradurally can be identified early, a “starting threshold” lowest limit of stimulation voltage or current can be established. If this is preserved throughout surgery, any palsy that may develop will be transient.

As with all intradural tumor resection, standard microsurgical dissection techniques should be employed. This is accomplished with extended endonasal instruments fashioned after open microsurgical dissectors and pistol-grip microscissors (see, Instruments section). The advantage of the EEA is that it can be used for tumors that directly abut or originate from the clivus. Therefore, these tumors are entered directly, and intradural tumors should be completely debulked internally prior to extracapsular dissection. Gentle countertraction with a teardrop-slotted suction will allow for blunt and sharp dissection of arachnoid bands or scar that are adherent to the tumor and neurovascular structures.

Reconstruction should be considered at the onset of the approach in order to preserve all reconstructive options. Clival defects without violation of the dura or significant exposure of the carotid arteries do not require reconstruction. In these cases, application of fibrin glue provides temporary protection of the surgical site and may promote healing. When repair of a dural defect or coverage of an exposed carotid artery is

![Endoscopic endonasal view of the clivus with a well-pneumatized clival recess (CR) allowing for easy identification of the paracloival internal carotid arteries (ICAs) (arrows). (S, sella; CP, carotid protuberance [parasellar]; ON, optic nerve.)](c) 2015 Wolters Kluwer. All Rights Reserved.
necessary, reconstruction with vascularized tissue is preferred. The dural defect is first repaired with an inlay collagen or fascial graft (e.g., allogenic dural substitute, cadaveric fascia, or autologous fascia lata) placed intradurally. Primary reconstructive options include a nasoseptal flap (see Chapter 42) or inferior turbinate flap (see Chapter 44). The nasoseptal flap is generally preferred due to the ease of dissection, minimal donor site morbidity, size, and wide range of rotation. It may be insufficient, however, for a deep or caudal clival defect. The coverage of the flap can be augmented by filling the clival defect with an autologous adipose tissue graft prior to placing the flap. Adipose tissue is also useful to bolster the reconstruction and prevents herniation of the brain stem into the defect. In this situation, care must be taken to ensure that the flap is in contact with normal mucosa or bone circumferentially to allow for healing. The rotation of the nasoseptal flap for a midclival or lower clival defect is more horizontal, and the width of the flap may be insufficient for the vertical dimension of the defect. This need is anticipated by extending the flap incisions to include the mucosa of the nasal floor, resulting in a wider flap. In addition, an onlay fascial graft can be placed to cover the entire defect, deep to the flap. An inferior turbinate flap is a useful option when a nasoseptal flap is not available due to prior surgery or tumor involvement of the vascular pedicle. The coverage area of an inferior turbinate flap can be augmented by including the mucosa of the nasal floor and even the ipsilateral nasal mucosa. When these flaps are not available, secondary options include an extracranial pericranial flap (see Chapter 46) or temporoparietal fascial flap (see Chapter 45).

**POSTOPERATIVE MANAGEMENT**

The usual postoperative precautions are taken following any intradural EEA. Transclival approaches are particularly at risk for catastrophic injury during passage of nasogastric tubes. If necessary, placement of a feeding tube should always be performed under direct endoscopic visualization to avoid disruption of the repair and passage of the tube intracranially. Signs to that effect should be placed at the patient’s bedside. Patients are cautioned to avoid nose blowing, bending over, or straining. Stool softeners are prescribed, and family members are advised to assist with any lifting. Sneezing is done with an open mouth to avoid the accompanying increase in intracranial pressure.

The role of lumbar drainage is not clear, but it probably plays a role in lowering postoperative cerebrospinal fluid (CSF) leak rates following intradural dissection. Reconstruction of large transclival defects is more difficult, and the reconstructive flap may provide limited coverage, increasing the risk of a CSF leak. A CT scan is obtained the evening of surgery to assess the degree of pneumocephalus (and ensure that there is no hemorrhage) prior to opening the lumbar drain. Elevation of the head of the bed, even during sleep, should be maintained for the first 2 weeks following intradural endonasal surgery.

When necessary, packing is left in place for 1 to 2 days following extradural surgery and 6 to 7 days following intradural dissection. Patients are maintained on a third- or fourth-generation IV cephalosporin (or equivalent if penicillin allergic) for 24 to 48 hours and then switched to an oral second-generation cephalosporin or equivalent until the packing is removed. Septal splints are maintained for 2 to 3 weeks postoperative if a septal flap has been employed. Nasal saline sprays are used liberally, and saline irrigations are instituted after several weeks. Patients are instructed to avoid activities that increase intracranial pressure for at 4 to 6 weeks if there has been a dural reconstruction. Gentle nasal debridement under endoscopic visualization is performed every few weeks for the first few months as needed.

Corticosteroids are generally reserved for patients who develop new cranial neuropathies that are thought to be transient and continued for approximately 48 hours, after which they are rapidly weaned to prevent complications of wound healing.
COMPLICATIONS

As emphasized above, the abducens nerve is at significant risk with a transclival approach. If the patient has a complete palsy, he or she will likely require temporary patching of the eye or prism placement in glasses. If the palsy is partial, patients are encouraged to tolerate this diplopia to speed adjustment or to alternate patching of the eyes. If the abducens nerve is sectioned or recovery is incomplete (after 6 months), referral to an oculoplastic surgeon should be made for consideration of correction.

Patients should be closely followed for signs of a CSF leak in the immediate postoperative period. With clival defects, CSF drainage can occur either from the nostrils or into the oropharynx, in which case the patient will complain of and should be questioned about salty drainage into the throat. This is typically worsened by the supine position.

Any vascular injury needs to be immediately evaluated with digital subtraction cerebral angiography to ensure that there is no pseudoaneurysm, thrombus, filling defect, or critical stenosis that would require anticoagulation, stenting, coiling, or arterial sacrifice.

Nasal morbidity is generally low. Patients notice diminished smell and taste function for several months following surgery. There is a small risk of epistaxis for several weeks from branches of the sphenopalatine artery. Nasal crusting is the greatest long-term morbidity but can be effectively managed with saline irrigations and periodic endoscopic debridement.

RESULTS

From April 2003 to September 2012, 84 patients with clival chordomas underwent EES at the UPMC Center for Cranial Base Surgery. Medical records and radiologic images were retrospectively analyzed and evaluated.

Eighty-four patients (59.5% male) with a median age of 44 years (range 4 to 88) underwent EES for primary (n = 46) or previously treated (n = 38) chordomas of the skull base. The overall rate of gross total resection (GTR) was 68% (n = 57). In the group of primary tumors, GTR was achieved in 36 cases (78%), near total resection (>95% of tumor removed) in 7 (15%), subtotal resection (>85% of tumor removed) in 2 (4%), and partial resection in 1. In the group of 38 previously treated chordomas, GTR was achieved in 21 (55%) patients, near total in 6 (16%), subtotal in 5 (13%), and partial in 6 (16%). Eighteen patients underwent staged surgeries, and in nine cases, EES was combined with craniotomy (11%). Fifty-five patients received adjuvant radiation therapy (proton beam in 43 cases). Surgical complications included CSF leakage in 16 cases (19%), new permanent cranial neuropathy in 5 (5.9%), and carotid injury in 3 (3.6%), all without neurologic sequelae. In a mean follow-up of 21 months (range 1 to 91), 28 patients developed recurrent disease (33%) and 20 among them underwent repeat EES. At the most recent follow-up, 49 patients (58%) are free of tumor, 26 (31%) have a stable residual or recurrent chordoma, and 9 (11%) died (eight due to disease progression). In total, the 84 patients underwent 143 surgical procedures.

PEARLS

- Petroclival meningiomas have extremely variable relationships to cranial nerves, and this should be evaluated and used as a major criterion for choice of approach to avoid manipulation of these structures.
- The paracloival ICA and vidian nerves provide the lateral boundaries for the midclival approach. Intraoperative navigation using CTA in combination with exposure of the sellar floor is helpful in identifying the paracloival ICA in a poorly pneumatized sinus.
- The abducens nerve is the nerve at greatest risk with an endonasal transclival approach. This can be minimized with gentle dissection technique and use of an electrical nerve stimulator.
- Inferior clival dural defects with a postoperative CSF leak can present as drainage down the back of the throat rather than from the nose.

PITFALLS

- Drilling of clival bone deep to the paracloival arteries can result in injury to the posterior surface of the arteries. Drilling from the contralateral nostril decreases the risk of injury to the artery from the shaft of the drill bit.
- The dura should be incised in the midline well above the vertebrobasilar junction to avoid injury to an abducens nerve displaced by tumor.
- Blind passage of nasogastric tubes postoperatively can result in intradural injury. This should be communicated to everyone involved in the care of the patient.
INSTRUMENTS TO HAVE AVAILABLE

- Zero- and 45-degree rod lens endoscopes (Storz)
- Extended tip micro-Doppler (for ICA identification)
- Standard sinus instruments
- Needle-tip and suction monopolar electrocautery tips
- High-speed electric drill with extended tip and extended drill bit (Stryker)
- Extended tip neurodissectors (KLS Martin)
- Pistol-grip Kurze microscissors (straight, curved left and right, and rotatable) (Storz)
- Pistol-grip bipolar cautery (side angle, “uptoe,” and fine, straight tip) (Storz)

ACKNOWLEDGMENT

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SUGGESTED READING


INTRODUCTION

Endonasal approaches to the ventral skull base include a midline corridor that extends from the frontal sinus to the superior aspect of the cervical spine. The transodontoid approach provides access to the region of the foramen magnum and includes the inferior aspect of the clivus and the superior cervical vertebrae (C1 and C2). The surgical field generally extends from the floor of the sphenoid sinus to the plane of the hard palate and is limited laterally by the parapharyngeal internal carotid arteries (ICAs) deep to the fossa of Rosenmüller. The inferior third of the clivus extends from the floor of the sphenoid sinus to the foramen magnum and is bounded superolaterally by the anterior genu of the petrous ICA. Inferolaterally, the inferior clivus is bounded by the occipital condyles and hypoglossal nerves. The inferior limit of the transodontoid approach is the body of C2 and is roughly defined by the nasopalatine line (NPL), a virtual line that is tangential to the inferior margin of the nasal bones and posterior edge of the hard palate (Fig. 37.1). The intersection of this line with the vertebrae establishes the inferior limit of endonasal access and corresponds to the lower dens or upper body of C2 in most patients. Posteriorly, the inferior clivus is bounded by the hypoglossal nerves, brainstem, and vertebral arteries.

The endonasal transodontoid approach avoids the morbidity of transoral/transpalatal approaches to the inferior clivus and superior cervical spine and is associated with a faster recovery (Table 37.1). Surgical advantages include improved visualization, greater access superiorly, and decreased bacterial contamination of the surgical field. Disadvantages include limited access to the inferior cervical spine and potentially greater risk of cerebrospinal fluid (CSF) leak following reconstruction of the dura. In our opinion, an endonasal approach is the preferred approach for lesions in the region of the foramen magnum that are bounded by the neural and vascular structures and for the resection of the odontoid process in the setting of basilar invagination.

HISTORY

Presenting symptoms will depend on the diagnosis, location, extent, and age of the patient. Patients may present with a serous middle ear effusion and conductive hearing loss due to eustachian tube dysfunction or obstruction. Involvement of cranial nerves can result in a wide variety of symptoms, including hypernasal speech and nasal reflux due to palatal dysfunction (CN IX/X); weak voice, dysphagia, and aspiration (CN X); and dysarthria (CN XII). Lower cranial nerve dysfunction can result from intradural compression or nerve involvement at their respective foramina. Coughing associated with meals or drinking should be questioned to check for active aspiration. A cervical mass (metastatic lymphadenopathy) is often the first symptom of nasopharyngeal cancer.
Bone disease with degenerative pannus or basilar invagination presents with myelopathy with or without dysphagia. Progressive loss of ambulation is a common complaint, and diagnosis is often delayed because of its insidious onset in elderly patients. Pain in the neck or occipital neuralgia can be indicative of active instability of the craniocervical junction.

**PHYSICAL EXAMINATION**

Physical examination includes a full examination of the head and neck including otoscopy, endoscopic visualization of the nasopharynx and hypopharynx, palpation of the neck, and assessment of cranial nerve function. Middle ear effusion may be the result of obstruction of the eustachian tubes. The type of hearing loss (conductive vs. sensorineural) can be confirmed with tuning fork testing (Weber and Rinne tests). The upper aerodigestive tract can be examined with a rigid nasal endoscope or flexible fiberoptic scope. The extent of mucosal lesions or masses should be noted. In particular, the fossa of Rosenmuller posterior to the eustachian tube should be carefully examined, as this is a common site for nasopharyngeal cancer. The neck should be palpated for metastatic cervical adenopathy. Assessment of cranial nerve function focuses on the lower cranial nerves: palatal dysfunction, vocal cord palsy, pooling of secretions in the hypopharynx with aspiration, and paresis of the tongue (deviation of tongue to the paralyzed side with protrusion). Range of mobility of the cervical spine can be grossly assessed with flexion, extension, and rotation. Signs of brainstem compression include weakness of the extremities and hyperreflexia. Gait assessment is important to determine if the gait is myelopathic or the result of another condition.

### TABLE 37.1 Comparison of Anterior Surgical Approaches to the Foramen Magnum

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<th>Transnasal Approach</th>
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<tr>
<td>Duration of hospitalization</td>
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<td>Inferior limit of exposure</td>
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<td>Palatal dysfunction</td>
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<td>Reconstruction (CSF leak)</td>
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<tr>
<td>Risk of infection</td>
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<td>Spine stability</td>
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<td>Swallowing function</td>
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<td>Visualization</td>
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+, advantage; −, disadvantage.
INDICATIONS

The primary principle of endonasal skull base surgery applies to the transodontoid approach: Avoid transgression or manipulation of major neural and vascular structures. If the lesion extends lateral to major vascular structures (carotid and vertebral arteries) or cranial nerves, an alternative approach or combination of approaches should be considered. For example, a large meningioma may require a combined approach (endonasal and retrosigmoid or far lateral) to access different areas of the tumor depending on its relationship to the neural and vascular structures.

Clinical indications for a transodontoid approach include neoplasms, inflammatory and degenerative disease with craniovertebral compression, and trauma. The most common neoplasms include intracranial tumors (meningioma), neoplasms arising from bone (chordomas, chondrosarcoma), and malignancies of the soft tissues (nasopharyngeal carcinoma). Inflammatory or osteoarthritic degeneration or congenital abnormalities of the atlantoaxial joint and associated ligaments can result in chronic instability of the spine and resultant inflammatory pannus or progressive invagination with brainstem compression. Generally, only ventral bony compression needs to be addressed with an anterior approach, whereas soft tissue/pannus usually will resolve over time with posterior decompression and arthrodesis. In cases of severe pannus compression, we still perform an anterior approach to facilitate rapid decompression and avoid a posterior decompression, leaving the surface of the posterior C1 ring intact for fusion. Rarely, traumatic fractures or dislocations of C1 and C2 can be decompressed endonasally. This is more common in the delayed setting of an os odontoideum. The transodontoid approach is applicable to both adult and pediatric populations.

Neoplasms arising from the bone of the inferior clivus (chordoma, chondrosarcoma) are ideally suited for an endonasal approach. These tumors tend to have a midline or paramedian origin and displace neurovascular structures laterally. As a result, resecting the tumor through a midline approach minimizes or obviates any manipulation of these structures. Intracranial tumors such as meningiomas of the foramen can be approached endonasally if they are mainly midline and without significant involvement of the vertebral artery. Tumor relationship to the lower cranial nerves is key, with tumors that displace the nerves laterally being well suited for a midline, endonasal approach.

CONTRAINDICATIONS

Active sinus infection is a contraindication for intracranial transnasal surgery but can usually be cleared rapidly with antibiotics with or without surgical drainage. Lesions that do not directly involve the occipitocervical joints in patients without preexisting instability should be approached with caution, taking care to avoid destabilizing the craniovertebral junction. Craniovertebral meningiomas, which would require resection of the odontoid, should be considered instead for a posterolateral approach if it is more likely to maintain occipitocervical stability.

Rarely, especially in elderly patients, the parapharyngeal ICAs can become ectatic and loop medially to approach the midline behind the nasopharynx. This should be considered a relative contraindication to an anterior approach. Depending on the lesion and its location, though, dissection can still be performed superior and deep to the ICAs, mobilizing them in a cuff of soft tissue.

PREOPERATIVE PLANNING

Any patient with signs of aspiration or subjective dysphagia should undergo a formal swallowing evaluation, including laryngeal endoscopy and an esophagram (barium swallow). If there is active aspiration preoperatively, the need for tracheostomy in the postoperative period should be discussed. Tracheostomy is not necessary for endonasal access to the craniovertebral junction or superior spine, but it may be safest to prevent aspiration in a weakened postoperative state.

Magnetic resonance imaging (MRI) and computed tomography angiography (CTA) are complementary for both planning and intraoperative navigation. MRI demonstrates soft tissue involvement and neural compression as well as tumor characteristics that can help with the differential diagnosis. Craniovertebral degenerative pannus can have a heterogeneous and atypical appearance but will appear more chronic on CT. CT can also show the degree of joint involvement, anomaly, or degeneration. CTA will demonstrate the degree of vertebral artery involvement and evaluate for an abnormal course of the parapharyngeal ICA, which can affect access. MRI should include both the skull base and cervical spine in the setting of pannus to determine if there is associated subaxial disease. Both modalities in addition to the clinical history and physical examination should be examined for evidence of acute or chronic sinus infection.

A midline sagittal reconstruction of the CTA should be evaluated for caudal extent of endonasal access. The simplest way to do this is to draw a line from the tip of the bony nasal bridge to the posterior hard palate and extend it to the spinal column (Fig. 37.1). This NPL is a rough approximation of the lowest point of access.
The usual degree of access illustrated by postoperative imaging was 12.7 mm above that predicted by the NPL, likely due to the failure of the line to account for soft tissue limitations and the lack of need to always reach the most inferior point possible.

Patients with signs or symptoms of instability should undergo flexion/extension lateral cervical spine radiographs to check for evidence of atlantoaxial subluxation or subaxial mobility as this can be made worse by anterior decompression or impact the inferior extent of subsequent spinal fixation.

**Surgical Technique**

The patient is positioned supine with the neck in a neutral position. When the head of the bed is elevated (reverse Trendelenburg position) to decrease bleeding, the angle of instrumentation to the upper cervical spine is optimal. Hyperextension can lower the spine relative to the plane of the hard palate and decrease inferior access. The head is rotated slightly toward the surgeons to provide a comfortable working position. The head position is fixed in pins with a Mayfield head holder, and registration of the navigation system is performed. Care should be taken during positioning to avoid excessive manipulation as these patients typically have significant cervicomedullary compression. Neur_monitoring includes measures of cortical brain function (somatosensory evoked potentials) with baseline potentials monitored prior to and throughout positioning to evaluate changes that may be related to positioning. Electromyography (EMG) of relevant cranial nerves is also performed. We typically monitor bilateral hypoglossal nerve EMG when performing an endonasal decompression of degenerative or congenital atlantoaxial disease since the anatomy is often abnormal and even a unilateral hypoglossal palsy in addition to preexisting dysphagia can be devastating for the patient’s quality of life. If brainstem compression or vascular involvement of the posterior circulation is present, brainstem function is also monitored with brainstem evoked response audiometry.

The nasal cavity is decongested with cottonoids soaked in 0.05% oxymetazoline. Antibiotic prophylaxis includes intravenous administration of a third- or fourth-generation cephalosporin or equivalent broad-spectrum coverage. The nasal aperture is prepped with Betadine solution, and the abdomen is prepped for a possible adipose tissue graft.

All operations are performed with a team consisting of an otolaryngologist/head and neck surgeon and a neurosurgeon. This combination allows for appropriate management of all relevant anatomy and pathology as well as providing for dynamic endoscopy and bimanual dissection.

The entire operation is usually performed with a 0 degree endoscope. The inferior and middle turbinates are lateralized to provide more room for instrumentation. If a large concha bullosa is present, the turbinate is partially resected. The surgical field for access to the foramen magnum and anterior arch of C1 extends from the floor of the sphenoid sinus down the wall of the nasopharynx to the plane of the soft palate and laterally from eustachian tube to eustachian tube (Fig. 37.2). Resection of a small amount of the posterosuperior nasal septum can improve initial visualization. This should be limited, however, as the field deepens rapidly allowing the endoscope to be placed posterior to the septum. This is the one exposure where a vascularized nasal septal flap does not have to be harvested at the beginning of the surgery because the entire surgical access is inferior to the vascular pedicle.

A suction monopolar electrocautery or microdebrider can be used to resect the soft tissue overlying the craniovertebral junction (nasopharyngeal mucosa, basopharyngeal fascia, longus capitis, and rectus capitis anterior muscle attachments). Attempts to preserve the nasopharyngeal mucosa and underlying muscle for reconstruction are not successful due to restriction of the surgical field and the depth of the final surgical defect. For most anterior pathology of the craniovertebral junction, the lateral margin of the surgical field should be limited to the medial border of the eustachian tube (torus tubarius). The field can be widened by either retraction (with a suction tip) or resection of the torus tubarius. Care should be taken to evaluate the course of the parapharyngeal ICA since it can be directly subjacent to the eustachian tube. Radical resection of the medial eustachian tube is not necessary and may affect palatal function.

**Figure 37.2**

Endoscopic endonasal intraoperative view of the nasopharynx, which provides direct access to the craniovertebral junction between the eustachian tubes (ET). Caudal access is limited by the hard palate (HP). The soft palate (SP) extends inferiorly from this and is not affected by an endonasal approach.
As the longus capitis and rectus capitis muscles are detached, their point of attachment should be identified. This supracondylar groove directly overlies and predicts the location of the hypoglossal canal in the depth and, as such, represents an important landmark if the condyle is to be exposed. Monopolar electrocautery is useful to completely remove fascial and muscle attachments from the foramen magnum and anterior arch of C1. Care should be taken if there is any gap between the foramen magnum and C1, though this is rare. The anterior tubercle of C1 should be identified since it serves as a valuable midline landmark.

An extended, downward curved drill with a thin, flexible drill bit allows extension of the caudal exposure. Additionally, reduction of the posterior maxillary crest (bony attachment of the nasal septum to the hard palate) to the plane of the hard palate will improve caudal access as this is the “highest” point of the hard palate. Care should be taken not to drill completely through the hard palate and violate the oral mucosa as this would create an oronasal fistula.

The anterior arch of C1 can be removed with a high-speed drill with a cutting or coarse diamond burr. For resection of the odontoid, the width of resection should be enough to expose the dens in its entirety (Fig. 37.3). Inferior access should be maximized at every step of the exposure. Once the dens is exposed, any soft tissue overlying its tip should be cauterized or resected with through-cutting sinus instruments. In cases of basilar invagination, the foramen magnum may need to be drilled to expose the invaginated odontoid peg. The dens should be drilled and removed from the tip down, as disconnection from the body of C2 at the neck would result in a floating tip with numerous dense ligamentous attachments that are difficult to detach from free-floating bone. Careful dissection of the inner cortex of the dens from the ligaments, especially at the tip, can be performed with extended tip dissectors (see instruments section below) or simply a Kerrison rongeur, with care taken to avoid further compression of the immediately subjacent neural tissues.

In cases of purely bony anterior compression, decompression to the tectorial membrane is adequate (Fig. 37.4). If the tectorial membrane is pulsatile and widely decompressed, it does not need to be removed. Even if there is extensive pannus, it can usually be debulked without fully exposing the underlying dura, since this dura is often thinned, friable, or eroded. If intradural resection of the tumor is intended, the tectorial membrane should be stripped to expose the dura completely. Intradural structures associated with the ventral craniocephalic junction include the vertebral and anterior spinal arteries, hypoglossal nerves, and C1 nerve rootlets. With the exception of the anterior spinal artery, all of these are structures that originate laterally and are usually displaced by the pathology away from the surgeon. As always, intradural dissection should be performed with strict adherence to microsurgical, bimanual technique.

Intraoperative imaging is important in order to ensure adequate decompression. At a minimum, AP and lateral radiographs with instillation of radiopaque dye into the defect should be performed. We are fortunate to have intraoperative CT, which is an ideal way to confirm complete decompression (Fig. 37.5).
In cases of purely extradural pathology without inadvertent dural breach, simple coverage of the surgical site with fibrin glue is adequate for repair. Secondary scar formation and remucosalization will occur naturally and effectively. If there is a small dural tear, reconstruction with an adipose tissue graft filling the soft tissue defect is usually effective. The defect tends to be deep and narrow, ideal for filling with adipose tissue, and is at low risk for a postoperative CSF leak.

If there is a wide dural opening, reconstruction with vascularized tissue is recommended. The nasal septal flap, pedicled on the posterior nasal branch of the sphenopalatine artery, provides a robust flap, but it may not reach a deep, caudal defect such as can be created with intradural endonasal surgery. Often, the deep defect created after removal of the lower clivus, anterior arch of C1, and/or dens needs to be filled in with an adipose tissue graft and the flap placed over this with its edges in alignment with the nasopharyngeal mucosa. An onlay allo- or autograft (such as AlloDerm, pericardium, or fascia lata) is often placed deep to the adipose tissue to provide dural reconstruction. Another vascularized option for craniocervical defects is an inferior turbinate flap. Silastic splints are sutured to the nasal septum. Packing is not necessary unless there has been repair of a dural defect.

**POSTOPERATIVE MANAGEMENT**

Many patients with craniovertebral disease, especially degenerative or rheumatoid, will require a posterior arthrodesis, regardless of the anterior approach. This can be performed before or after an anterior decompression. When indicated, we prefer to perform the endonasal decompression first, since this provides rapid neural decompression, which may increase the safety of the posterior approach (as the cervicomedullary junction is no longer at risk from the anterior vector). It can also provide more bone surface for fusion since the posterior arch of C1 can often be left intact if there is adequate anterior decompression. Patients may undergo arthrodesis during the same anesthetic or the following day, depending on the length of surgery and associated patient factors.

If patients require fixation, they are left in either a hard cervical collar or halo vest for 2 to 4 weeks. A halo vest is not required with modern arthrodesis techniques, but may aid healing of the occipitocervical incision by avoiding all pressure on this area.

Regardless of other treatment, patients with intradural approaches should have typical endonasal postoperative precautions: avoidance of nose blowing with strict orders to avoid positive pressure ventilation and nasal instrumentation unless under direct endoscopic visualization. The head of bed is elevated to 30 degrees at all times for 2 weeks. Nasal splints are removed at 1 week if a septal flap has not been used and at 3 weeks if employed. Saline nasal sprays are instituted immediately postoperative, and saline irrigations can be started at 2 to 3 weeks. Periodic nasal endoscopy with debridement of nasal crusts is performed until healing is complete.

Patients with craniocervical disease should be evaluated pre- and postoperatively for signs of dysphagia, vocal cord paresis, or other lower cranial neuropathies, since this can result in aspiration and resultant lung injury. Most patients should only be fed once this has been assessed. However, one of the main advantages of an endonasal approach is that patients can resume a transoral diet immediately if safe and appropriate.

Patients who do not have preexisting or clear postoperative instability should be followed for sign or symptoms of progression. Regular cervical spine films with flexion/extension views should be obtained during
the first 2 postoperative years or at any time when the patient develops new onset of pain in the neck, headache, or radiculopathy.

**COMPLICATIONS**

CSF leak remains a concern for any patient undergoing intradural endonasal surgery. Large dural defects in the craniocervical junction can prove a challenge for reconstruction, but tend to heal well. Injury to the lower cranial nerves can be subtle and go unnoticed until patients become quite sick (aspiration and associated complications) and thus should be carefully evaluated. Patients who have intraoperative vascular injuries, though rare with this approach, should undergo immediate angiography to determine the extent and consequences of the injury as well as need for further treatment such as endovascular coiling or sacrifice of the artery.

**RESULTS**

We conducted a retrospective review of all patients who underwent a purely endoscopic endonasal odontoid resection for decompression of the cervicomedullary junction from 2004 to 2010. Patient outcomes were assessed using the Neck Disability Index and NURICK cervical myelopathy scale. Special attention was also paid to complications and postoperative swallowing function.

Twenty-nine patients underwent complete endoscopic endonasal resection of the odontoid. The most common pathology \( n = 23 \) treated was spondylitic pannus. Other pathologies included chondrosarcoma, meningioma, type 2 odontoid fracture, os odontoideum, and metastatic carcinoma. The mean patient age was 67.9 years. Twenty-seven of the twenty-nine patients underwent a posterior fusion.

All patients had either improvement or stabilization of their neurologic status (none worsened). NURICK and NDI data were available for 15 patients who had a mean follow-up of 27.6 months (range 3 to 57). The mean NURICK score postoperatively was 1.0, and no patient received a score of 5. The mean NDI score was 9.2 (range 0 to 32). Nine of twelve patients had an NDI score of less than 15.

Two patients had preoperative swallowing dysfunction, which required a preemptive gastrostomy. Postoperatively, it appeared there was no change in the need for supplementation. Five patients (17%) required placement of a gastrostomy tube for postoperative dysphagia. In two of these patients, the tube was removed within 6 weeks postoperatively as the patient resumed normal swallowing function. The remaining 23 patients (73%) were able to continue oral feedings with minimal or no problems. No patient was found to have developed permanent velopharyngeal dysfunction postoperatively although one patient did have velopharyngeal insufficiency preoperatively related to a prior inadequate transoral approach for odontoid resection. This patient did not experience worsening velopharyngeal insufficiency following the endonasal approach.

Prior to leaving the OR, all patients underwent either instillation of radiopaque dye under fluoroscopy or intraoperative CT to assess the adequacy of decompression. All patients underwent a postoperative CT scan to assess the adequacy of their decompression. No patient had evidence of residual compression, and no patient required a repeat anterior approach for further decompression.

Two patients required intraoperative repair of CSF leaks at the time of the initial surgery. In both patients, the dura was approximated with U-clips and augmented with Duragen and an autologous adipose tissue graft. Both patients were treated with lumbar drainage for 5 days and suffered no sequelae.

Respiratory complications were the most frequently encountered nonneurologic complication. Four patients experienced respiratory failure secondary to pneumonia. These four patients required a temporary tracheostomy. One additional patient required a tracheostomy for respiratory failure secondary to chronic pulmonary disease and deconditioning; this patient was eventually decannulated. No patient had a tracheostomy performed as part of the surgical procedure. Two patients had aspiration pneumonia treated with antibiotics. One patient had a deep venous thrombosis without evidence of pulmonary embolism and was placed on anticoagulation. One patient died 8 days following surgery from cardiac arrest.

**PEARLS**

- The NPL drawn on a midsagittal CT approximates the most inferior point of endonasal access.
- Reduction of the posterior maxillary crest with a drill until it is flush with the rest of the hard palate provides a significant increase in caudal access.
- In general, the approach should be chosen based on the relationship of the pathology to associated nerves and vessels. For anterior or midline pathologies that displace neurovascular structures posterolaterally, an endonasal approach is ideal. However, potential destabilization must be taken into account when addressing the craniovertebral junction, as this can have equal impact on patient outcome and quality of life.
PITFALLS

- Tortuous parapharyngeal ICAs may approach the midline of the nasopharynx and be at risk for injury.
- Failure to drill the tip of the dens before detaching it from the body of C2 makes it difficult to detach the ligaments.
- Care should be taken not to drill through the entire hard palate since an oral nasal fistula may occur if the underlying mucosa is violated.

INSTRUMENTS TO HAVE AVAILABLE

- A full set of standard sinus instruments (Storz).
- Extended tip dissectors (KLS Martin).
- An extended, downward curved drill with thin, flexible drill bit allows extension of the caudal access. Cutting and coarse diamond bits are ideal.
- Fine and angled tip, pistol-grip bipolar electrocautery forceps (Storz) are critical for extra- and intradural hemostasis.

SUGGESTED READING


INTRODUCTION

Tumors involving the clivus are usually difficult to access because of their deep, midline location anterior to the brainstem and anterior to the cranial nerves. The position of the petrous portion of the temporal bone and the configuration of the tentorium are some of the limiting factors to the use of traditional approaches such as the retrosigmoid approach or a transsylvian approach, where a surgeon ends up working along a very long and narrow path leading to the tumor. The working area is very restricted, creating a less than satisfactory situation. The combined approach is designed to overcome some of these limitations. Partial or complete drilling of the temporal bone brings the surgeon closer to the target pathology, while cutting the tentorium enlarges the working space by allowing the surgeon to use both the supra- and infratentorial compartments, which are combined into one.

HISTORY

Since these tumors are usually slow growing, most patients will have very few complaints even with large tumors. Headache, gait, and balance problems are the most common symptoms.

PHYSICAL EXAMINATION

Neurologic examination may reveal ataxia, weakness of the upper or lower extremities. Compression of cranial nerves can produce hearing loss, diplopia, facial numbness or pain, and occasionally, facial weakness.

INDICATIONS

This approach is primarily useful for extra-axial tumors anterior and anterolateral to the brainstem. It can also be used for some intra-axial processes such as cavernous angomas in the brainstem that come close to the anterolateral surface of the brain. Examples include intradural tumors such as meningiomas, schwannomas, and epidermoid tumors; extradural tumors such as chordomas and chondrosarcomas that may also have intradural extensions are also candidates. Some of the smaller tumors that are confined to the upper clivus can also be removed by the anterior transpetrosal approach (described in Chapter 32).
CONTRAINDICATIONS

There are no contraindications to using this approach.

PREOPERATIVE PLANNING

A high-quality MRI scan done before and after administration of gadolinium is essential. Meningiomas and schwannomas enhance vividly with gadolinium. A trigeminal schwannoma can occur anywhere along the course of the nerve, posterior fossa, middle fossa, and infratemporal fossa, or in a dumbbell-shaped configuration straddling the compartments. Those that occupy the posterior fossa and middle fossa are eligible for this approach. Meningiomas show vivid and uniform enhancement and have a broad dural base at the clivus and petrous bone (Fig. 38.1A and B). Schwannomas are more rounded in appearance. They may contain areas of cystic change. In most instances, there is an arachnoid plane separating the brainstem, the blood vessels, and the cranial nerves from the tumor. Infrequently, the tumor may violate the arachnoid and invade the pia causing edema of the brainstem. T2-weighted images and FLAIR sequences will demonstrate edema of the brainstem when present (Fig. 38.2A and B). A high T2 signal within the tumor may indicate that the tumor is soft in consistency. Hyperintensity or diffusion-weighted images are diagnostic of an epidermoid tumor. A CT scan is helpful if additional anatomical information about bone is needed with respect to the temporal bone. Evaluation of the surrounding vascular anatomy can be performed using MRI (Fig. 38.3A and B), an MR arteriogram and venogram, or a digital subtraction angiographic study. The MR arteriogram is adequate for assessing large vessels and venous sinuses, but a more detailed assessment of the arterial and venous system and flow characteristics is best obtained by an angiogram (Fig. 38.4A–C). If there is significant blood supply from the external carotid branches or the intracavernous internal carotid artery, embolization may be helpful for surgery. The venous anatomy and drainage is carefully evaluated with respect to the temporal draining veins and the size and dominance of the sigmoid sinus, in case the sigmoid sinus is ligated or gets injured during the operation.

SURGICAL TECHNIQUE

Anesthesia, Intraoperative Neurophysiologic Monitoring, and Positioning

General intravenous anesthesia is used during the tumor phase of the operation because of the need for intraoperative neurophysiologic monitoring. Intra-arterial and venous lines are place. Continuous neurophysiologic monitoring of cranial nerves VII and VIII, somatosensory and motor evoked potentials, and transcranial facial

FIGURE 38.1 A. Axial MRI T1 with gadolinium showing the well-defined tumor left of the midline with extension into the left Meckel’s cave (arrowheads). B. Axial T2 shows tumor and brainstem border (arrowheads). There is no edema within the brainstem. The ventricles are enlarged in this case.
FIGURE 38.2  A. Sagittal T2 MRI shows encasement of the basilar artery within the tumor (arrowheads). B. There is extensive high signal within the brainstem indicating invasion of the pia by the tumor producing edema (asterisk); arrowheads indicate the tumor–brainstem interface; T, tumor.

FIGURE 38.3 Axial T2 MRI showing that the tumor surrounds the posterior cerebral artery (arrowheads) (A) and the basilar artery (arrowhead) (B).

FIGURE 38.4 A. Cerebral arteriogram, external carotid injection showing the blood supply to the tumor from the middle meningeal artery (arrowheads). B. The basilar artery and its branches are displaced by the tumor (arrowheads).
nerve evoked potentials are very helpful during these operations. Lumbar spinal drains and external ventricular drains are usually not necessary. Broad-spectrum antibiotics and anticonvulsant prophylaxis are administered at the beginning of the operation.

The patient is positioned supine with a soft roll under the ipsilateral shoulder, and the head is turned to the contralateral direction about 60 degrees and stabilized in a three-point headrest (Fig. 38.5). The extent of the head rotation is for the surgeon to be able to visualize and access both the base of the tumor along the petrous ridge and the surface of the tumor pressing into the brainstem. The head is kept elevated relative to the chest and body to facilitate venous drainage.

**Scalp Incision and Soft Tissue Flaps**

A large “C”-shaped flap is used located above, behind, and below the ear and centered at the ear (Fig. 38.5). The posterior limit of the incision should extend about an inch posterior to the mastoid tip. The scalp flap is elevated up to the external ear canal, which has to be carefully identified and separated from the bony ear canal. The muscle flaps are elevated superiorly and inferiorly, by making an incision horizontally separating the temporalis muscle from the nuchal muscles. The posterior temporal line, which is the posterior extension of the zygomatic arch, is identified, which separates the floor of the middle cranial fossa from the mastoid.

**Craniotomy and Bone Work**

The opening of the bone can be done in two ways: One way is to perform a craniotomy first and then a retro-labyrinthine mastoidectomy, and the other way is to perform the mastoidectomy first and then use that as the starting point for the craniotomy. In order to perform the craniotomy first, one burr hole is made above the sigmoid–transverse junction (Fig. 38.6A), at the junction of the squamosal suture with the posterior temporal line. The second burr hole is made below the sigmoid–transverse junction at the asterion (Fig. 38.6A and B). Since there is a deep groove housing it, the sinus can be readily injured here. Therefore, a bony trench is drilled joining the two burr holes. Once the dura has been separated from the bone, a combined temporal and posterior

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**FIGURE 38.4 (Continued)**

C. The venous phase shows a large temporal draining vein (arrowheads) coursing along the inferior surface of the temporal lobe to drain into the tentorium and then into the sigmoid–transverse junction. This venous channel must be preserved while the tentorium is being incised.

**FIGURE 38.5**

The patient is positioned with the head turned away from the side of the tumor about 60 degrees. The surgeon sits behind the patient. The incision is “C” shaped such that the posterior limb is about 1 inch posterior to the tip of the mastoid.
fossa craniotomy is made with the high-speed craniotome following the dotted line in Figure 38.6A. Traversing the posterior part of the transverse sinus with the saw is safe because there is no bony groove. The retrolabyrinthine mastoidectomy is now carried out unroofing the sigmoid sinus down to the jugular bulb and the superior petrosal sinus.

In the other option, the mastoidectomy is performed first, skeletonizing the labyrinth and exposing the sigmoid sinus entirely from the sigmoid–transverse junction down to the jugular bulb. The subtemporal and presigmoid dura are exposed so that the superior petrosal sinus and the endolymphatic sac are fully unroofed. It is very important that the unroofing of the sigmoid sinus be carried out all the way down to the jugular bulb and the thin ridge of bone between the two structures be drilled down carefully. This reduces the venous bleeding from the area of the jugular bulb that can occur when the sigmoid sinus is retracted posteriorly during the tumor resection phase. The labyrinth must be fully skeletonized so that the maximal exposure of the dura between the sigmoid sinus and the posterior semicircular canal can be achieved. The petrous bone can be drilled down further anteriorly by performing a partial or complete labyrinthectomy and even by drilling down the cochlea to provide a larger exposure while minimizing brain retraction. A combined temporal and posterior fossa craniotomy is started at the mastoidectomy defect. The anterior extent of the temporal craniotomy should extend to above the external ear canal. The inferior extent of the posterior fossa craniotomy should be almost down to the foramen magnum. It must provide enough temporal exposure to allow for placement of a temporal lobe retractor without limiting the retractor by the bone edge of the craniotomy. Posteriorly, the craniotomy must extend far enough behind the sigmoid sinus to allow the sinus to be retracted posteriorly and also to allow the surgeon to perform a retrosigmoid exposure should it be needed in addition to the presigmoid exposure (Fig. 38.7).
Dural Exposure and Opening

The brain must be relaxed prior to opening the dura. The exposure can be markedly compromised if the brain is tight. Administration of mannitol, hyperventilation, and elevation of the head are the usual maneuvers to facilitate relaxation of the brain. If hydrocephalus is present, an external ventricular drain can be placed prior to positioning for the craniotomy. Drainage of cerebrospinal fluid (CSF) can also be performed by making a limited opening in the posterior fossa dura, elevating the cerebellum and opening the cisterna magna or the lateral cerebellomedullary cisterns.

The temporal dura is opened horizontally along the lower part of the temporal lobe starting at the anteriormost limit of the temporal craniotomy and extending posteriorly past the sigmoid–transverse junction (Figs. 38.8A and 38.9). A “T”-shaped extension is made in the inferior direction toward the superior petrosal sinus. The temporal lobe is gently elevated to look for temporal bridging veins entering the venous sinuses below. These veins have to be preserved while cutting the superior petrosal sinus and the tentorium below. This dural incision has to be made anterior to these bridging veins, such that the veins will continue to drain posteriorly into the venous sinuses (Fig. 38.8B). The posterior fossa dura is opened vertically, in front of the sigmoid sinus and behind the opening of the endolymphatic sac. Inferiorly, it is taken down to the jugular bulb and superiorly, up to the superior petrosal sinus. The superior petrosal sinus is coagulated with the bipolar cautery, staying anterior to the temporal bridging veins, and then divided with microscissors (Fig. 38.10).

Prior to extending this incision into the tentorium, a Cottonoid patty is passed along the bottom of the temporal lobe without disrupting the draining veins and another one is over the cerebellum to protect these respective surfaces. The tentorium can be quite vascular, especially in the case of meningiomas, and needs to...
be coagulated prior to cutting. The incision is made parallel to the petrous ridge and slightly behind it all the way to the incisura. Prior to cutting down to the incisura, the trochlear nerve is visualized separated from the tentorium by a layer of arachnoid at a point posterior to its entry into the incisura. The anterior edges of the dura adjacent to the labyrinth are tented up with sutures (Fig. 38.9).

A retractor is placed to gently elevate the temporal lobe, which is being protected by a Cottonoid. This retractor must be placed such that the posterior leaf of the cut edge of the tentorium is lifted up with the temporal lobe and its draining veins all together such that there is no stretch or avulsion of these veins. The tumor can now be visualized anterior to the brainstem, nestled medial to the cranial nerves (Fig. 38.8B).

Tumor Removal

Careful dissection following the arachnoid planes is very important in order to separate the tumor from the cranial nerves, the vascular structures, and the brainstem. The cerebellum is carefully retracted posteriorly after dissecting it free from the seventh and eighth cranial nerves, which are usually displaced laterally and inferiorly by the tumor. The safest area to begin debulking the tumor is under the temporal lobe and above the seventh and eighth cranial nerves, where the trigeminal nerve root will be located, usually displaced laterally and inferiorly by the tumor. Thorough intracapsular debulking of the tumor is essential before any significant dissection, and separation of the tumor capsule can be carried out. An ultrasonic device with a fine tip is useful. Debulking is carried out by working in between the cranial nerves starting at the top and identifying the trigeminal nerve. The temporal lobe may need to be retracted upward while working on the upper pole of the tumor. However, continuous retraction of the temporal lobe should be avoided, and the retractor should be moved away while working on the other parts of the tumor. While debulking the tumor, it is preferable to stay toward the base of the tumor, which simultaneously devascularizes the body of the tumor since the blood supply is coming from anteriorly at the base. The 6th nerve is at risk of injury at the base of the tumor and needs to be carefully sought out and preserved. As the tumor is progressively debulked, the capsule gets softer and can be gradually delivered and cut away or removed with the ultrasonic aspirator. Pulling on a tense capsule prior to adequate debulking is dangerous since it can avulse vessels and damage cranial nerves.

The inferiormost limit of exposure by the presigmoid approach is up to the top of the 9th and 10th cranial nerves. If the lower pole of the tumor reaches below the level of these nerves, removing or delivering this may be difficult. In such instances, the retrosigmoid dura is opened to provide access to the lower pole.
of the tumor. Like all lateral approaches, the presigmoid as well as the retrosigmoid approach requires the surgeon to work in between the cranial nerves. It is therefore very important to be as gentle as possible with these nerves. Intraoperative neurophysiologic monitoring of these cranial nerves may be helpful to minimize the trauma.

Because of the curvature of the clivus and petrous bone, the attachment of the tumor at the ipsilateral part of the clivus and petrous bone is usually difficult to visualize from the lateral perspective of the presigmoid approach. The overhang of the labyrinth and petrous apex can be reduced by performing a partial laminectomy in which the superior and posterior semicircular canals are drilled down and occluded with bone wax. If the patient has poor or no hearing, the entire labyrinth can be drilled away, uncovering the internal auditory canal over 270 degrees circumference. If this additional bone drilling is not an option, opening the retrosigmoid dura and looking along the cerebellum provides an excellent visualization of the ipsilateral clivus and petrous apex dura.

The degree of tumor removal is dictated by factors such as its size, consistency, adherence to important structures, and presence of an arachnoid plane. If the preoperative MRI shows a high T2 signal within the brainstem adjacent to the tumor, it indicates that there is invasion of the pia by the tumor and some tumor will have to be left against the brainstem in order to avoid permanent damage to the brainstem and perforator vessels (Fig. 38.2A and B).

**Closure**

The dura is closed primarily or with a dural graft to get as much of a watertight closure as possible. The mastoid is occluded with bone wax, and special attention is paid to the mastoid antrum. A small chip of bone and bone wax are used to close this off so that CSF is not able to enter it. The mastoid defect is filled with a free adipose tissue graft usually harvested from the abdomen. Fibrin glue is used to seal this in place. The craniotomy bone flap is replaced and fixed with titanium miniplates. A titanium mesh cranioplasty is performed to cover the mastoidectomy defect. The two muscle flaps are sutured back into position on to the titanium mesh, and the skin and subcutaneous tissues are closed. A subcutaneous drain tube is left in place, brought out through a separate stab wound and attached to a closed, gravity drainage system since CSF tends to build up and can stress the suture line. The drain is usually left in for 2 to 3 days.

**POSTOPERATIVE MANAGEMENT**

The patients are monitored in the neurosurgical intensive care unit. Temporal lobe edema and contusion are closely monitored as reflected by the patient’s level of consciousness. A noncontrast CT scan is performed the next day before the patient is transferred out of the unit and mobilized out of bed. Seizure prophylaxis is also maintained postoperatively. Sequential compression boots are maintained as deep vein thrombosis prophylaxis, and subcutaneous heparin or enoxaparin is given 24 hours after surgery.

**COMPLICATIONS**

Complications can be divided into the following:

1. Cranial nerve problems
2. Temporal lobe problems
3. Brainstem problems
4. Arterial injury
5. CSF leaks

1. Cranial nerve problems: The third through the tenth cranial nerves on the ipsilateral side are encountered during this approach. The tumors are usually located medial to these nerves, and hence, the surgeon has to work in between these nerves to debulk and remove the tumor. To make matters more complex, the nerves are often stretched posteriorly or even surrounded by the tumor, making them attenuated and compromised to begin with and therefore more vulnerable to manipulation. Temporary impairment of their function is often seen although they tend to improve with time. If a patient experiences diplopia or ophthalmoplegia, wearing an eye patch over the eye is sufficient until the function returns. In some cases, oculoplastic procedures may be needed if the function does not improve in 6 to 9 months. Conductive hearing loss can result from effusion in the middle ear space from the mastoidectomy and is self-limiting. Nerve deafness is irreversible. The incidence of facial palsy can be minimized by using facial nerve monitoring with direct stimulation as well as transcranial stimulation. Protection of the eye is important if a patient has complete facial paralysis. Placement of a gold weight and lubrication of the eye need to be rigorously implemented,
and the patient has to be educated regarding these. A combined trigeminal nerve and facial nerve deficit is a serious problem for the eye. A tarsorrhaphy may be needed in order to avoid repeated corneal ulcers and eventual blindness. Lower cranial nerve palsies will result in dysphagia and hoarseness. A modified Barium swallow test is performed early in the postoperative period if significant manipulation of the lower cranial nerves has been performed. Since postoperative nutrition is very important in the recovery of the patient, gastrostomy tube placement is considered early to minimize the chance of malnutrition and aspiration pneumonia. In most instances, this is only a temporary measure and the tube can be removed in a few months when the patient resumes oral intake.

2. Temporal lobe problems: The majority of problems with the temporal lobe are caused by retraction and injury to the veins draining to the temporal lobe that travel from the undersurface of the temporal lobe to the tentorium. Prevention is the main strategy, since, once the problems have started, the neurologic consequences are serious and can be irreversible, especially on the side of the dominant temporal lobe. There can be more than one vein in this area, and all of them need to be preserved. The tactics described above need to be diligently implemented. The surgeon should retract sparingly and intermittently, by working in different portions of the tumor instead of working in one part of the tumor for a long period of time needing prolonged retraction.

3. Brainstem problems: It is very important to review the preoperative T2-weighted and FLAIR MR images prior to the operation. High signal within the brainstem adjacent to the tumor indicates that the tumor has violated the arachnoid and the pia producing edema in the brainstem. The dissection plane is absent in these situations, and also the perforating arteries to the brainstem are often adherent to the tumor or even supply the tumor. This situation presents a risk of direct injury to the brainstem while peeling the tumor capsule or perforator injury resulting in a stroke. In these situations, it is advisable to leave a portion of tumor on the brainstem.

4. Arterial injury: The basilar and vertebral arteries and their branches are often intimately involved with these tumors. If there is complete encasement of the vessel, there is a high risk of injury and the surgeon has to be extremely cautious in such cases. The risk increases in firm tumors and vascular tumors because visualization of the structures and planes becomes more difficult in such cases. Blood supply to the tumor from the vertebobasilar system and its branches seen on an angiogram is a warning sign and demands meticulous technique and judgment as to aggressiveness of resection.

5. CSF leak: During closure, the mastoid antrum leading to the middle ear space needs to be closed thoroughly and completely. Watertight dural closure is not possible in most instances, and a dural substitute is placed over the dural repair as well as over the drilled surface of the mastoid. A sealant is used to hold these in place, and an adipose tissue graft is laid on top of this.

RESULTS

This approach allows excellent access to the tumors described above. The resectability of these tumors depends on several factors. The consistency of the tumor plays an important role; the softer the tumor, the easier it is to remove it without undue manipulation of the nerves or the brainstem. If the tumor invades important blood vessels or even surrounds them, complete removal may not be possible due to the risk of causing a brainstem infarct. If the plane between the tumor and the brainstem is not defined by a distinct arachnoid layer, the surgeon will be obligated to leave some tumor behind on the brainstem to avoid injury.

Tumors that are very vascular are a particular challenge because the blood supply comes from its attachment to the clival dura. The surgeon does not gain access to the blood supply till quite late in the procedure, and therefore devascularization of the tumor early on is not usually possible unless some preoperative embolization has been carried out.

PEARLS

- Careful analysis of the preoperative imaging studies is critical in defining whether the approach is suitable for the lesion to be treated.
- The patient and the family need to be thoroughly educated regarding the potential risks and how they will be managed. The recovery process can be quite stormy, and it is important that a good understanding and relationship be established with the patient and family prior to the surgery to avoid their dissatisfaction.
- The patient must be positioned carefully so that the head is not turned too sharply compromising the venous return. This can produce a “full brain” that will severely limit the exposure and can even prevent the surgeon from proceeding with the operation. If a full brain is encountered after opening the dura, the surgeon may elect to place a ventricular drain in the lateral ventricle through the temporal lobe, elevate the head, or even “un-turn” the head to some degree to achieve relaxation.
- The temporal bone should be drilled down to the jugular bulb, and there should be no bone left on the sigmoid sinus. This is important in order to be able to mobilize the sigmoid sinus adequately to work in front of it.
PITFALLS

- If careful arachnoid plane dissection is not followed, damage to the cranial nerves, the blood vessels, and the brainstem will likely occur with many adverse consequences.
- Retraction of the sigmoid sinus for any prolonged period should be avoided to prevent thrombosis of this structure.

INSTRUMENTS TO HAVE AVAILABLE

- Surgical drill
- Reciprocating saw
- Temporal lobe retractor
- Bipolar electrocautery
- Ultrasonic aspirator
- Titanium mesh

SUGGESTED READING

INTRODUCTION

Several pathologies can be addressed with a far lateral approach to the lower clivus and upper cervical spine. The most common lesions for which surgeons would choose this approach are skull base tumors, such as meningiomas of the foramen magnum and lower clivus, and vascular lesions, such as aneurysms of the vertebral artery or posteroinferior cerebellar artery (PICA). Less common lesions include clival chordomas and tumors of the lower cranial nerve sheath, in addition to metastases from various sites and occasionally an extensive glomus tumor. The approach is chosen to provide a lateral approach to enable the surgeon to remove tumors and treat vascular lesions situated lateral and anterior to the upper cervical spine and medulla (Fig. 39.1).

HISTORY

The most common symptoms of a lesion of the lower clivus and upper cervical spine are headache and pain in the neck. If the lower clivus and condyles are involved, as in cases with an extensive chordoma, pain may be associated with movement of the head. Schwannomas of the lower cranial nerves may have symptoms referable to the involved nerve (e.g., weakness of the tongue, hoarseness, or difficulty swallowing). If the lesion is large enough, there may be compression of the cervicomedullary junction, with associated long tract signs such as weakness or numbness, which is usually asymmetric. In such cases, upper motor neuron weakness, with spasticity, gait difficulties, and occasionally sensory loss, may be present.

Obviously, in cases of aneurysmal subarachnoid hemorrhage (SAH), the presentation will involve acute severe headache and impairment of the neurologic sensorium. Severe meningismus will accompany the SAH with neck rigidity. There is nothing specific to the presentation of a ruptured aneurysm of the posterior circulation in most cases, but a local hematoma may produce specific cranial nerve deficits, such as hearing loss or swallowing difficulty.

PHYSICAL EXAMINATION

During a thorough neurologic evaluation, particular attention should be paid to the cranial nerve examination. Even in the absence of symptomatology, subtle cranial nerve deficits may be noted. A diminished gag reflex may be the result of cranial nerve IX and X deficits that may not have reached the magnitude for the patient to note difficulty with swallowing. Long tract signs may manifest as upper motor weakness and spasticity with increased tone and associated reflexes in the affected arm or leg. Similarly, there may be associated sensory deficits of various modalities. Gait evaluation may reveal ataxia with a positive Romberg sign. In addition to the signs and
symptoms of SAH, I have also seen presentation of dissecting aneurysms, common in the vertebral artery and PICA, presenting with specific ischemic syndromes, such as the lateral medullary syndrome of Wallenberg.

INDICATIONS

Classic indications for a far lateral approach include pathology anterior to the lower brainstem and upper cervical spine. This includes meningioma (at the foramen magnum or upper anterior spine in location), chordoma of the lower clivus or upper cervical spine, lower cranial nerve schwannoma, or vascular lesion (most commonly aneurysms) involving the vertebral artery or PICA.

CONTRAINDICATIONS

Contraindications for this approach are few, but include congenital anomalies of the upper cervical spine, which might predispose to instability and perhaps an isolated vertebral artery when the contralateral vertebral artery is compromised. This latter condition could increase the chances of devastating posterior circulation ischemia with injury to a sole vertebral artery. Relative contraindications to the approach are paralysis of the contralateral vocal cord or other dysfunction of the lower cranial nerves, which would predispose to a life-threatening bilateral vocal cord paralysis or swallowing difficulties with additional cranial nerve injury on the operated side.

PREOPERATIVE PLANNING

In most instances, magnetic resonance imaging with contrast enhancement is the best imaging study to characterize the nature of the tumor in the upper cervical or clival region. The signal characteristics of specific tumors are characteristic in this location. A meningioma usually will be isointense with the brain on T1-weighted imaging and will avidly enhance with the administration of gadolinium contrast. Chordomas may involve the bone of the clivus or upper cervical spine and are usually erosive. They do enhance with contrast administration, but more specifically are of high signal intensity on T2-weighted imaging, which is a useful tool to differentiate from other tumors such as metastasis. Any involvement or encasement of major vessels, often the vertebral artery or PICA at its origin, should be noted.

In cases of aneurysms, computed tomography (CT) will more accurately demonstrate subarachnoid blood and the predominant location (cervicomedullary cistern or 4th ventricle) may indicate a verteobasilar or PICA location. In these cases, a CT angiogram (CTA) study is indicated, which may demonstrate the aneurysm. In some
cases, with extensive bone and beam-hardening artifacts in the base of the skull, a conventional digital subtraction angiogram will be necessary to demonstrate the vascular lesion, particularly in cases with dissecting aneurysms.

The rationale for choosing a far lateral approach to the cervicomedullary junction is to provide a more lateral trajectory to the region to avoid or reduce retraction on the brainstem and cerebellum (Fig. 39.1). The region is replete with important cranial nerves and the vertebral and basilar arteries and their branches and perforating vessels. During preoperative planning, imaging is carefully studied, noting the size and location of the tumor and its relationship to the brainstem and vasculature. It is common to encounter tumors in this location that completely enuence one vertebral artery in its intradural course. As such, the potential for injury during resection must be considered during planning, and, in such cases, I like to document bilateral vertebral arteries that have a normal course and anastomose at the basilar junction. A common variant is a small vertebral artery on one side that terminates ends in PICA; in such cases, a balloon occlusion test of the involved vertebral artery should be performed, and planning will include repair or revascularization by bypass if the vessel cannot be sacrificed safely.

An important consideration when resecting tumors of this region is the stabilization of the cranio-occipital junction. I have had several cases in which extensive chordomas and glomus tumors in this location have resulted in bone erosion such that after their removal the craniocervical junction is destabilized by the tumor erosion and additional drilling of the bone. This needs to be anticipated, and I have performed both simultaneous and staged cranio-occipital stabilization procedures with spine specialists in these cases.

With vascular lesions, especially aneurysms of the vertebral artery or PICA, surgical planning will include any options for endovascular treatment of these lesions. If an open surgical approach is deemed the optimal treatment, planning for treatment will include anticipating options such as vessel sacrifice if tolerated or clip-wrap and bypass techniques.

**SURGICAL TECHNIQUE**

The location of the tumor, its area of attachment, and involvement of any vascular structures are noted and included in the decision-making process. The extent of drilling of the skull base and condyle is not uniform and is tailored to the particular tumor or vascular lesion. In general, more bone drilling is used for extensive chordomas in this location than for other tumors. The amount of the condyle removed is planned based on the trajectory needed. In most cases of vertebral artery or PICA aneurysms, extensive resection of the condyle or drilling of the jugular tubercle is not necessary.

It has been estimated by some authors that the posteromedial one-third of the occipital condyle may be resected without inducing instability. This issue should be considered on opening, and it should be determined prior to drilling whether bone removal in combination with tumor erosion will result in destabilization of the unilateral condyle region. I have had experience with such cases in which, in addition to the condyle itself, the bone superior to the condyle was involved with tumor such that the condyle was disconnected from the remainder of the skull base, which produced the same destabilizing result.

**Far Lateral Transcondylar Approach**

The patient is placed in the lateral position with the head in Mayfield three-point fixation (Fig. 39.2), with extensive padding between the legs and in the axilla. The upper arm is supported by an airplane rest and padded accordingly. An important feature of positioning is that the upper arm is directed inferiorly to pull the ipsilateral shoulder as low as possible. This, in combination with lateral flexion of the neck, provides more operative room in the lateral suboccipital–cervical region. A Foley catheter and arterial line are placed prior to positioning.

Several options have been described for skin incision for a far lateral exposure. I use one of two options depending upon the extent of exposure noted and whether the need for the occipital artery for revascularization is anticipated. The first is a curved incision extending from the retromastoid region (approximately 2 to 3 cm behind the mastoid) to the lateral neck down to approximately C4 in most cases (Fig. 39.2). This approach provides rapid exposure to the region of interest with the least soft tissue disruption and postoperative pain. Alternatively, if more exposure is needed to the midline for placement of stabilization hardware or in cases involving harvesting of the occipital artery, I use a larger incision extending to the midline and then laterally in a hockey-stick fashion producing a flap. The occipital artery may then be dissected as necessary in preparation for bypass.

The skin flap is elevated in two layers. First, the incised skin and galea are elevated to expose the pericranium above the superficial fascia of the neck, which may be harvested as a fascial graft for later watertight dural closure. The pericranium and the superficial fascia are then elevated to expose the underlying musculature.

During the dissection, three layers of muscle are identified. The superficial layer, including the trapezius and sternocleidomastoid muscles, and the middle layer, consisting of the splenius capitis, longissimus capitis, and semispinalis capitis muscles, are incised and reflected as a single layer posteriorly. This exposes the suboccipital triangle (Fig. 39.3), which is opened by detaching the insertions of the superior and inferior oblique muscles from the transverse process of C1 and reflecting them posteriorly. The rectus capitis major is detached from the inferior nuchal line and reflected posteriorly, after which the C1 lamina and vertebral artery will become more apparent. Further exposure of the laminae of C2 or C3 may be performed if more inferior exposure is needed.
FIGURE 39.2
A. Diagram showing the patient placed in the lateral position. The head is held in three-point pin fixation with the neck slightly flexed, the vertex angled slightly down, and the face slightly rotated ventrally, so that the ipsilateral external auditory meatus and the mastoid bone are at the highest point.
B. Retroauricular curvilinear skin incision (dotted line).

FIGURE 39.3
Illustration showing the suboccipital triangle, which is bound medially by the rectus capitis posterior major (RCM) muscle, inferiorly by the inferior oblique (IO) muscle, and superolaterally by the superior oblique (SO) muscle and serves as an anatomic landmark for identifying the dorsal ramus of the C1 nerve root and the V3 horizontal segment of the vertebral artery (VA).
CHAPTER 39 Far Lateral Transcervical Approach to the Lower Clivus and Upper Cervical Spine

The extradural course of the vertebral artery from the foramen transversarium of C2 to the occiput is identified to facilitate exposure. The ventral ramus of the C2 nerve root, found between the laminae of C1 and C2, can be traced laterally until it crosses dorsal to the vertical segment of the vertebral artery, coursing between the foramen transversarium of C2 and C1 (Fig. 39.4). Small muscular branches and the posterior meningeal artery arising from the horizontal segment of the vertebral artery can be safely coagulated. In some cases, the posterior spinal artery and the PICA arise extradurally; care must be taken to avoid injury to these structures. Subperiosteal dissection of the vertebral artery from the vertebral groove reduces bleeding from the venous plexus by leaving the periosteal sheath around the artery intact. The atlanto-occipital membrane is sharply divided to expose the underlying dura. Vertebral artery transposition can be performed by opening the foramen transversarium of C1 with a high-speed diamond drill and mobilizing the artery inferomedially away from the atlanto-occipital joint. Although transposition is not necessary in most cases for the standard far lateral transcondylar approach, this maneuver is important for gaining a direct lateral (extreme lateral) trajectory to resect the lateral mass of C1, the lateral aspect of the occipital condyle, the odontoid process, and the inferior clivus, as described in the extreme lateral approaches for resection of extradural lesions of the craniovertebral junction. Subsequent occipitocervical stabilization, which is necessary if the atlanto-occipital joint is resected, can be performed unilaterally with the same surgical exposure immediately after resection.

I use a craniotome and rongeurs initially to create a lateral suboccipital craniectomy or craniotomy extending toward the midline medially, to the inferior nuchal line superiorly, to the posterior rim of the foramen magnum inferiorly, and up to the occipital condyle laterally (Fig. 39.5). For more superior access to the cerebellomedullary angle, I extend the craniectomy up to the transverse–sigmoid junction. Then, the sigmoid sinus and jugular bulb are exposed by using rongeurs and a high-speed drill. The posterior condylar emissary vein will be encountered as it travels from the jugular bulb and exits the condylar fossa via the condylar canal to join the extradural venous plexus. Hemostasis can be achieved by packing the vessel with Surgicel. An ipsilateral hemilaminectomy of C1 extends the exposure of the dura inferiorly, and removal of the hemilamina of C2 and C3 provides additional inferior exposure for lower-lying lesions.

Extradural reduction of the occipital condyle is one of the key maneuvers in maximizing exposure to the ventral aspect of the craniovertebral junction while avoiding brainstem retraction (Fig. 39.6). Partial resection of the condyle increases the angle of exposure, the working space at the level of the foramen magnum, and the visualization of the ventral and ventrolateral aspect of the craniovertebral junction and the contralateral aspect of the inferior clivus. Although the degree of removal of the occipital condyle necessarily varies widely, from no resection to complete resection, my experience indicates that removal of the posterior and medial

![Diagram of the course of the vertebral artery](c) 2015 Wolters Kluwer. All Rights Reserved.
one-third of the condyle usually is adequate if more ventral exposure is needed. It is important to study preoperative CT images of the cranial base, because not all patients require resection of the condyle. Resection of the condyle may not be necessary to widen the surgical corridor (Fig. 39.7) if the patient has small occipital condyles and a large foramen magnum or if the tumor has eroded the condyle and displaced the brainstem medially. The craniovertebral junction becomes more unstable when more than 50% of the condyle is resected.

**FIGURE 39.5** A. Illustration of retrosigmoid lateral suboccipital craniectomy (dotted line), extending toward the midline medially, to the inferior nuchal line superiority, to the posterior rim of the foramen magnum inferiorly, and up to the occipital condyle laterally. B. The craniectomy can be extended up to the transverse–sigmoid junction to provide more superior access to the cerebellopontine angle, as shown. The dural incision (dotted line) is made in a curvilinear fashion several millimeters posterior to the sigmoid sinus and extends inferiorly toward the C2 lamina, staying posterior to the vertebral artery where it pierces the dura. A relaxing “T” incision is made just superior to the entry of the vertebral artery, leaving a cuff of dura around the vertebral artery for later watertight closure.

**FIGURE 39.6** Illustration showing reduction of the occipital condyle (OC) and jugular tubercle (JT), which increases the angle of exposure and visualization of the ventral foramen magnum past the midline of the clivus (shaded triangle).
or destroyed by the lesion; in these patients, occipitocervical stabilization may be necessary. The posteromedial aspect of the occipital condyle is removed with a high-speed diamond drill, taking care to protect the vertebral artery (Fig. 39.8). Once the cortical layer of bone is removed, the soft cancellous bone is encountered. Further drilling will expose another cortical layer of bone that covers the hypoglossal canal. Identification of the medial aspect of the hypoglossal canal usually indicates that approximately one-third of the posterior condyle has been removed. Because the hypoglossal canal is directed anteriorly and laterally at a 45-degree angle with the sagittal plane, further skeletonization of the canal to its lateral extent usually results in removal of the lateral aspect of approximately the posterior two-thirds of the condyle. Removal of bone is next directed superiorly toward the inferior margin of the jugular bulb.

Extradural reduction of the jugular tubercle is the key step in maximizing intradural exposure across the anterior surface of the brainstem and midclivus (Fig. 39.8). This maneuver also may make it easier to visualize the

FIGURE 39.7 A. Diagram demonstrating a ventral foramen magnum tumor compressing the brainstem. A far lateral transcondylar transtubercular approach (shaded in gray) provides excellent exposure for a lesion in this region. B. A very large tumor of the clivus compressing the ventral and lateral aspects of the brainstem that has eroded the occipital condyle. A far lateral approach without transcondylar or transtubercular resection would be sufficient in removing this tumor because the tumor has created a large surgical window by displacing the brainstem medially. Postoperative occipitocervical stabilization should be strongly considered because the tumor has eroded a significant portion of the occipital condyle.

FIGURE 39.8 A. Illustration showing inferior view of the base of the cranium and the anatomic relationship of the jugular tubercle, hypoglossal canal, and occipital condyle. The jugular tubercle is situated superior to the hypoglossal canal. The occipital condyle is inferior to the hypoglossal canal. B. Extradural reduction of the posterior third of the occipital condyle and the superomedial aspect of the jugular tubercle is the key maneuver for gaining access to the ventral foramen magnum.
some vertebrobasilar junction aneurysms and vertebral artery–PICA aneurysms. Failure to reduce a prominent jugular tubercle adequately may result in an obstructed view of the basal cisterns and clivus anterior to the lower cranial nerves. Reduction of the jugular tubercle should focus on the superomedial aspect portion, which is the major area of obstruction. Where they cross over the deep aspect of the jugular tubercle into the jugular foramen, cranial nerves IX, X, and XI may be at risk of damage by direct trauma, stretching of the dura mater, and heat generated by the drill. To minimize these risks, the center of the tubercle is cored out with a high-speed diamond drill and copious irrigation, leaving an eggshell-thin layer of bone covering the dura mater that can be elevated with a microdissector.

Intradural exposure is necessary for accessing intradural lesions, such as meningiomas, schwannomas, aneurysms, and vascular malformations (Figs. 39.9 and 39.10). I make a curvilinear incision of the dura several millimeters posterior to the sigmoid sinus, extending inferiorly toward the C2 lamina and staying posterior to the vertebral artery where it pierces the dura mater (Fig. 39.5). I prefer to extend the dural opening anteriorly in a “T” fashion, just superior to the vertebral artery, to enable increased exposure. The incision can be extended up to the junction of the transverse–sigmoid sinus if more exposure of the cerebellopontine angle is needed. A dural cuff is preserved around the vertebral artery for later watertight closure. The anterior leaflet of the dura mater is reflected laterally and is held with tacking sutures for maximal exposure. Adequate reduction of the occipital condyle and jugular tubercle should provide a straight surgical trajectory to the craniovertebral junction parallel to the intracranial course of the vertebral artery. Structures of the inferior aspect of the cerebellopontine angle and the cerebellomedullary angle are visualized. Sharp arachnoid dissection is performed, and cranial nerves V through XII, the basilar artery, the vertebrobasilar junction, the PICA, and the anteroinferior cerebellar artery can be visualized (Fig. 39.10).

Closure

A primary watertight closure of the dura should be performed. If necessary, an autologous pericranium or fascial graft can be harvested from the neck wound and supplemented with autologous adipose tissue and fibrin glue or fascia lata or abdominal fascia may be used. The exposed mastoid air cells are closed with bone wax. The muscle layers are reapproximated carefully to avoid postoperative leakage of cerebrospinal fluid (CSF). Temporary CSF diversion with a lumbar drain can be used to promote sealing of the wound and reduce the risk of a pseudomeningocele developing.

**FIGURE 39.9**
Preoperative MRI scans.
Sagittal FLAIR (A) and axial T1 with contrast (B) views demonstrate a ventrally based foramen magnum meningioma compressing the cervicomedullary junction in a 36-year-old man who presented with progressive myelopathy. Gross total resection was achieved by use of a far lateral approach. **C.** Postoperative sagittal MRI scan.
In Video 39.1, a 56-year-old man has suffered a severe subarachnoid hemorrhage from a ruptured proximal fusiform aneurysm of the left posteroinferior cerebellar artery. The plan was to either repair the aneurysm after inspection or perform distal bypass and trap the aneurysm. Shown in the video is the harvesting of the occipital artery from the flap in preparation for the bypass if needed. Ultimately, the aneurysm was clip–wrapped with muslin gauze to prevent rebleeding.

POSTOPERATIVE MANAGEMENT

The patient is monitored in the intensive care unit postoperatively. Depending on the nature of the lesion, the major risks are damage to the lower cranial nerves and vertebral artery. Careful airway management is essential, and evaluation of vocal cord and swallowing function is performed in the intensive care unit to determine if there is a risk for aspiration.

COMPLICATIONS

The most common complication noted is development of CSF pseudomeningocele from lack of an adequate dural closure. To prevent this complication, I use an adipose tissue graft extradurally to eliminate dead space and bolster the dural closure. The abdomen or lateral thigh may be used for donor sites. The most serious complications relate to vascular injury to the vertebral artery or lower cranial nerve palsy (swallowing, airway protection, or hypoglossal nerve weakness). Rarely, overresection of the occipital condyle–C1 joint may lead to instability of the neck.

RESULTS

The approach is ideal for the resection of a meningioma of the foramen magnum (Fig. 39.9). The surgeon has an excellent trajectory anterior to the brainstem and upper cervical spine. Similarly, this is the approach of choice for aneurysms of the vertebral artery or proximal aspect of the PICA. The wound heals well, with a cosmetically acceptable scar whether a curvilinear or larger incision is used. The patient may complain of stiffness of the neck early postoperatively, but, in the absence of instability or fixation, should be reassured that full mobility of the neck will resume with time (usually a few weeks). If the smaller curvilinear incision is used, the postoperative pain is minimized as there is relatively little posterior cervical muscular disruption.
PEARLS

- Prior to surgery, a rigorous evaluation includes magnetic resonance imaging, with evaluation of vascular involvement by computed tomographic angiography or digital subtraction angiography if necessary.
- Preoperative counseling of the patient should include a thorough discussion of the possibility of lower cranial nerve dysfunction.
- Meticulous bimanual microsurgical dissection is the best option for safe surgical removal. Blunt dissection is to be avoided, and careful attention is paid to all perforating vessels to the brainstem and to careful preservation of all lower cranial nerves.

PITFALLS

- Attention must be paid to minimize intraoperative manipulation of lower cranial nerves since unilateral lower cranial nerve palsies may be significantly morbid and bilateral palsies are potentially fatal.
- CSF leak or pseudomeningocele development is a risk if closure of the dura is not performed adequately. Dural closure is challenging in this region and use of dural grafts is usually necessary.

INSTRUMENTS TO HAVE AVAILABLE

- Needle-tip monopolar electrocautery
- Bipolar cautery
- High-speed cutting (3 to 4 mm) and diamond (3 to 4 mm) drills
- Microscope
- Suction–irrigator or surgical assistant to provide irrigation while drilling
- Microsurgical dissectors

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SUGGESTED READING

INTRODUCTION

Cerebrospinal fluid (CSF) rhinorrhea is a condition that in most patients is not diagnosed early unless it is precipitated by trauma, either penetrating or blunt. CSF leaks encountered during sinus surgery could be the result of progression of the disease process, which may be inflammatory or neoplastic in origin. Benign or malignant tumors may produce spontaneous CSF leaks due to local growth that may penetrate the dura or the arachnoid membrane. CSF leaks can be divided into four categories in order to plan a repair of the dural defect: spontaneous leaks, leaks resulting from penetrating trauma, leaks resulting from blunt trauma, and surgically planned leaks.

HISTORY

It is important to elicit a careful history in the diagnosis and management of CSF leaks. A history of clear nasal discharge following nasal trauma is useful in assessing the etiology of the condition. Spontaneous clear nasal discharge is usually an indication of a leak from one of the sites of nonfusion of the skull base, or erosion from a lesion at the same region. Blunt, nonpenetrating trauma produces leaks by an imploding pattern of injury. This contrasts with surgical trauma following endoscopic surgery in the skull base region where there is a clear site of penetration.

PHYSICAL EXAMINATION

Physical examination in patients with CSF leaks is strictly limited to an endoscopic examination of the nasal cavity under topical vasoconstriction. Endoscopic examination with a 0-degree and a 30-degree rigid endoscope is valuable in searching for the anatomic location of the defect and the surrounding pathology (Fig. 40.1). The nasal discharge should be collected in a clear tube and analyzed for beta-2 transferrin enzyme, which is the most accurate laboratory test for diagnosing CSF leak. This enzyme is contained in the CSF, vitreous humor, and cochlea. Collection of a minimal amount of 0.4 mL is adequate to make the diagnosis biochemically.

INDICATIONS

All dural defects associated with CSF leaks should be surgically closed in order to prevent meningitis or cerebritis, which otherwise will ensue.
CONTRAINDICATIONS

There are relatively few contraindications for this surgical procedure. If a CSF leak is seen in the face of an infection, it may be wise to treat the inflammation or infection prior to the surgery. This is especially seen in patients with spontaneous leaks or when there is evidence of blunt trauma to the head. It is preferable to have stable mucosa that has better potential to heal well postoperatively.

PREOPERATIVE PLANNING

In the preoperative planning of the reconstruction of defects in the skull base, radiologic examinations in the form of a CT scan and MRI scan are absolutely necessary. A CT scan with a triplanar view for image guidance will help in analyzing the defect and also help in the surgical planning. These are usually nonoverlapping axial scans of the head with sagittal and coronal reconstructions (Fig. 40.2). The second imaging modality that should be obtained in all of these cases is an MRI scan with contrast. This helps to identify the extent of brain and meningeal involvement in these defects. They also help to identify important neurovascular structures near the site of the defect. When planning a surgical repair of these defects, the choice of nonvascular material for closure of small defects is usually an autologous homograft. The best choices are a free adipose tissue graft and fascia lata graft, which have the highest potential to heal well. The use of the lumbar drain should be considered in select cases where the potential to obtain a satisfactory result is improved by decreasing intracranial pressure for a short period of time. This is usually the case in spontaneous leaks where the patient’s body mass index is high and associated with high intracranial pressure.

In my experience, the use of intrathecal fluorescein has been a valuable adjunct in identifying the site of the CSF leak in the skull base. Occasionally, there may be multiple leaks that may be overlooked when
there is one particular site that is large. This is usually seen in congenital, small skull base bone defects. Fluorescein is injected after a lumbar puncture at the beginning of the surgical procedure. Patients are usually pretreated with diphenhydramine and dexamethasone upon arrival to the operating room, prior to induction of anesthesia. The dosage of fluorescein is usually 0.25 mL of 10% fluorescein diluted in 10 mL of CSF. The use of blue light with or without an amber blocking filter is also helpful in certain cases (Fig. 40.3). It should be noted that this use of fluorescein is off-label. I usually favor a team approach with a neurosurgeon for the closure of these defects, as it is helpful in the entire management of the patient and improves the outcome.

**SURGICAL TECHNIQUE**

The patient is turned in lateral position, and a lumbar puncture is performed. If a lumbar drain is planned, it should be placed at this time. Now 10 mL of CSF is withdrawn and diluted with 0.25 mL of 10% fluorescein and reinjected into the intrathecal space. The patient is placed in the supine position. Head pins are then placed, and the image guidance system is calibrated for accuracy. CT scan image guidance is used in most cases. Dual MRI scan image guidance can also be used simultaneously.

Once the patient is prepared for surgery, cottonoids soaked in 4 mL of 4% cocaine are inserted into the intranasal cavity for vasoconstriction. This is helpful in diagnostic intraoperative endoscopic examination. Once the defect is localized, a regional vascular strip injection for ethmoidectomy, sphenoidotomy, or frontal recess surgery is carried out based on the location of the defect. It is ideal to have a clear view of the site of the defect prior to instrumentation. The bone defects in the skull base are usually well identified with a 30-degree or a 45-degree rigid endoscope, and the edges of the defect are freshened up. Small defects require careful attention during this process, as aggressive instrumentation may enlarge the defect, requiring different forms of closure. Small skull base defects are usually easily identifiable. For low-pressure, low-volume leaks, a free adipose tissue graft, harvested from the anterior abdominal wall, can be placed using an underlay technique for adequate closure. Once closed, endoscopic visualization with blue light...
may be used to verify a watertight closure. Subsequently, Duraseal and Floseal can be applied in that area to augment the closure. Defects in the roof of the sphenoid, the ethmoid, or the nasal cavity medial to the vertical lamella of the middle turbinate are relatively easy to close as the plane of closure is horizontal, and positioning the graft is convenient and uncomplicated. Small leaks in the lateral lamella of the frontal recess or the lateral wall of the sphenoid sinus require more careful planning, as the plane of closure is oblique and requires careful attention when freshening up the defect prior to closure. Finally, a Telfa sponge is applied to support the graft.

If the defect is large enough to warrant a fascia lata graft (2 cm × 2.5 cm), a gasket seal closure should be considered. This helps to improve the rate of successful closure in small defects that are more challenging. The edges of the bone are first freshened up, and fascia lata is harvested from the lateral aspect of the thigh. The graft is fashioned to be larger than the defect and then inset into the defect. A Medpor prosthesis is then countersunk into the defect to ensure complete closure at the edges of the defect (Fig. 40.4). Duraseal is usually applied thereafter, followed by Floseal, which is a useful adjunct in these closures. Once the procedure is completed, the patient is extubated without coughing to ensure that the graft is not displaced. Antibiotics are used in the high-risk category of patients: patients with resolving infections, those with comorbid conditions, and patients with poor wound healing conditions.

**FIGURE 40.4**

A. Schematic view of the various steps of gasket seal closure.  B. Schematic coronal view of the gasket seal demonstrating closure of the edges of the leak and with obliteration of the dead space with adipose tissue when there is an indication for it.
CHAPTER 40 Nonvascularized Repair of Small Dural Defects

POSTOPERATIVE MANAGEMENT

Postoperative management of these patients should be carefully planned and carried out. I usually see patients 1 week postoperatively to examine the wound healing process. Careful endoscopic debridement is useful in removing the epithelial debris and crusts to enhance wound healing. I have my patients use saline spray mixed with an antibiotic to ensure rapid healing. Patients are then seen at 3-week intervals until the wound is well epithelialized as confirmed by nasal endoscopy (Fig. 40.5). Patients are advised to refrain from physical activity for a period of 3 weeks after surgery.

COMPLICATIONS

Postoperative complications are relatively uncommon following endoscopic closure of small defects. Recurrent leaks due to poor wound healing or displacement of the graft in the postoperative period are the most common complications. Meningitis, cerebritis, brain abscess from an infected graft, unexplained headaches, and seizures are very unusual complications that one may encounter in the closure of small defects. The position of the Medpor prosthesis is usually not exposed after wound healing is complete. Occasionally, granulation may be seen at the surgical site, and gentle debridement promotes successful healing.

RESULTS

The wound healing and the choice of the graft material with the technique of closures usually have a major role in the success of the closure. The closure rate is usually in the high 90% range and improved further by placement of a gasket seal.

PEARLS

- An accurate radiologic, biochemical, and endoscopic diagnosis should be made prior to surgery.
- The etiology and the mechanism of the leak should be evaluated prior to surgery.
- The choice of graft material must be planned prior to surgery.
- Consider short-term lumbar drainage (48 hours) in spontaneous, small high-pressure leaks.
- Use of intrathecal fluorescein is a valuable adjunct with image guidance for identifying the site of leak for closure.
- A team approach with a neurosurgeon leads to improvement of the results of CSF leak closure.
- Endoscopic postoperative surveillance of the surgical site is absolutely necessary until the wound heals well.
- It is important to have longer instruments than the conventional sinus instruments to access these areas in the skull base.

FIGURE 40.5 Endoscopic view of the gasket seal closure intraoperatively (FL, fascia lata; MP, Medpor prosthesis) and a healed gasket seal of the roof of the ethmoid sinus.
PITFALLS

- Poor preoperative evaluation with poor planning always leads to poor results.
- Surgical closure in the presence of an infection at the surgical site area leads to a higher incidence of graft rejection.
- Compromising on the choice of instruments to use in endoscopic skull base surgery leads to poor outcome including leaks.

INSTRUMENTS TO HAVE AVAILABLE

- Standard endoscopic sinus surgery instruments
- Endoscopic skull base surgery instruments

SUGGESTED READING


INTRODUCTION

Large dural defects are usually the result of a major resection of the dural layer for oncologic purposes. After expanding the endonasal approach, theoretically, the dura of the entire ventral skull base, as far as the upper spine, can be resected. Rarely, these defects can be part of a more complex condition related to skull base and cranial malformations. In these latter cases, their presentation is really variable; the most extreme situation is when brain parenchyma can be seen through the oral cavity. Other cases are less clinically evident, especially given the age of the patients, and can become clinically evident after an episode of meningitis.

An important and critical concept needs to be strongly underlined: It is not the size of the defect that makes the reconstruction complex. Rather, it is the location and the definition of the borders of the defect that make the procedure either easy, complex, or sometime impossible. A huge defect in the anterior cranial fossa extending from orbit to orbit and from the planum sphenoidal to the frontal sinuses can be easier to repair than a much smaller defect of the lateral recess of the sphenoid sinus in which the precise borders are hardly identifiable.

HISTORY

With regard to the majority of postresection cases, we must focus on the history of the underlying pathology, but this aspect is addressed in other chapters of this book. Focusing on the topic of congenital malformations, the problem in defining an informative history is related to the young age of the patients. In obvious malformations involving the head and the cranium, no particular difficulty is present in raising doubts about the presence of skull base malformations. In less apparent cases, in which the patient is otherwise normal, a high degree of suspicion is needed. Most of these patients come to attention after an episode of meningitis; rarely are they found incidentally. This is quite obvious because watery secretions in infants, in other aspects normal, are really a common situation. For this reason, delay in diagnosis is the rule and not the exception.

PHYSICAL EXAMINATION

Most of the large dural defects are a consequence of a wide dural resection during removal of a tumor of the anterior cranial fossa. Given the possibility of compromising the availability of fascia lata, previous surgery to the legs must be evaluated. In the significantly rarer cases related to severe malformations of the skull base, a thorough evaluation of the head and cranium is necessary. In some situations, the malformations are so complex that they must be evaluated in a multidisciplinary manner rather than simply with an endoscopic approach. The proper solution should be offered after a careful examination by a team including a neurosurgeon, a maxillofacial surgeon, and a reconstructive surgeon. Notwithstanding this, whenever possible, the endoscopic approach alone should be chosen for the more minor malformations (Fig. 41.1).
**INDICATIONS**

Every case of a dural defect with or without cerebrospinal fluid (CSF) leak must be repaired. Reconstructions strive to recreate a separation of the cranial cavity from the sinonasal cavity, to prevent CSF leak, pneumocephalus, and intracranial infection. Small defects in the skull base can be reconstructed using different types of free grafts with a high rate of success (>95%) (Castelnuovo, 2001). However, larger dural defects should be reconstructed by means of vascularized flaps. Among these, the nasoseptal flap is the preferred choice (Harvey, 2009; Patel, 2010). Personally, I consider every patient a candidate for a nonvascularized reconstruction, unless bone edges are not present. The absence of these bone edges prevents the proper positioning of the inlay grafts, the first intracranial intradural, and the second intracranial extradural (in a sort of “epidural pocket”), and so the risk of postoperative leakage is significantly increased. In this respect, most of the defects of the anterior cranial fossa are amenable to this reconstruction, while for defects of the middle and posterior cranial fossa, the percentage decreases significantly. Anatomically speaking, when dealing with the anterior cranial fossa, the surgeon can extend the intracranial supraorbital dissection without any risks. The same consideration is not appropriate for the middle and posterior cranial fossa. In these cases, the

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**FIGURE 41.1**

The multidisciplinary approach among otolaryngologist, neurosurgeon, maxillofacial surgeons, and reconstructive surgeons allows for proper management of complex cases. A 3-year-old patient with multiple malformations underwent a surgical reconstruction of the cleft lip and palate, combined with the endoscopic endonasal skull base reconstruction of a large meningoencephalocele (asterisk in the figures).

A. Preoperative CT scan in sagittal view. B. Preoperative MR scan T2 weighted in sagittal view. C. Preoperative MR scan T1 weighted in coronal view. D. Postoperative MR scan in sagittal view in sequence T2 weighted, showing the skull base reconstruction (white arrow). E. T1 weighted, showing the skull base reconstruction (white arrow).
presence of the optic chiasm/pituitary stalk and the abducens nerve makes intracranial dissection very dangerous and not advisable.

**CONTRAINDICATIONS**

Given the necessity to have bone edges to support the inlay graft (second layer), their absence represents the most important contraindication to a standard multilayer technique with nonvascularized grafts. With regard to the anterior cranial fossa, almost every case can be managed with the nonvascularized graft technique. In this respect, surgeons need to be aware that the roof of the orbit is still present, even in complex cases of congenital malformations or in difficult revision cases, so that it can be used to support the graft. The same considerations are not always true in the middle and posterior cranial fossa, where, after wide resection of bone and dura, really limited edges of bone and dura are present. In some of these cases, we perform a sort of “gasket seal” technique (Lenz, 2008) usually using some type of elastic material such as septal or conchal cartilage to fix the connective tissue inside the dural defect. Furthermore, I am personally convinced that most cases of high-flow CSF leaks can be well managed with this technique if the inlay graft or the gasket seal technique is well conducted. Nevertheless, in some selected cases, especially when dealing with posterior cranial fossa and complex pituitary CSF leaks, I prefer to adopt a hybrid technique in which the multilayer technique is associated with a vascularized flap.

**PREOPERATIVE PLANNING**

Most of the large dural defects are the result of a resection for sinonasal malignancy. In those cases, resection of the dura is tailored to the needs of the patient and so can be extended from orbit to orbit and from frontal sinuses to planum sphenoidale. Thus, in every case I approach, a large dural defect is anticipated and reconstruction is planned. In this respect, especially when intradural work is anticipated, preoperative imaging is critical in order to evaluate the intracranial relationship of the lesions, mostly with respect to blood vessels (Fig. 41.2). Particular sequences of MR, not limited to anterior cranial fossa but extended to evaluate the entire skull base, are of paramount interest in the detection of suspicious areas, especially in cases of malformations (Fig. 41.3).

In these latter cases, CT scans demonstrate their utility allowing a precise and accurate evaluation of the bone structures of the sino–orbito–cranial interface. The preoperative understanding of the surgical field allows an accurate identification of the possible “supporting” structures for the reconstruction.

Of not minor importance is the identification, given our first choice for connective tissue of the patient, of previous surgery in the areas typically as donor sites. I personally prefer fascia lata and the iliotibial tract, so any kind of previous surgical procedures or trauma to the legs is evaluated. Possible connective tissue pathology is ruled out by means of history.

**FIGURE 41.2** Preoperative imaging is critical in order to evaluate the intracranial relationship of the lesions, mostly with respect to blood vessels. A 19-year-old patient previously treated with transcranial surgical approach for posttraumatic pneumocephalus and CSF leak had a history of recurrent meningitis. Before the endoscopic endonasal surgical revision of the skull base reconstruction, an MR scan was performed (A) and angiography (B), which revealed the presence of the medial orbitofrontal artery (MOA, arrow) inside the scar of the previous surgery, in the same region of the meningoencephalocele. This preoperative finding needs to be carefully evaluated during the surgical procedure, in order to avoid the risk of damaging vascular structures.
My choice for autologous material is based on the scientific demonstration of good integration of the connective tissue, and on long-time otologic experience concerning repair of the tympanic membrane. Rarely, there is some extrusion of the heterologous material even some years after surgery, while no similar problems with autologous materials have emerged. As a technical hint, I advise the use of adipose tissue in small pieces for the reconstruction for two main reasons. The first is related to the role of dead space fillers, and the second one is due to the regenerative power of the adipose tissue cells.

I discourage the use of a bone graft for the reconstruction after resection of skull base malignancies, given the frequent need for postoperative radiotherapy, thus removing the risk of sequestration. Furthermore, I do not advise, in this case for oncologic reasons, the use of the nasoseptal flap for the reconstruction after resection of cancer because it may be involved in the disease process.

Sometimes, it may be possible to use, as the third layer, a free graft of mucoperiosteum from the floor of the nasal fossae that allows rapid and better healing of the surgical field compared to fascia lata. This difference is related to the biologic behavior of the fascia lata. Its direct exposure to air promotes a necrotic phenomenon.
of the uncovered surface. This favors the presence of abundant crusts for a long period but does not impact the success of the reconstruction.

**SURGICAL TECHNIQUE**

The technique used is similar regardless of the type of pathology, and it is based on a standardized surgical checklist. First, and probably most importantly, one must expose the defect perfectly. All the bone boundaries, if still present, should be smoothed as much as possible, and every dead space should be removed. In oncologic cases, before opening the dura, it is critical to create an epidural space that allows the placement of an intracranial extradural layer (Fig. 41.4). If the surgeon opens the dura before this step, then the creation of such spaces is technically much more difficult. Obviously, these considerations are valid only for the anterior cranial fossa where it is possible to dissect intracranially without the risk of creating severe damage to critical structures. In this respect, this step is absolutely avoided when dealing with middle and posterior cranial fossa defects. Once the borders of the defect are adequately exposed, the first layer is placed, intracranially and intradurally, as accurately as possible (Fig. 41.5). Usually, the size of this graft exceeds the size of the defect by 30% (Schick, 2003). After the position of the first layer, I place the second one in the pocket between the bony skull base and the dura, intracranially extradurally. A very important consideration in this step is to verify the absence of vacuum spaces. If present, these need to be filled by autologous materials (pieces of fascia, adipose tissue, muscle) in order to keep the grafts in contact with something other than air (Fig. 41.6). The presence of such defects in between the reconstruction is a factor that predisposes to failure. After the placement of the second layer, I use fibrin glue. Fibrin glue should not be placed on the entire surface of the graft but only on the borders of the reconstruction. Then, once the integrity of the reconstruction has been verified, a third layer is placed as overlay, on any remaining bony border. This is compressed a little bit with Tabotamp or Gelfoam. Care is taken in pressing the graft to the remaining bony borders, if any, or to the orbit. In very rare cases, it is also possible to partially fix the graft with sutures. This maneuver is not done to obtain a watertight closure but to guarantee stability of the reconstruction.

In the middle and posterior cranial fossa, where bony structures are frequently not available to support the inlay graft, we use a “gasket seal” technique (Fig. 41.7). A large piece of fascia is placed in the dural defect, and the central part of the fascia is pushed intracranially intradurally by means of an elastic material (usually the quadrangular cartilage, when available, or auricular conchal cartilage). If the relationship between the size of the dural defect and the size of the elastic material is acceptable, this procedure is highly effective. Other fascia grafts are usually placed as overlay in order to reinforce the closure. Spongostan and fibrin glue usually complete the reconstruction.

Small technical differences are present when dealing with patients with congenital malformations. There is the need to use larger grafts because these cases usually occur in children and it is important to think of further development. Of course in these cases, it is of paramount importance, especially due to the unfamiliar

![Figure 41.4](image-url)
anatomy, to follow the critical structures in order to create accurate borders for the reconstruction. The role of
the orbit should not be underestimated. As additional advice, to reduce the bulging of the brain parenchyma
within the nose, a careful and delicate bipolar coagulation of the mass usually permits its reduction and removal
to the level of the skull base.

Regardless of the kind of reconstruction performed, it is important to clean the fascia lata accurately from
the detached fibers and adipose tissue once taken from the leg, in order to make it more manageable. If this
is not done, during the placement of the grafts, the surgeon can have nasty surprises: The graft can remain
attached by means of these fibers to the instruments and removed with it. The iliotibial tract (Fig. 41.8) is
thicker and allows easier placement of the grafts during the reconstruction, while fascia lata is thinner and
sometimes not as easy to place.

I do not advise the use of any supporting structures for the reconstruction, such as balloons. I put only
a limited amount of Oxicell on the borders of the reconstruction in addition to fibrin glue. This demonstrates
our philosophy of not producing a counterpressure on the reconstruction, but only acting on the borders of
the reconstruction. In this respect, I pack the nose only at the level of the floor of the nasal fossae, thus leaving an
empty, ventilated space below the reconstruction. This allows better healing of the surgical field, and it is in
contrast with what I did in our first years when I completely filled the nasal cavity, which resulted in delayed
recovery of the mucosa.

FIGURE 41.5
Sagittal representation
of multilayer skull base
reconstruction of anterior
cranial fossa. The size of the
first layer, placed intradurally,
has to exceed the size of
the defect by 30% at least.
The second layer is placed
in the pocket between the
bony skull base and the dura
(epidural space); the third
layer is placed extracranially
in overlay fashion (white line,
dural layer; green, light blue
and purple lines, iliotibial tract
grafts in multilayer fashion;
yellow areas, adipose tissue).

FIGURE 41.6
During the skull base
reconstruction, all the bony
boundaries, if still present,
should be smoothed as much
as possible and every dead
space should be removed.
After pressing the layer from
the center to the borders to
remove residual air, some
fragment of autologous
material (i.e., adipose tissue,
muscle) can be placed
along the borders, between
the second and third layer
(white line, dural layer;
green, light blue, and purple
lines, iliotibial tract grafts in
multilayer fashion; yellow
areas, adipose tissue).

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POSTOPERATIVE MANAGEMENT

Serial careful endoscopic evaluations are done in the early postoperative period in order to check for any signs of CSF leakage. Prophylactic therapy (antibiotics, antihistamines, and laxatives) is given for 7 to 10 days. An early (<24 hours) postoperative CT scan is performed in order to evaluate the presence of pneumocephalus. Nasal packing is usually removed on the 2nd postoperative day under endoscopic vision, and if no sign of CSF leak is visible, the patient is allowed to remain in a sitting position. Major crusts have to be removed, unless underlying tissues are bleeding. In that case, they should be left in place and allowed to heal naturally. It should be understood that the presence of crusts acts in favor of superinfections. Patients are asked not to blow their nose for at least 1 month and not to fly in an airplane until the sinus ostia are well cleared and ventilated. During the follow-up, patients are seen as necessary. For the first few months, patients are asked to avoid excessive physical activity. Usually, within a few months, complete mucosalization of the graft is visible.

COMPLICATIONS

Complications are usually related to the lack of integration of the grafts. CSF leaks are uncommon, occurring in less than 8% of cases. When the reconstruction is “wet,” or in very rare cases of CSF tears, I usually prefer a conservative procedure based mostly on lumbar drainage (for 5 days) and endoscopic reinforcement of the reconstruction. In the case of progressive pneumocephalus, the lumbar drainage must absolutely be avoided, while revision surgery is indicated (Fig. 41.9). If the leak is more evident, an early second return to the operating room is needed in order to reexplore the surgical field. In most of these cases, I did not observe a failure of the whole reconstruction, and the leakage is usually related to a circumscribed defect.

I strongly call for early revision surgery if the amount of the leakage is significant. In this respect, I have reported a subdural hematoma caused by an excessive leakage. In our series, I have had no meningitis in patients with CSF leaks, probably due to the antibiotic therapy. Nevertheless, this is a critical problem, and the presence of CSF leaks should not be underestimated and calls for early intervention.

Rarely, complications can also be related to technical errors or most commonly to incorrect preoperative planning. I have had a vascular injury of the medial fronto-orbital artery during revision surgery that required transcranial management. In that specific case, the position of the frontopolar artery was not correctly evaluated in the preoperative images.

FIGURE 41.7 Skull base reconstruction technique adopted for the middle or posterior cranial fossa defects (according to the Naples’ group) or “gasket seal” (according to the New York group) (white line, dural layer; purple line, large piece of fascia placed on the dural defect; green layer, cartilage or other elastic material; light blue layer, Hadad flap placed in an overlay fashion).

FIGURE 41.8 Fascia lata (FL) (A) and iliotibial tract (ITT) (B) employed as a graft for the skull base reconstruction.
FIGURE 41.9 A patient with a left ethmoidal squamous cell carcinoma T3N0M0, with contrast enhancement T1-weighted MR scan in coronal view (A) and sagittal view (B) who underwent an endoscopic resection with transnasal craniectomy (ERTC). The postoperative CT scan in coronal view (C) and sagittal view (D) reveals a large and progressive pneumocephalus (asterisk in the figures); a strong indication for early revision surgery. The CT scan in coronal view (E) and sagittal view (F) performed 5 days after the endoscopic endonasal revision of the skull base reconstruction (white arrow) confirms that the complication has resolved.
Although in our series no major postoperative bleeding has been described, probably due to accurate management of the nasal vessels, I underline how this complication can represent a significant problem, especially in the early weeks after surgery.

The presence of crusting is not to be considered as a complication, representing the natural way nature heals.

RESULTS

I reported an overall failure rate of about 8% in a series of more than 100 cases of reconstruction of large skull base defects for different conditions, most of these regarding the anterior cranial fossa. However, if we analyze the data according to the time course, it is understood that the rate of CSF leaks in the last 5 years is less than 2%. This is due mostly to the standardization of the technique and to the refinement of the surgical details and secondarily to the learning curve of the surgeons.

By selecting my evaluation of middle and posterior cranial fossa reconstructions, I observed a similar rate of recurrence. This suggests that, if the technique is well applied and the patient selection well conducted, an avascular reconstruction is possible and effective also in these areas (Fig. 41.10).

PEARLS

- Whenever possible, autologous materials are preferred due to good biologic integration.
- Creation of an epidural space in order to place the second layer (intracranial extradural). This maneuver is better performed before opening the dura.
- Placement of the grafts as accurately as possible, 30% size larger than the dural defect. Fill all the dead spaces with autologous materials (adipose tissue, muscle, fascia).
- Accurate post-op management with CT scan and serial endoscopic evaluations is critical for good healing.

FIGURE 41.10 Endoscopic endonasal skull base reconstruction after resection of sinonasal malignancies encroaching on the anterior skull base. Contrast enhancement T1-weighted MR scan in coronal (A) and sagittal (B) view of an intestinal-type adenocarcinoma (ITAC) with intracranial extension (T4bN0M0), marked in the figures with black asterisk, that underwent an endoscopic resection with transnasal craniectomy (ERTC). Postoperative T2-weighted MR scan in coronal (C) and sagittal (D) view, showing the skull base reconstruction (white arrows). 3D-VIBE sequence MR scan in coronal
PITFALLS

- Revision surgery calls for careful examination in order to accurately plan the surgical procedure and identify possible risky points.
- Optimal exposure of the surgical defect with clear identification of the borders and smoothing of the surrounding bone is essential.

INSTRUMENTS TO HAVE AVAILABLE

- Double curved forceps
- Angled positioners (with teeth on the tip)
- Angled instruments with spatula tips are useful in performing extradural pockets

SUGGESTED READING

INTRODUCTION

The nasoseptal flap (NSF), based on the posterior septal branch of the sphenopalatine artery, is a popular flap used to repair defects in the skull base. It is versatile and reliable and can be used to repair defects of the anterior, middle, clival, and parasellar skull base. Along with multilayered reconstruction, it has reduced the incidence of postoperative cerebrospinal fluid (CSF) leaks to that of open approaches (3% to 5%).

The flap was first described in 2006 as a novel reconstruction technique by Hadad et al. and was named the Hadad-Bassagasteguy flap (HBF). More commonly, the flap is described as the nasal-septal flap (NSF). The NSF has been described in the reconstruction of a variety of skull base defects, and its use has been reported in patients as young as 14 years of age. In my personal experience, it can be used in younger patients with favorable anatomy.

HISTORY

A full rhinologic history should be obtained, including a history of recurrent sinus infections, chronic sinusitis, previous septoplasty or other sinonasal surgery, trauma, and granulomatous diseases. Patients should be asked about their use of topical nasal sprays and of cocaine abuse. A previous septoplasty is not a contraindication to a NSF but will make raising the flap more challenging.

PHYSICAL EXAMINATION

Office-based endoscopy with rigid or flexible endoscopy must be performed preoperatively. The septal flap is usually harvested from the right side of the nasal septum; however, it can also be harvested from the left side if the approach dictates sacrifice of the right pterygopalatine fossa contents. Septal deviation, previous septoplasty, septal spurs, or perforations should be considered when planning for the harvest of the NSF.

INDICATIONS

- CSF leak repair
- Reconstruction of anterior fossa, middle fossa, clival (posterior fossa), and parasellar skull base defects
- Vascularized coverage of internal carotid artery

Allan Vescan
CONTRAINDICATIONS

- Previous posterior septectomy
- Large septal perforation
- Previous wide sphenoidotomy with sacrifice of posterior septal artery
- Transpterygoid approaches requiring sacrifice of the sphenopalatine artery
- Tumor involvement of the septum or pterygopalatine fossa
- Embolization of terminal vasculature of internal maxillary artery

PREOPERATIVE PLANNING

- Examine the CT scan to look for a septal deviation and for evidence of previous septal surgery.
- If a revision case, review previous operative notes to understand what septal surgery was performed.
- Determine the length and width of flap based on the extent of planned skull base resection.
- Determine the side of maximal tumor dissection (transpterygoid approach).

SURGICAL TECHNIQUE (VIDEO 42.1)

General anesthesia is induced and the patient placed in the supine position. The nasal mucosa is decongested with one-inch neuropledgets soaked in 1:1,000 topical adrenaline. The right side is usually selected for flap harvest, although the left is an appropriate option. The septum is infiltrated with 1% lidocaine with 1:100,000 epinephrine in the submucoperichondrial and submucoperiosteal plane. The inferior turbinate is out fractured, and the middle turbinate is usually resected.

Exposure should then develop to allow for the planned inferior and superior incisions and includes resection of the inferior two-thirds of the superior turbinate and a posterior ethmoidectomy (Figs. 42.1 and 42.2). To aid visualization of the surgical field, insert a flexible suction catheter in the other nasal cavity to suction the plume from electrocautery. The inferior incision, performed with a needle-tip monopolar cautery, starts at the lateral aspect of the roof of the choana and is brought medially onto the vomer and then anteroinferiorly onto the nasal floor (Fig. 42.3). This incision is then continued anteriorly to the squamociliary junction, at the nasal vestibule.

The superior incision starts at the ostium of the sphenoid sinus and is then brought anterosuperiorly in a sharp curve to 1 cm below the skull base (Fig. 42.4). This is then brought anteriorly to the same vertical plane as the anterior limit of the inferior incision, and a vertical incision connects the two (Fig. 42.5).

The flap is then elevated in the submucoperichondrial and submucoperiosteal plane, back onto the face of the sphenoid, and as far as possible laterally (Fig. 42.6). This can be done with a combination of a Cottle elevator and endoscopic scissors. The flap is tucked into the nasopharynx until the tumor is removed, and it is needed for reconstruction (Fig. 42.7). The location of the pedicle must be kept in mind during the surgery so that it is not injured, especially during drilling of the floor of the sphenoid sinus. Alternatively, if a clival resection is planned, a wide antrostomy is performed and the flap is stored in the maxillary sinus to avoid obstruction of the surgical field throughout the procedure.

As part of the repair of the defect, the flap is brought up from the nasopharynx, usually with a suction in the left hand and neurosurgery pituitary forceps in the right. The flap is smoothed out in its normal rotation so that the mucosal side is facing externally and the pedicle not kinked. Ensure that mucosa is not folded on itself to help prevent late mucocele formation (Fig. 42.8).
FIGURE 42.2
Endoscopic view after middle turbinectomy and posterior ethmoidectomy. (S, septum; IT, inferior turbinate; SO, sphenoid ostium.)

FIGURE 42.3
Inferior incision. Note how it is brought from the roof of the choana, onto the vomer, and then anteroinferiorly onto the floor of the nose.

FIGURE 42.4
Superior incision beginning at the ostium of the sphenoid sinus, curving sharply superiorly onto the septum.

FIGURE 42.5
Anterior vertical incision connecting the two incisions.
FIGURE 42.6
Flap elevated in the submucoperichondrial/submucoperiosteal plane. The free end is reflected posteriorly to aid visualization and to provide tension. (SC, septal cartilage; HBF, Hadad-Bassagasteguy flap.)

FIGURE 42.7
Flap elevated laterally off the anterior wall of the sphenoid sinus and tucked into nasopharynx. (V, vomer.)

FIGURE 42.8
The nasoseptal flap is placed as an overlay, ensuring close approximation with underlying tissue.
In addition to the NSF, a multilayered reconstruction can help ensure a CSF leak–free postoperative outcome. This is usually done with collagen matrix (Duragen®) as a dural underlay to reconstitute the arachnoid plane, followed by the NSF as an extradural, extracranial bony overlay. The edges of the flap are covered with Surgicel, and the whole area is matted with fibrin glue. Saline-soaked Gelfoam follows, and a Foley catheter is gently inflated and buttressed against the repair. Doyle Silastic splints are sutured across the septum.

In general, because the flap is harvested before the actual size of the defect is known, the surgeon should plan a generous-sized flap to overcompensate. If, however, a larger defect is anticipated, such as in a resection of the anterior skull base, the flap can be made larger by extending the inferior incision into the inferior meatus and the superior incision to the cribiform plate. Conversely, anticipated small defects can be covered with a smaller flap, with the incisions on the septum, and with the anterior incision further posteriorly.

**POSTOPERATIVE MANAGEMENT**

General principles of management of a CSF leak are recommended. The Foley catheter is removed 3 to 5 days later, and the Doyle splints are removed at 3 weeks postoperatively. The patient is instructed to use gentle saline irrigations on a daily basis. The patient is seen at 4 to 6 weeks postoperatively and regularly thereafter for gentle debridement without disrupting the flap.

**COMPLICATIONS**

Complications of the NSF are generally mild and well tolerated. Complications related to elevation of the flap include a septal perforation, epistaxis, nasal crusting, and loss of olfaction. In patients with prior septal surgery (septoplasty, transeptal approach to skull base), the dissection of the flap is more difficult and the contralateral mucosa is prone to injury. The contralateral mucosa should also be protected from instrumentation during surgery. Nasal crusting is a consequence of the loss of normal nasal mucosa and exposed cartilage. This can be minimized by covering the flap donor site with a free mucosal graft from a resected middle turbinate. Epistaxis is usually a consequence of bleeding from the flap pedicle or a branch of the sphenopalatine artery. Bipolar cautery should be used sparingly since excessive cauterization may injure the vascular pedicle of the flap.

The most significant complication is a postoperative CSF leak. Potential risk factors are myriad and include patient factors, technical issues, and perioperative care. Inadequate coverage of the defect requires supplementation with nonvascularized tissue (fascia or adipose tissue grafts). Factors contributing to failure with CSF leak include inexperience, high intracranial pressure, large defects, and lack of a multilayer closure supported by a Foley catheter. Flap necrosis due to injury to the vascular pedicle is extremely rare. The best management for a postoperative CSF leak is usually early surgical intervention with endoscopic repair supplemented with a lumbar spinal drain.

**RESULTS**

There are increasing numbers of studies reporting on the successful use of the NSF for a variety of indications. A recent retrospective review of 32 patients reported a CSF leak rate of less than 2.5%. Another study reported no leaks in 14 patients when used to repair traumatic CSF leaks. In a meta-analysis of the skull base literature, reconstruction with vascularized tissue has been shown to be superior to nonvascularized tissue for the repair of large dural defects and results in fewer postoperative CSF leaks.

Quality of life studies demonstrate that sinonasal outcomes (SNOT-22) are temporarily decreased following reconstruction with a NSF, but these differences disappear after several months. Temporary adverse effects of the flap include nasal congestion, crusting, and decreased olfaction. A permanent decrease in olfaction has been associated with the use of NSFs, but the mechanism is unclear.

**PEARLS**

- Obtain proper exposure (including middle turbinate resection and posterior ethmoidectomy) to help plan the incisions.
- Use a guarded needle-tip monopolar cautery. Bend the tip 45 degrees.
- The inferior incision should always be on bone. If it is brought out inferior to the vomer into soft tissue, elevation of this area will be difficult.
- Ensure all areas of the incision are through the mucosa before attempting elevation of the flap.
- When elevating the flap, flip the free edge posteriorly to provide tension and expose the remaining area to be separated.
Be careful to not injure the pedicle when drilling the floor of the sphenoid sinus; protect the pedicle with a suction.
Store the septal flap in the maxillary sinus for transclival approaches.
Modifications of the flap are possible to meet the anticipated size of the defect and location requirements.

PITFALLS

- Previous septoplasty can make it very challenging to harvest the flap.
- Exercise caution with the superior incision as this can lead to olfactory loss.

INSTRUMENTS TO HAVE AVAILABLE

- Guarded needle-tip monopolar cautery
- Cottle elevator
- Endoscopic scissors
- Flexible tracheal suction catheter

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SUGGESTED READING

INTRODUCTION

The wide popularization of endoscopic endonasal skull base surgical techniques has taken place in the past decade. This is due not only to advances in technology but also to the improved understanding of endoscopic skull base anatomy and the expanding expertise of skull base surgeons. One of the greatest challenges in mastering endoscopic skull base surgery has been developing techniques to prevent cerebrospinal fluid (CSF) leaks. The introduction of pedicled, vascularized flaps for use in cranial base surgery has met with great success. The middle turbinate flap serves as one of the latest additions to the armamentarium of vascularized flaps accessible to the skull base surgeon.

Vascularized pedicled flaps in endoscopic endonasal surgery became widely accepted after the advent of the Hadad-Bassagasteguy (HBF) or nasoseptal flap (NSF). Advantages provided by the use of vascularized flaps include restoration of local blood flow to the wound site, improved healing, decreased rates of surgical infection, decreased graft migration, and most importantly, decreased rates of CSF leak.

Since the nasoseptal flap was first described, a number of different pedicled flaps for reconstruction in endoscopic endonasal surgery have been described. These include the transpterygoid temporoparietal fascia flap, the endoscopic-assisted transglabellar pericranial flap, the posterior pedicle inferior turbinate flap, and the palatal flap. More information with regard to these flaps may be found in Table 43.1 of this chapter.

Prevedello et al. first described the middle turbinate flap for skull base reconstruction in a cadaveric feasibility study in 2009. In most cases, the middle turbinate flap serves as an alternative to the nasoseptal flap for reconstruction of small defects of the sella, fovea ethmoidalis, and planum. Although small defects of the skull base have a 95% chance of successful closure with free tissue, vascularized repair is believed to improve healing rates and decrease the chance of CSF leak.

HISTORY

It is understood that a patient being considered for a middle turbinate flap will be undergoing a skull base procedure. The issues specific to this type of reconstruction are any history of previous nasoseptal surgery (septoplasty, partial septectomy) and nasoseptal deformities (i.e., known septal deviation) that may inhibit the ability of the surgeon to perform a nasoseptal flap. Previous sinus surgery should alert the surgeon to examine for the presence of large sphenoidotomies that could have compromised the distal sphenopalatine vasculature. Also, a history of previous skull base surgery will prepare the surgeon for the possible absence of certain vascularized reconstructive options. Lastly, the history and nature of the skull base pathology in question will alert the surgeon to perform a thorough physical examination to determine which reconstructive options are available in order to maintain oncologic principles (i.e., involvement of the septum by malignancy).
PHYSICAL EXAMINATION

As with all skull base pathology, a thorough head and neck examination as well as assessment of cranial nerve function should be performed. Nasal endoscopy is necessary to further assess the individual patient’s anatomy. Attention should be placed on identifying signs of previous nasoseptal surgery (septoplasty, partial septectomy) and nasoseptal deformities (large septal spurs, septal perforations) that may inhibit the ability of the surgeon to perform a nasoseptal flap. Previous sphenoid and pterygoid surgery should also be noted, as the distal sphenopalatine vasculature may have been compromised. Anatomical anomalies of the middle turbinate (paradoxical middle turbinate, concha bullosa, and unilateral hypoplasia) exist in 25% of the population and should be identified as they may contribute to increased difficulty in raising a middle turbinate flap.

INDICATIONS

The middle turbinate flap is most often used for reconstruction of skull base defects when the nasoseptal flap is unavailable. This may occur in patients with septal defects, previous septal surgery, and history of sphenoidotomy with possible compromise of the posterior septal artery and patients in whom the nasoseptal flap has been tried and failed. The middle turbinate flap may also be used for repair of posttraumatic or spontaneous CSF leaks. It has recently gained popularity for use in situations in which the need for a combination of flaps is anticipated. Some authors have also described the use of the middle turbinate flap for reconstruction following endoscopic endonasal nasopharyngectomy.

CONTRAINDICATIONS

Contraindications include an anticipated large defect to repair. Prevedello et al. found the average length and width of the middle turbinate flap to be 4.04 and 2.8 cm, respectively. Relative contraindications include anatomical variance of the middle turbinate and ability to perform a nasoseptal flap, which remains the gold standard vascularized flap for endoscopic anterior skull base reconstruction.

PREOPERATIVE PLANNING

Preoperative planning includes a thorough physical examination with diagnostic nasal endoscopy. CT images should be reviewed. It has been suggested that the middle turbinate length should be measured since the ability of the flap to reach the sella may be less likely in turbinates measuring less than 4 cm in length.
CHAPTER 43 Middle Turbinate Flap

SURGICAL TECHNIQUE

The nasal cavity is decongested with oxymetazoline 0.05%. Figure 43.1 demonstrates the endonasal anatomy prior to flap elevation. The middle turbinate and septum are infiltrated with 1% lidocaine with 1:100,000 epinephrine. A vertical incision is then made through the mucosa at the anterior aspect of the middle turbinate. This is followed by a horizontal incision through the mucosa at the superomedial aspect of the middle turbinate. Care is taken to preserve the attachment of the bony middle turbinate to the cribiform plate. The mucoperiosteum is then elevated from the underlying bony middle turbinate (Fig. 43.2A and B). The bone of the middle turbinate is then removed in piecemeal fashion (Fig. 43.3A and B). An incision is then made through the axilla of the middle turbinate to detach the turbinate from the skull base. This incision is carried in a dorsal direction. Once the entire turbinate bone has been excised, the mucoperiosteum can be unfolded or “opened like a book.” If a need for extra length is anticipated, the pedicle may be dissected to the level of the sphenopalatine foramen; this increases both length and mobility. The flap may then be protected within the nasopharynx (Fig. 43.4) or maxillary sinus for the remainder of the procedure. Fibrin glue is applied once the flap has been appropriately positioned. Gelfoam is then packed around the site, and supporting nondissolvable packing is placed.

POSTOPERATIVE MANAGEMENT

Postoperatively, the patient is instructed on maintenance of CSF leak precautions. This includes no nose blowing, no straining, no heavy lifting (>15 lb), stool softeners, and open mouth sneezing. Although no clear evidence exists as to efficacy, a third-generation cephalosporin is routinely administered in the perioperative period. An MRI or CT may be obtained to confirm tumor resection and evaluate for evidence of intracranial
bleeding or pneumocephalus. Also, adequate perfusion of the flap can be confirmed on MRI. The packing is left in place until postoperative day 5. Following removal of the packing, the patient is asked to use nasal saline spray. Two weeks following surgery, the patient returns to the office for routine sinonasal debridement.

**COMPLICATIONS**

Complications are rare in skilled hands. Unintentional fracture of the cribriform plate may occur while the turbinate is being excised. Injury to the pedicle may devascularize the graft. As with all vascularized repairs, there is potential for the reconstruction to be inadequate and CSF leak to manifest itself.

**RESULTS**

The middle turbinate flap is relatively newly described and most often serves as an alternative for reconstruction when it is not feasible to use the nasoseptal flap. There are few data in regard to its use in the literature. In Prevedello’s initial cadaveric feasibility study, the flap was shown to have good coverage of all defects in the fovea ethmoidalis and planum. However, the reach to the sella was more variable, with 10 of 12 flaps being deemed adequate for reconstruction of the sella. A recent retrospective review by Julian et al. showed 100% success rate of the middle turbinate flap with no CSF leak in a series of 10 patients. Most authors note that it takes, on average, 30 minutes to complete the flap.

**PEARLS**

- Anatomical variation of the middle turbinate exists in 25% of patients (concha bullosa, paradoxical middle turbinate, unilateral hypoplasia) and should be considered in preoperative planning.
- Identification and preservation of the sphenopalatine artery branch to the middle turbinate is essential to maximize the length of the middle turbinate flap.
CHAPTER 43 Middle Turbinate Flap

PITFALLS

- The middle turbinate flap may be technically challenging.
- Destabilization of the middle turbinate bone prior to elevation of the mucoperiosteal flaps may significantly increase the difficulty of the procedure.

INSTRUMENTS TO HAVE AVAILABLE

- Oxymetazoline-soaked pledgets
- 1% lidocaine with 1:100,000 epinephrine
- Bayonet forceps
- Nasal speculum
- 0-degree endoscope, light source, and camera
- Freer elevator
- Cottle knife
- Sickle knife
- Rongeurs
- Turbinate scissors
- Bipolar electrocautery device
- Nondissolvable packing

SUGGESTED READING

INTRODUCTION

Reconstruction of defects of the cranial base has been one of the greatest challenges of endoscopic endonasal surgery. Over the last decade, there has been an evolution of reconstruction techniques with a progressive decrease in the incidence of postoperative cerebrospinal fluid (CSF) leaks. A reconstructive algorithm provides a graded approach to reconstruction ranging from nonvascularized tissue grafts to local vascular flaps to regional vascular flaps to microvascular free flaps. Most large defects of the ventral skull base are effectively reconstructed with a vascularized septal mucosal flap or extracranial pericranial flap. When a septal mucosal flap is not available due to prior surgery or by involvement of tumor, an inferior turbinate flap (ITF) is a viable alternative for suprasellar and clival defects.

The ITF is pedicled on the lateral nasal branch of the sphenopalatine artery (Fig. 44.1). The sphenopalatine artery exits the sphenopalatine foramen at the posterosuperior corner of the maxillary sinus and branches into multiple arteries including the posterior septal branch and lateral nasal branches to the middle and inferior turbinates. The artery to the inferior turbinate courses along the inferior turbinate in a posterior to anterior direction and also sends minor branches to the inferior meatus.

Several variations of the ITF are available (Fig. 44.2). A standard ITF consists of the mucosa covering the inferior concha and inferior meatus. An extended ITF (EITF) includes the mucosa of the floor of the nose. The ITF can be extended further by including the mucosa of the nasal septum. This creates a flap that is comparable in size and reach to a nasoseptal flap. The septal extension probably has a random blood supply and is at greater risk of distal ischemia than is a typical nasoseptal flap.

HISTORY

It is important to inquire about prior nasal surgery including nasal septoplasty, turbinate reduction, endoscopic sinus surgery, treatment of epistaxis, and endoscopic or microscopic skull base surgery. Prior surgery may have sacrificed the vascular pedicle to the nasoseptal flap or ITF and compromised the nasal mucosa. Rarely, chronic inflammatory disease such as granulomatous disease may damage the mucosa.

PHYSICAL EXAMINATION

Nasal endoscopy includes an assessment of mucosal surfaces and integrity of the vascular pedicles. A large maxillary antrostomy that extends to the sphenopalatine foramen may have compromised the vascular supply. Similarly, a large sphenoid antrostomy with sacrifice of the posterior septal artery precludes the use of a nasoseptal flap.
FIGURE 44.1  Vascular anatomy of the lateral nasal wall. The inferior turbinate flap is supplied by a branch of the sphenopalatine artery that courses along the length of the inferior concha.

FIGURE 44.2  Variations of the inferior turbinate flap (ITF). A standard ITF consists of the mucosa covering the inferior concha and inferior meatus (green). An extended ITF (EITF) includes the mucosa of the nasal floor (blue). The EITF can be extended further by incorporating the mucosa of the nasal septum (blue dotted line).
Deviation of the nasal septum will make the dissection of the flap more difficult on the convex side and increases the risk of tearing the mucosa. Generally, a flap will be performed on the side of the nasal cavity with the most room for instrumentation. Increased tumor dissection on one side may necessitate using a flap where the pedicle is based on the contralateral side.

**INDICATIONS**

An ITF is indicated for large dural defects when a nasoseptal flap is unavailable or for coverage of exposed vascular structures (internal carotid artery). The ITF has a limited arc of rotation due to the orientation of the vascular pedicle, and the mucosa of the inferior concha does not conform well to a new surface. An EITF is used in most cases but may include a septal extension if a longer flap is needed and the septal mucosa is available. Due to the limited arc of rotation, an ITF is ideally suited for clival defects and provides optimal coverage in a horizontal orientation.

**CONTRAINDICATIONS**

Contraindications to the use of an ITF include the absence of a vascular pedicle (prior surgery or embolization of the internal maxillary artery) or prior resection of the inferior turbinate. Adhesions between the inferior turbinate and the nasal septum can be lysed prior to elevation of the flap. A severely deviated nasal septum is a relative contraindication and may need to be corrected to allow room for dissection. If bilateral transpterygoid approaches are necessary, exposure may be limited by the flap pedicle. In such cases, mobilization of the pedicle into the pterygopalatine space may be necessary.

A defect that is too large or distant to be completely covered by an ITF is a relative contraindication. Alternative flap reconstructions should be considered first. If the ITF is insufficient to provide complete coverage, it can be used in combination with multilayered fascial grafts. A deep clival defect may need to be filled with adipose tissue grafts deep to the flap so that the ITF can provide complete mucosal coverage. Tumor involvement of the nasal mucosa is a contraindication, especially for high-grade malignancies such as squamous cell carcinoma, adenocarcinoma, or melanoma or when final tumor margins are difficult to assess such as with adenoid cystic carcinoma.

**PREOPERATIVE PLANNING**

The surgical team should discuss the surgical approach, extent of exposure, and reconstructive needs prior to the surgery. Large dural defects should be reconstructed with vascularized tissues whenever possible. Every operation should have a backup plan for reconstruction if the primary reconstruction is not possible due to loss of the vascular pedicle or involvement by tumor.

Preoperative imaging of the vascular supply to the flap is not necessary. If preoperative embolization of a tumor is performed, communication with the interventional radiologist will ensure that vessels to reconstructive flaps will be preserved when feasible.

**SURGICAL TECHNIQUE (VIDEO 44.1)**

It is important to preserve the vascular supply to the ITF as part of the surgical approach and resection. The flap is usually harvested at the time of dural reconstruction unless the vascular pedicle is blocking access (transpterygoid approach). If the flap is elevated early in the procedure, the flap is protected by passing it through the antrostomy into the maxillary sinus. Vasoconstriction of the nasal mucosa is achieved by inserting cottonoid pledgets soaked in 0.05% oxymetazoline for several minutes and injection of local anesthetic (0.5% Xylocaine, 1:200,000 epinephrine) into the surrounding mucosa.

**Standard Inferior Turbinate Flap**

A generous middle meatal antrostomy is performed with removal of bone posteriorly to the sphenopalatine foramen and inferiorly to the attachment of the inferior turbinate. Care should be taken to avoid injury to the sphenopalatine artery and its branches through excessive removal of bone or electrocautery.

Using an insulated needle-tip electrocautery bent at a 45-degree angle, a mucosal incision is made through the mucosa to the underlying bone starting at the anterior margin of the antrostomy. The incision is extended along the anterior tip of the inferior turbinate in an S-shaped line that follows the curvature of the turbinate. It then curves around the anterior margin of the inferior meatus to the floor of the nasal cavity just...
inside of the pyriform aperture. An incision is made posterior to the sphenopalatine foramen on the medial surface of the medial pterygoid plate. The incision courses inferiorly and anteriorly to encompass the mucosa of the inferior meatus (Figs. 44.2 and 44.3).

A Cottle elevator is then used to elevate the flap in a subperiosteal plane. The bone of the inferior concha is very coarse and adherent to the flap, making it very difficult to elevate the flap from the inferior concha. Dissection begins at the anterior tip of the inferior turbinate, both medial and lateral to the conchal bone. The S-shaped incision is followed to elevate the mucosa superiorly in the inferior meatus. The bony canal of the nasolacrimal duct is identified, and the mucosa is sharply transected with fine-tip scissors (Kurze) in the subperiosteal pocket. The remaining mucoperiosteum of the inferior meatus is easily elevated in an anterior to posterior direction toward the vascular pedicle. The vascular pedicle can be further mobilized with careful dissection.

**FIGURE 44.3** Incisions for a standard ITF. **A.** The anterior incision starts at the middle meatal antrostomy (circle) and follows an “S”-shaped course along the anterior projection of the inferior turbinate to expose the concha. The posterior incision is between the vascular pedicle (arrow) and eustachian tube. The two incisions connect along the nasal floor. **B.** Coronal view of anatomical dissection demonstrates elevation of the flap (asterisk) from the inferior concha with inclusion of mucoperiosteum from the floor of the nasal cavity.
The bone of the inferior concha is removed with rongeurs, and small fragments remaining are dissected free from the flap if possible. The flap is then ready to be used for reconstruction. It is rotated inferomedially to the site of the defect. A standard ITF provides minimal coverage of small midclival defects (Fig. 44.4). The flap retains the shape of the inferior concha, and it can be difficult to position properly. The flap must be in contact with bone or dura for healing to occur; all surrounding mucosa should be removed first.

The edges of the flap are covered with postage-stamp size pieces of Surgicel to anchor the flap, followed by similar-sized pieces of Gelfoam soaked in thrombin solution. Nasal packing consisting of a Foley catheter inflated with saline or nasal tampons (Merocel) is carefully placed to support the reconstruction.

Extended Inferior Turbinate Flap

Due to the limited size of a standard ITF, an EITF that includes the mucosa of the floor of the nasal cavity is used most commonly. The posterior mucosal incision extends across the nasal floor at the posterior edge of the hard palate. The medial limit is the junction of the nasal septum and premaxilla. This results in a flap that is wider than the standard ITF and adds an additional vertical dimension when it is transposed horizontally over the clival defect (Figs. 44.2 and 44.3B).

When maximal coverage is needed, the septal mucosa can be included in the design of the flap (Fig. 44.2). The anterior and posterior mucosal incisions are continued with parallel vertical incisions up the nasal septum, following the septal incisions for a nasoseptal flap. The superior septal incision parallels the skull base approximately 1 cm below the olfactory sulcus and includes the septal mucosa anterior to the olfactory sulcus and deep to the nasal bones. The septal mucoperichondrium/mucoperiosteum is elevated from the septal cartilage and bone with a Cottle elevator. At its junction with the premaxilla, the flap is adherent and sharp dissection may be necessary to avoid tearing the flap.

The flap is then rotated posteriorly to cover the skull base defect as described above (Fig. 44.5). The donor site on the cartilaginous nasal septum can be covered with a free mucosal graft (mucoperiosteum) from the resected middle turbinate. It is secured with a single suture and then covered with Silastic Doyle splints. This speeds the mucosalization of the nasal septum and minimizes long-term problems with septal crusting.

POSTOPERATIVE MANAGEMENT

Nasal packing is removed after 5 to 7 days. Antibiotic prophylaxis is maintained while the packing is in place. If an EITF is performed, the Silastic splints are maintained for 3 weeks to enhance mucosalization of the septum and to prevent postoperative synchia. Nasal saline rinses are started after the splints are removed and are used daily to minimize crusting and promote cleansing of the nasal cavity. Endoscopic debridement of postoperative debris and crusts is carefully performed periodically over the first several months until healing is complete.

COMPLICATIONS

Complications may be related directly to the reconstructive site or the flap donor site. Necrosis of the flap is rare but usually indicates a problem with the vascular pedicle. Direct injury to the vessels can occur from dissection at the sphenopalatine foramen or excessive cauterization of the stump of a resected middle turbinate. Torsion of the pedicle or compression from nasal packing or balloon may compromise blood flow. Ischemia of the distal portion of the flap could result from perforation of the flap or narrowing of the pedicle, especially when an EITF is employed.
A postoperative CSF leak is usually related to technical factors of the reconstruction rather than flap necrosis. Possible reasons include a flap that is too small for the defect, inadequate length with tension of the flap pedicle, poor apposition to underlying dura and bone, and elevated CSF pressure. If a leak develops, prompt endoscopic repair in the operating room is recommended to avoid the risk of meningitis. Most postoperative CSF leaks involve a small area of the reconstruction and can be repaired with repositioning of the flap edge or augmentation with fascia or adipose tissue grafts.

An expected sequela of surgery is crusting of the nasal cavity as mucosalization of the donor site occurs. It can take several months for healing to be complete and crusting to diminish. A minority of patients may suffer from chronic dryness from altered airflow due to loss of the inferior concha and associated crusting. Mucosal grafting of the donor site using a free mucoperiosteal graft from a resected middle turbinate can help minimize long-term crusting.

Temporary edema and stenosis of the nasolacrimal duct can result in epiphora. If it persists, consultation with an ophthalmologist is recommended for evaluation of the entire lacrimal drainage system and placement of lacrimal stents.

RESULTS

ITFs have a very reliable vascular pedicle and provide a good mucosal barrier for reconstruction of the dura or coverage of the internal carotid arteries. They are best suited for infrasellar defects that don’t require extensive rotation of the flap pedicle.

Examples of clinical applications include coverage of an exposed vertebral artery aneurysm clip (Fig. 44.4), closure of a dural defect following a transclival approach, coverage of exposed paraclival internal carotid arteries (Fig. 44.5), and protection and revascularization of clival bone following debridement for radio-necrosis and osteomyelitis.

The size of the ITF has been reported to be 5.4 cm in length and 2.2 cm in width. The length of the EITF is consistent with the previously described ITF, while the width is 250% that of the ITF. This difference is accounted for by inclusion of the mucosa of the nasal floor, thus increasing its mean surface area to 27.26 cm² (Fig. 44.6). The surface area was sufficient to cover defects spanning the clivus from one paraclival internal carotid artery to the other. The EITF compares favorably to the nasoseptal flap for reconstruction of infrasellar defects. The nasoseptal flap has a mean surface area of 25 cm²; the EITF is slightly larger. When the septal mucosa is available for use with the EITF, the mean surface area increases to 40.53 cm², which is significantly larger than the mean surface area reported for the nasoseptal flap. The addition of the nasal mucosa also decreases the arc of rotation by providing a longer flap with greater reach.
PEARLS

- The superior incision should start at the anterior margin of the maxillary antrostomy. The inferior incision begins posterior to the sphenopalatine foramen and runs between the posterior tip of the inferior turbinate and the eustachian tube. Narrowing of the pedicle will increase the arc of rotation of the flap.
- The flap is ideally suited for clival defects and is best oriented horizontally.
- The flap should be dissected from the inferior concha while it is still attached; otherwise, it is very difficult to remove the bone fragments from the flap.

PITFALLS

- The distal end of the nasolacrimal duct is sharply transected to prevent stenosis.
- With an extended flap, the septal mucosa may receive a random blood supply and be susceptible to ischemia.
- The conchal part of the flap is difficult to position properly since it retains its original shape and does not lie flat.

INSTRUMENTS TO HAVE AVAILABLE

- Needle-tip monopolar electrocautery (insulated) bent to 45 degrees
- Cottle elevator
- Fine-tip scissors (Kurze): straight or curved
- Silastic Doyle splints
- Merocel nasal tampons
- Silastic Crawford lacrimal stents (optional)

SUGGESTED READING

INTRODUCTION

As advances have been made in skull base surgery over the last several decades, improvements have taken place in several areas. This includes more advanced, minimally invasive surgical techniques, a greater ability to perform open surgery for advanced lesions safely, better diagnostic testing specifically with respect to radiographic imaging and evaluation of intracranial arterial cross flow, more refined and highly focused radiation therapy delivery systems, and an emphasis on improved patient outcomes.

Critical to the improvement of overall outcomes in patients undergoing skull base surgery is the ability to reliably reconstruct the cranial base after major ablative procedures. The basic physiologic principle is that a vascularized tissue layer must be available to separate the intracranial contents from the extracranial environment, specifically the sinonasal cavity. Although minimally invasive endoscopic approaches are continuing to evolve, the reconstruction of major defects without such vascularized tissue has an increased likelihood of cerebrospinal fluid leak, meningitis, and delayed healing. This is particularly applicable to patients who have been radiated previously.

A variety of reconstructive techniques and approaches have been used to provide this vascularized layer. These include the very reliable pericranial flap, based anteriorly on the supraorbital vessels, the temporalis muscle for more lateral defects based in the middle fossa, and microvascular free tissue transfers from a variety of donor sites.

The temporoparietal fascial flap (TPFF) also lends itself well to the reconstruction of the cranial base. This highly vascularized tissue has a reliable blood supply and is immediately adjacent to defects in the middle, posterior, or central skull base as well as selected defects in the anterior cranial fossa. This chapter outlines the use of the TPFF in skull base surgery. The relevant surgical anatomy is reviewed as well as indications, contraindications, surgical technique, and perioperative management.

The temporoparietal fascial flap has been used extensively in reconstructive surgery for decades. This flap has been used as a free flap in extremity repair for tendon coverage and other indications in the hand. It has been used as a pedicled flap for soft tissue coverage after primary and secondary auricular reconstruction using cartilage autografts. In the 1990s, it was widely popularized as a pedicled flap by Cheney to reconstruct a wide range of defects following head and neck surgery. With the development of enhanced ablative skull base procedures, the flap has found a role in reconstruction of the lateral, central, posterior, and selected defects in the anterior cranial base.

The surgical anatomy of the lateral scalp has been studied extensively over the last several decades. The temporoparietal fascial flap donor site is located in the lateral scalp (Fig. 45.1).

The most superficial layers of the scalp include the skin and underlying subcutaneous tissue, which in the lateral scalp is comprised primarily of the hair follicles. The hair follicles are an important landmark in the harvest of this flap. The temporoparietal fascia is found immediately deep to the hair follicles. The superficial temporal artery and vein and its anterior and posterior divisions are found within this layer. The frontal branch
of the facial nerve also runs in this layer anteriorly over the zygomatic arch and extending toward the frontalis muscle. Deep to the temporoparietal fascia is the layer of loose areolar tissue, and deep to this lies the fascia of the temporalis muscle. The fascia of the temporalis muscle is a firm dense layer of connective tissue typically used in tympanoplasty for reconstruction of defects in the tympanic membrane. The temporalis muscle is found deep to this layer. Superior to the superior temporal line, the temporalis fascia becomes contiguous with the pericranium and the temporoparietal fascia becomes contiguous with the galea aponeurotica. The temporalis muscle fascia inserts inferiorly onto the superior border of the zygomatic arch.

The nutrient vessel of the TPFF, the superficial temporal artery, is one of the two terminal branches of the external carotid artery. After passing through the parotid gland, it is found immediately superior to the posterior aspect of the zygomatic arch, where it is identified prior to branching into its anterior and posterior components. The superficial temporal vein parallels the superficial temporal artery. In some cases, it may run posterior to the ear to drain into the postauricular vein, which can result in a shorter vascular pedicle.

**HISTORY**

Patients who are possible candidates for TPFF reconstruction of the cranial base will present with either an anticipated postablative or traumatic defect involving selected areas of the base of the anterior, middle, or posterior cranial fossa. For defects in these areas, the TPFF is best suited to providing a lining (such as an orbital exenteration cavity), a barrier (to separate the middle fossa dura from the sinonasal cavity), or a vascularized obliterative volume of tissue (as in a large mastoid cavity following revision cholesteatoma surgery with exposed dura). Patients who have had prior surgery that may have disrupted either the TPFF layer or the integrity of the superficial temporal vessels should be considered for a different reconstructive approach. Patients who will require a large volume of soft tissue to reconstruct the defect, such as a total maxillectomy and orbital exenteration, when it is desired to repair the entire defect, likewise should be reconstructed with a larger-volume flap such as a rectus abdominis, anterolateral thigh, or scapular free flap. A resection that may also include either a subtotal or total parotidectomy where the nutrient vessels may be sacrificed should force consideration of an alternative reconstructive option.
CHAPTER 45  The Temporoparietal Fascial Flap in Skull Base Reconstruction

PHYSICAL EXAMINATION

The patient should be examined preoperatively to determine the suitability of using the TPFF for reconstruction. The nature of the defect, the volume of tissue required, the distance of the defect from the fulcrum of the pedicle, and the integrity of the donor sites should all be assessed. Careful inspection of the lateral scalp should be performed with special attention to detect well-healed scars. The superficial temporal artery pulse should be located and palpated. Any evidence of previous surgery in this area should raise the possibility of the need for an alternative plan for the reconstruction. Evidence of severe radiation changes in the soft tissue of the lateral scalp in patients with previous radiation therapy undergoing revision or salvage surgery should also be a contraindication to the use of the TPFF.

INDICATIONS

The temporoparietal fascial flap is indicated in the reconstruction of lateral and posterior defects of the skull base that require a vascularized layer of tissue to separate the intracranial contents from the extracranial contents. It is useful for defects in the midline skull base, the orbit, and the mastoid cavity. Its proximity to the recipient site as well as minimal donor site morbidity, including essentially an undetectable cosmetic defect, makes it a very useful flap for reconstruction of defects in these sites.

CONTRAINDICATIONS

Previous surgery in the lateral scalp that has disrupted the blood supply to this layer by injuring the superficial temporal artery and vein is a contraindication to the use of this flap. In addition, any concerns about the viability of the remaining skin overlying the craniotomy defect, particularly for middle cranial fossa surgery, should also raise some concern. Radiated skin or a diabetic patient would potentially not heal if the temporoparietal fascia were harvested.

PREOPERATIVE PLANNING

Preoperatively, it is important to understand and to visualize exactly where the superficial temporal artery lies in each individual patient. This information is used in outlining the incision. Typically, an ultrasonic Doppler flow meter is used to map out the superficial temporal artery as far distally as possible.

SURGICAL TECHNIQUE

The patient’s scalp is prepped into the field usually in conjunction with the prepping and draping done by the skull base ablative team. An incision is outlined that takes its origin immediately anterior to the tragus and extends vertically in a hemicoronal plane to just above the superior temporal line. The incision then forks into an anterior and posterior limb forming a large Y-shaped incision (Fig. 45.2). This allows maximal harvest of the temporoparietal fascia and also allows extension of the flap over the superior temporal line to include the galea aponeurotica for cases requiring additional length.

FIGURE 45.2
Incisions marked for the TPFF. The anterior line marks the path of the frontalis branch of the facial nerve.
The most challenging aspect of harvesting the temporoparietal fascial flap is making the skin incision at the proper depth without injury to the nutrient vessels and elevating the skin flap so it does not damage either the temporoparietal fascia by dissecting too deeply or the hair follicles by dissecting too superficially. It is best to start in the midportion of the vertical incision on the anterior half of the scalp flap by using a no. 15 blade and a double hook. The initial step in elevation of the scalp flap is to locate the deep undersurface of the hair follicles. When in the correct layer, adipose tissue remains on the undersurface of the follicles and no adipose tissue remains on the surface of the temporoparietal fascia. Once the follicles are identified, a small, pair of sharp scissors is used to divide the soft tissue layer immediately deep to the undersurface of the follicles. If while harvesting this layer, cut ends of the hair follicles are seen, the dissection is too superficial. This tends to be a very vascular dissection, and care must be taken to cauterize specific bleeding points using bipolar cautery. Indiscriminate use of monopolar and bipolar electrocautery will cause alopecia by damaging the hair follicles.

Once the anterior flap is widely elevated to a boundary immediately posterior to the path of the frontal branch of the facial nerve, the posterior skin flaps are elevated in a similar fashion. Lastly, the triangular portion within the two limbs of the Y-shaped incision is elevated up to the superiormost point at which the flap will be taken. At this point, the superficial temporal arterial and vein can be visualized and palpated in the temporoparietal fascial layer (Fig. 45.3). It is important to be certain that the venous outflow of this flap parallels that of the arterial supply. In a few cases, the superficial temporal vein will actually drain posteriorly into the postauricular vein.

Once the scalp flaps are elevated, the next step is to isolate the temporoparietal fascia and mobilize it based on its blood supply. After identifying the anterior and posterior branches of the superficial temporal artery, dissection proceeds deeply down along the anterior border of the outlined flap, through the temporoparietal fascia to the level of the temporalis fascia. Once the temporalis muscle fascia is identified, the anterior incisions are completed from the point of initial fascial identification superiorly to the superiormost aspect of the flap harvest and then down posteriorly to about midpoint of what would be the flap harvest. Working from superior to inferior, the temporoparietal fascia (and in some cases a galeal extension) is mobilized off the deep tissue. Above the temporal line, this deep layer is the pericranium, and below the temporal line, this is the deep muscular fascia of the temporalis muscle. Once this layer is identified, mobilization of the flap begins with the superficial temporal artery and vein in direct view. The flap can be narrowed as it is brought to its more proximal arterial and venous base. The flap should be mobilized and tailored to the extent of mobilization required to reach the defect (Fig. 45.4). The artery and vein can be dissected down into the parotid gland if necessary to provide additional mobility.
Once the defect is created, the flap is then inset into the recipient site. In cases where a middle fossa craniotomy has been performed, it is a simple matter to lay the flap into the infratemporal fossa immediately inferior to any dural reconstruction or the native dura. This flap will easily reach into the posterior cranial fossa to obliterate dead space within the temporal bone and to cover the posterior fossa dura with a layer of vascularized tissue. It can be extended into the sphenoid sinus to help obliterate any potential space around the cavernous sinus and anteriorly will extend into the orbit and periorbital area (Fig. 45.5A–D). If a minimally invasive resection of the central skull base has been performed, it is possible to tunnel the temporoparietal fascia flap into the central skull base. Typically, if the flap must be tunneled into the central cranial base, an incision is made through the temporalis muscle fascia just above the zygomatic arch. Blunt dissection can then be done along the tendinous insertion of the temporalis muscle medial to the ramus of the mandible. Depending upon the end point, the tunnel is either taken into the oral cavity for defects that were created transorally or into the sinonasal cavity (usually by passing through the maxillary sinus) for defects were developed transnasally. The fascia can be sutured into place in the open cases, but typically when the transnasal approach has been used, packing will be used to keep the flap in position.

The wound is typically closed in two layers using an absorbable suture layer for the subcutaneous layer and a skin layer using either staples or nylon suture. A large suction drain is placed unless there is a concern about fostering a cerebrospinal fluid leak.

**POSTOPERATIVE MANAGEMENT**

There is no specific postoperative management necessary. The only caveat would be not to place any tight dressings around the pedicle of the flap particularly in cases where the flap is tunneled under the temporalis fascia into the central cranial base.

**COMPLICATIONS**

The most common complications of this flap are alopecia and/or loss of the skin flaps that are elevated and partial or complete flap loss. This flap is extremely reliable, and complete loss is unlikely. Flap extensions superior to the superior temporal line, involving the galea, do result in a more tenuous blood supply in the most distal tissue.
RESULTS

This pedicled temporoparietal fascia flap is an extremely reliable reconstructive technique. Because there is no microvascular anastomosis, complete flap failure is nearly unheard of. The donor site defect is quite acceptable since there is essentially no contour defect.

PEARLS

- It is most important to develop the initial skin flap elevation in the proper plane.
- The key to this flap elevation is proper identification of the deep surface of the hair follicles.
- Other potential problems may relate to trying to ask too much of this flap with respect to length.

PITFALLS

- Cutting across the hair in the depth of the follicles will result in alopecia and a more noticeable donor site.
- The flap is extremely reliable up to the level of the superior temporal line.

INSTRUMENTS TO HAVE AVAILABLE

- Ultrasonic Doppler
- Standard head and neck tray
- Short, sharp scissors to facilitate elevation of the skin flap

SUGGESTED READING

INTRODUCTION

Dr. Alfred Ketchum in the 1960s best described the craniofacial resection as a combination of both transfrontal and transfacial approaches to tumors from the sinonasal cavity that involve the skull base and the intracranial cavity. The initial reconstructions were done with avascular onlay grafts using either temporalis fascia or tensor fascia lata. While some of these were successful, cerebrospinal fluid (CSF) fistula in the postoperative period was still commonplace. As more advanced lesions and higher-grade tumors were being removed with craniofacial resections, the use of adjuvant therapy in the form of radiation or chemoradiation became standard. This adjuvant therapy placed the patient at an even greater risk for disruption and necrosis of avascular skull base repairs; therefore, the importance of meticulous skull base reconstructions using vascularized free tissue transfer became routine in the 1970s and the 1980s.

Cranial base surgery has multiple goals and challenges as they relate to the intricate anatomy around the brain, eyes, and facial skeleton. Beyond the primary tumor resection (whether it be to decompress a cranial neuropathy or obtain negative margins for a sinonasal cancer removal) is the other primary goal of the operation which is reconstruction which includes cosmetic goals, such as reconstructing the bony vault around the orbit or the appropriate contour around the zygomatic or malar complex. However, beyond the cosmesis is the more important and potentially lifesaving reconstruction of a dural defect and closure of the CSF leak after tumor removal. Following a craniofacial resection, the standard technique is direct suture repair of the dural defect with an overlay reconstruction using a vascularized pericranial scalp flap. The goal of the pericranial flap is to cover the dura and to separate the sinonasal tract from the intracranial space with a robust vascular tissue barrier (Fig. 46.1).

The introduction of endoscopic endonasal skull base techniques has created new challenges in the reconstruction of the anterior cranial fossa. While a dural defect similar to an open craniofacial resection can be achieved endoscopically (with a dural defect from the meridian of the orbit to the meridian of the opposite orbit and from the optic chiasm to the frontal sinus), the ability to reconstruct such a defect is more challenging than in open surgery. The pedicled nasoseptal flap has produced excellent outcomes as a primary reconstructive option for endoscopic intradural skull base surgery. It has an axial blood supply based on the posterior nasoseptal artery and is readily available in the sinonasal cavity; therefore, it does not create a separate donor site defect. However, most sinonasal cancers have midline and septal involvement, and therefore the need to take widely negative margins often precludes the use of a nasal septal flap in this setting. Recently, the pericranial flap has become a useful and novel flap for endoscopic reconstructions. Operative techniques for both open and endoscopic pericranial flap use require an intimate knowledge of the vascular anatomy of the anteriorly based pericranial flap, as well as an understanding of the complex layers of the frontal and temporal scalp.

The pericranial flap is supplied by the supraorbital and supratrochlear arteries (Fig. 46.2). The main trunk and superficial branches of these arteries course from the orbit into the galea and frontalis muscle layer and give rise to deep branches that supply the pericranium. These deep branches can arise at the level of the orbit or...
within 10 mm of the orbital rim. It is important to understand that the deep branches that supply the pericranium may exit up to 1 cm above the exit point of the supraorbital and supratrochlear foramina; dissection of the flap beyond this level can injure the blood supply.

**HISTORY**

Once the patient has been appropriately evaluated for the presence of a skull base tumor of the cribriform area or anterior cranial base, surgical planning proceeds around the goals for the primary tumor resection. Staging for distant and regional metastatic disease in the setting of sinonasal cancer is performed, and a firm histologic diagnosis is required for optimal treatment planning. Following a thorough discussion with the patient regarding operative options (whether it be an open or endoscopic craniofacial resection), the surgeon must inquire about prior procedures and prior trauma to the scalp area to know whether a pericranial flap is a viable reconstructive option. Patients with prior bicoronal approaches often have a truncated flap due to the low placement of the coronal incision. In the setting of revision surgery, the vascular pedicles of the pericranial flap may have been interrupted, or the scalp flap was elevated without regard to the potential future use of a pericranial flap; therefore, it can be scarred and/or have a significant numbers of holes. Poorly vascularized flaps that are not fully intact make for a suboptimal skull base reconstruction. It should also be noted that tumors of the sinonasal region and skull base can involve the orbit, as well as the soft tissues of the face and glabella. If an orbital exenteration has to be undertaken, sacrifice of the flap pedicle necessarily occurs on that side. If a significant amount of facial soft tissue has to be resected from the periorbital region or frontal scalp, the pedicle of the flap may be compromised. A history of prior radiation therapy is not a contraindication to the use of a pericranial flap.

**PHYSICAL EXAMINATION**

Physical examination should proceed to evaluating any prior trauma or scarring, as well as the presence of tumor protruding into the soft tissues of the glabella, scalp, forehead, or orbits. The ophthalmic division of the trigeminal nerve as well as the frontal branches of the facial nerve are at risk with harvesting a pericranial flap.
CHAPTER 46 Extracranial Pericranial Flap

flap. A detailed examination of the cranial nerves, paying close attention to these two cranial nerves, should be performed. If the patient has had prior surgery or trauma, the flap pedicles can be evaluated with Doppler ultrasound to see if they are intact. This confirms vascularity at the supratrochlear and supraorbital exit points; however, it does not fully confirm vascularity of the entire axial flap.

Indications

In my opinion, a large dural defect with a sinonasal fistula is an absolute indication for reconstruction of the skull base with a vascular flap. Indications for reconstruction with a pericranial flap include an anterior skull base defect with resection of the dura resulting in an intra-arachnoidal and sinonasal CSF fistula. Relative indications include extradural resection without intraoperative CSF leak but in a patient undergoing radiation therapy.

Contraindications

Contraindications to the use of pericranial flaps include patients without an intact flap pedicle or suitable flap quality.

PREOPERATIVE PLANNING

Imaging studies, whether it be CT or MRI, should be devoted to the evaluation of the extent of the primary tumor. There are no special imaging studies that need to be devoted to planning the reconstruction with the pericranial flap. Next is preoperative planning of the primary route of access for resection of the tumor. An open craniofacial resection is going to require coronal access to the scalp in a very wide plane, and therefore the pericranial flap and the pedicles would need to be actively protected during the exposure and resection of the tumor. However, if an endoscopic transcribriform resection is planned, then the endonasal resection can proceed endoscopically until negative margins are obtained. If the operation must be converted to an open craniofacial resection to obtain clear margins, then the above principles still apply. However, if that is not the case, the operative surgeon should understand that the endonasal defect must include a Draf III frontal sinusotomy to allow for wide frontal sinus access and drainage since the pericranial flap is going to be transposed across the midline of the floor of the frontal sinus. With an endoscopic transcribriform approach, I have a separate instrument table and endoscope set that are clean for the scalp portions of the case.

SURGICAL TECHNIQUE (VIDEO 46.1)

Surgical techniques include the open extracranial pericranial flap as well as the endoscopically assisted pericranial flap for endonasal reconstruction; these will be discussed separately.

Description of the Open Anteriorly Based Pericranial Flap

The patient is placed under general anesthesia in a supine position. The patient is often placed in Mayfield head pins or on a horseshoe. If the patient is to be pinned, the pins should be placed posteriorly along the occiput or into the posterior temporal bone to allow for closure of the bicoronal defect, as well as to allow for posterior extension of the pericranial flap harvest. The coronal incision is made through the skin, the deep dermal tissues, and the galea. At this point, the galea separates superiorly, and Raney clips can be placed to control bleeding from the scalp edges, or selected bipolar cautery of the galea can be performed. The loose areolar tissue beneath the galea and superficial to the periosteum is identified. Once the superficial layer of the deep temporal fascia is incised, dissection can proceed within the superficial temporal adipose tissue pad to the level of the zygomatic arch, and the frontal nerve within the temporoparietal fascia is elevated anteriorly. The temporal line of fusion is where the superficial and deep layers of deep temporal fascia split around the superficial temporal adipose tissue pad on top of the zygomatic arch. Once the superficial layer of the deep temporal fascia is incised, dissection can proceed within the superficial temporal adipose tissue pad to the level of the zygomatic arch, and the frontal nerve within the temporoparietal fascia is elevated with the scalp flap as it is retracted inferiorly. This protects the facial nerve overlying the zygoma and provides a fascial plane along the deep surface of the scalp during the dissection. The periosteum
of the scalp is then elevated along the zygoma to the lateral orbit. This should be done on both sides to allow for a maximum exposure of the frontal bones and orbital bar anteriorly. The pericranial flap can now be incised along the lateral aspect of the frontal bone, preserving the anteriorly based supraorbital and supratrochlear arteries on both sides. The thinning of the flap from the galea should be discontinued approximately 10 mm above the orbits, and if more rotation is needed, then a portion of the galea should be left on the flap above this to protect the deep branches (see Introduction). Now, the pericranial flap is pedicled anteriorly for use after the tumor is removed. If a subfrontal or supraorbital bar approach is to be performed (Fig. 46.3), then the supraorbital and supratrochlear foramina need to be fractured inferiorly to allow for mobilization of the pedicle down from the orbit while the orbital roof is lifted superiorly. Protection of the pedicle during this portion of the case is of paramount importance.

The frontal craniotomy is now opened, the dura is incised, and the frontal lobes are elevated, margins are taken, the transfascial portion of the tumor resection is taken up to the level of the cribriform and roof of the ethmoid, and incisions are made from the cranial and facial sides, excising the dura, roof of the ethmoid, and cribiform areas. The specimens are then sent to pathology to evaluate the surgical margins, and the wound is then copiously irrigated. Reconstruction of the dura is performed with a dural patch sutured to the dorsal edges. The pericranial flap is then rotated into the defect overlying the orbital bones and tucked above the planum sphenoidale. If the flap is long enough, it can be folded on itself to provide a thicker layer. The flap on the facial side is examined to make sure that it is tucked into appropriate position within the bony defect. Once it is in appropriate position, the brain is allowed to rest on the flap. The frontal bone is replaced leaving enough space to avoid compression of the axial blood supply to the flap. The scalp flap is replaced, and the incision is closed. Drains are not needed. The facial defect is then packed, usually with Vaseline-coated 1/2- to 1-inch packing brought out through the nostril, and then the facial incisions are closed in a cosmetically acceptable fashion. A head wrap is placed on the patient for compression of the scalp dissection making sure to not compress the pedicles.

**Description of the Endoscopically Harvested Pericranial Flap for Endonasal Reconstruction**

The endoscopically harvested pericranial flap uses similar methods; however, instead of a full coronal incision and being pedicled on both sides, the endoscopic pericranial flap is pedicled on one side and is harvested endoscopically through a 5-cm incision that is in the plane of the coronal incision (Fig. 46.4). A 5-cm incision is marked and then incised down through the galea into the loose areolar tissue. This is then back elevated to approximately the midline of the scalp and laterally to the temporal line. Using lighted and malleable retractors, an assistant retracts and a scope is introduced through the defect, and the loose areolar tissue is dissected anteriorly to the level of the supraorbital and supratrochlear arteries. The supraorbital arteries are located with a Doppler probe at the beginning of the operation and marked because the flap pedicle is going to be narrowed to within a 3-cm window around the Doppler signal. Usually, this corresponds to the medial canthal area to approximately 3 cm lateral to this. Once the subgaleal dissection has been completed, an extended guarded needle tip Bovie bent to a 45-degree angle is used to incise the pericranium under endoscopic assistance with an assistant retracting and suctioning smoke. The incision extends from the 3-cm pedicle and the supraorbital rim laterally along the temporal line and posteriorly at least 4 to 5 cm posterior to the coronal incision. It then travels medially to the midline scalp, and the incision continues along the midline to the glabellar area and
then courses back into the medial brow. At this point, an elevator is used to elevate the pericranial flap from the underlying scalp. This is elevated from the cranium to the level of the supraorbital rim.

Once the flap has been harvested, it then has to be transposed into the endonasal defect. Transposition occurs through a 1-cm glabellar incision. This is made in the glabellar concavity for appropriate cosmesis and healing with monopolar electrocautery. The nasion is identified, and a 4-mm rough diamond drill bit is used to drill an osteotomy across the nasion from the medial canthus to the medial canthus protecting the medial canthal tendons and the lacrimal system, approximately 1.5 cm wide and 4 mm in height. A subperiosteal dissection is then performed from the glabellar side connecting it to the midline pericranial dissection. This is then widened to the side of the flap to allow for an appropriate tunnel for the flap to be transposed. The flap is then transposed through the tunnel and then passed through the glabellar defect to cover the endonasal defect. First, a collagen graft is placed intradurally. The flap overlays the dural defect and the bone defect. The Draf III frontal sinusotomy is left open via both lateral ports, while the flap is brought down the middle of the frontal sinus floor. The flap is placed over the lateral orbits and back into the sphenoid sinus and then is packed into

FIGURE 46.4. Endonasal pericranial flap. A. A 5-cm coronal plane port with outlines for planned unilateral endoscopically harvested pericranial flap. B. Dopplered supraorbital artery (SOA) and planned 3-cm pedicle. Nasion incision is shown in the concavity between the nasal and frontal bones. C. Transposed pericranial flap through the glabellar incision. Within the glabellar incision, the nasionectomy is shown. D. Endoscopic view from the nasal side looking into the endonasal defect through the nasionectomy. E. Endoscopic endonasal view of a transcribriform defect resulting from resection of an esthesioneuroblastoma from orbit to orbit and from planum to frontal sinus. F. Endoscopic view of pericranial flap skull base reconstruction of the defect (edges marked with dots) shown in (E).
place with Surgicel followed by glue or sealant and absorbable and nonabsorbable packing, such as collagen or Gelfoam, and finally Merocel sponges. These are left in place for 5 to 7 days. The glabellar incision is closed with absorbable sutures, and the 5-cm port incision in the coronal plane is closed in a standard fashion. The routine use of drains is not needed. A head wrap is placed on the patient for compression of the scalp dissection making sure to not compress the pedicles.

**POSTOPERATIVE MANAGEMENT**

A head wrap is left on the patient for the first 2 postoperative days. If the patient has a coagulopathy or a bloody dissection, a JP suction drain can be placed at the flap donor site. If a lumbar drain is to be used, it should be monitored carefully, often in an ICU setting. I use lumbar drains when the defect includes the suprasellar cistern but not if solely confined to the cribiform area. Patients are placed on stool softeners and told not to blow their nose and to sneeze with their mouth open for 6 weeks. They have bed rest for approximately 3 days with subcutaneous heparin for prophylaxis against deep venous thromboembolism. Facial sutures and coronal sutures are removed on postoperative days 7 to 10 or if the patient has been irradiated up to day 14. Packing is removed on days 5 to 7, and the patient is told to start nasal saline rinses on day 7, three times a day. I do not routinely use airway diversion with tracheostomy.

**COMPLICATIONS**

Complications include hematoma at the donor site, nerve injury (sensory or motor), necrosis of the skin flap, hair loss at the incision site, infection, and contour deformity in the area of the flap, as well as flap necrosis and postoperative CSF leakage. If the patient does develop a small low-flow CSF leak in the postoperative period, it can be managed with a lumbar drain and expectant management; however, I take all of these patients back to the operating room for reexploration from the nasal side to see if this is related to death of the flap, malpositioning of the flap, or presence of a small fistula within the flap. If it is related to death of the flap, then a secondary flap such as a free flap may have to be placed into the defect; however, if the flap is viable and the leak is due to a malpositioning or a small hole in the flap, then this can be patched with adipose tissue, mucosal grafts, or an inlay/onlay with acellular dermis allograft. Lumbar drainage is used for 3 days if a postoperative CSF leak occurs. The rate of postoperative CSF leak should be less than the accepted historical standard of 10%.

**RESULTS**

Many studies examining the use of vascularized reconstruction of skull base defects, both open and endoscopic, have shown that the pericranial flap is an excellent vascularized flap to reconstruct the cribriform area. The donor site defects are minimal, the risks to cranial nerves are minimal, and the prevention of fistula in the postoperative setting is excellent. CSF leak rates are less than 10% in large series of craniofacial resections, and a high-volume referral center should strive for CSF leak rates of less than 5%.

**PEARLS**

- Prior frontal and scalp surgery should alert the surgeon to have secondary options for skull base reconstruction.
- Tumor invasion into pedicles or frontal areas is a contraindication to pericranial flap reconstruction.
- Understanding the relationship of the facial nerve, zygomatic arch, and temporoparietal fascia and deep temporal fascia planes is important to preserve frontal facial nerve function when elevating the flap.
- Understanding the relationship of the supraorbital and supratrochlear arteries and the deep branches to the pericranium in the 1-cm area above the orbital rim is important to preserve the blood supply to the flap.
- Extracranial pericranial flap dissection for endonasal reconstruction is a complex technique that requires time and a steep learning curve. Having patience and practicing in the laboratory are recommended.

**PITFALLS**

- Postoperative CSF leakage is often from the suprasellar cistern over the planum sphenoidale secondary to malpositioning of the flap. It is this area where the optic nerves are coursing medially and the optic chiasm is difficult to see and the surgeon does not perform an adequate inlay of the flap in this area. This is also the area that is most difficult to perform primary dural repair. To minimize this risk, transcervical examination of the flap inset once the frontal bone flap and scalp are closed should be performed. The use of an endoscope (even in the setting of open surgery) can provide excellent visualization of the flap in this area. If the flap has slipped forward, it should be repositioned over the planar bone and supported with a bolster.
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INSTRUMENTS TO HAVE AVAILABLE

- Craniotomy tray or large plastic tray
- Drill
- Doppler probe

SUGGESTED READING

INTRODUCTION

The primary options for reconstruction of defects of the dura of the anterior cranial base now include multilayer fascial grafts, the nasoseptal flap, and the pericranial flap. The pericranial flap has been the preferred form of reconstruction following craniofacial resection for multiple decades. It is a versatile and reliable vascularized flap that can be employed in a variety of surgical situations.

The scalp has five layers corresponding to the acronym SCALP: skin, subcutaneous tissue, aponeurosis, loose areolar tissue, and periosteum. The pericranial flap consists of the inner two layers of the scalp: the loose areolar and periosteal layers. A pericranial flap may be combined with the galeal layer (aponeurosis) to form a galeopericranial flap.

The pericranial flap is pedicled on the supraorbital and supratrochlear vessels, branches of the ophthalmic artery (Fig. 47.1). Of these, the supraorbital vessel is dominant and exits from the supraorbital foramen. It divides into superficial and deep branches to supply the galeal and pericranial layers, respectively. The pericranial flap merges with the galeal layer near the orbital rim. The sensory innervation of the frontal scalp also arises from the supraorbital and supratrochlear neurovascular bundles (ophthalmic division of the trigeminal nerve) and perforates the galeal layer. The motor supply of the frontalis muscle is provided by the temporal branches of the facial nerve. The anatomy of the frontal scalp allows a flap to be elevated that is pedicled on the vascular supply of the supraorbital and supratrochlear vessels with preservation of the sensory and motor innervation of the scalp.

HISTORY

A detailed history regarding prior cranial surgery is important to determine reconstructive options. Prior scalp incisions may interrupt the vascular supply and limit the length of the pericranial flap. Prior reconstruction with a pericranial flap may preclude the use of a new pericranial flap although it is often possible to harvest one from the other side if only one pedicle was used previously. It is also possible that a galeal flap could be used if the pericranium is not available. Caution is advised when reading operative reports since many surgeons incorrectly use the term galeopericranial flap to describe flaps that are actually pericranial flaps. Prior orbital surgery may also compromise the vascular anatomy of the pericranial flap.

A history of prior radiation is also important to ascertain since the vascularity of the scalp may be compromised. Dissection of a pericranial or galeopericranial flap may further compromise the vascularity and result in necrosis of the scalp. A history of trauma to this area is important in decision making.
PHYSICAL EXAMINATION

The scalp is examined to note the location of prior incisions or trauma (Fig. 47.2). These may limit the length and design of the pericranial flap. The sensory and motor innervation of the frontal scalp is assessed. Intact vasculature (supraorbital and supratrochlear vessels) can be confirmed using Doppler sonography.

INDICATIONS

The primary use of the pericranial flap is for the repair of large defects of the dura following a craniofacial resection using either a transcranial or an endonasal approach. Neoplasms commonly encountered include sinonasal malignancy (olfactory neuroblastoma, squamous cell carcinoma, adenocarcinoma, sinonasal undifferentiated carcinoma), olfactory groove meningioma, and suprasellar neoplasms (craniopharyngioma, extrasellar giant pituitary adenoma). Cerebrospinal fluid (CSF) leaks resulting from surgery or trauma or arising spontaneously can also be repaired with a pericranial flap. The pericranial flap can reach as far as the lower clivus.
Pericranial flaps can be used to provide soft tissue coverage of exposed bone following excision of a tumor or resulting from radionecrosis. The vascularity of a pericranial flap is sufficient to support a skin graft. Pericranial flaps may be used to provide protection of critical tissues such as the dura and the carotid arteries. This not only protects the structures from desiccation but also promotes vascularization and healing. Similarly, a pericranial flap can be used to cover exposed hardware or to separate the sinuses from the deep tissues.

A pericranial flap is a superior alternative to adipose tissue grafts for obliteration of the frontal sinus following excision of tumors, debridement of infected bone, or comminuted fractures. The anterior wall of the frontal sinus is excised, and all mucosa is drilled from the walls of the sinus. The pericranial flap is placed into the sinus providing vascularized tissue that facilitates rapid healing and avoids infection. In contrast to adipose tissue, there is no loss of tissue volume. The anterior wall of the sinus can be replaced with titanium mesh.

**CONTRAINDICATIONS**

The only absolute contraindication to the use of a pericranial flap is the absence of a blood supply. This may result from prior surgery or trauma or the needs of the current surgery (e.g., orbital exenteration). Small defects of the dura can be repaired effectively using alternative reconstructive methods. A relative contraindication is a scalp with compromised vascularity from prior radiation therapy. Lateral defects, especially those requiring bulk, are better repaired using a temporalis transposition flap.

**PREOPERATIVE PLANNING**

Every cranial base surgery requiring reconstruction should have a backup plan including one or two alternatives, in case the blood supply to the flap is sacrificed or the flap provides insufficient coverage. If the vascular supply to the pericranium is in doubt, Doppler sonography can be used to confirm blood flow through the vascular pedicle. The surgical approach should be planned in a manner such that the reconstructive tissues are not compromised.

**SURGICAL TECHNIQUE**

The patient’s head should be accessible for a bicoronal scalp incision from ear to ear. The head can be supported on a padded horseshoe headrest or immobilized with a Mayfield head holder. The pins should be placed posterior to the bicoronal plane and allow subgaleal dissection posterior to the incision. A thin strip of hair (2 cm) is shaved along the incision line, and the proposed incision is infiltrated with approximately 20 mL of 0.5% Xylocaine/1:100,000 epinephrine. Temporary tarsorrhaphy sutures are placed, and the field is prepped and draped.

A large Ioban plastic drape (3 M Company) covers the entire surgical field (Fig. 47.3). This avoids the placement of bulky towels over the eyes and compression of the orbital tissues when the scalp is reflected inferiorly. Staples are placed parallel to both sides of the bicoronal incision to prevent movement of the drape and towels.

A bicoronal scalp incision is made over the vertex of the scalp from ear to ear. This incision provides the greatest exposure and is cosmetically favorable, even in balding individuals. The incision extends through all layers of the scalp to the underlying bone; laterally, the incision extends to the deep temporal fascia enveloping

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**FIGURE 47.3** A thin strip of hair is shaved along a bicoronal line that extends from ear to ear. A. The entire surgical field is covered with a plastic drape to minimize orbital compression. B. Staples are placed parallel to the incision to secure the drapes.
the temporalis muscle. If a longer pericranial flap is needed, subgaleal dissection posterior to the incision is performed. The pericranial layers are then incised to the underlying bone.

The pericranial flap may be dissected at the time of the scalp elevation or delayed until the time of reconstruction. An advantage of initial dissection is an easier plane of dissection from the galea. Disadvantages include a thinner pericranial flap due to failure to include all of the loose areolar layers of tissue and desiccation of the flap during a long surgery. For these reasons, I prefer to dissect the flap at the end of the surgery.

The scalp is elevated from the underlying cranium; laterally, this requires separation of the pericranium from the deep temporal fascia at the margin of the temporalis muscle using a broad periosteal elevator. The peristomeum is then elevated to the level of the superior orbital rims. Laterally, the pad of adipose tissue between the superficial and deep layers of the deep temporal fascia is dissected to protect the temporal branches of the facial nerve. The supraorbital neurovascular bundle is identified at the supraorbital notch and carefully dissected free. In a minority of patients, the supraorbital neurovascular bundle is enclosed by a bony foramen up to 1 cm from the orbital rim. In such cases, it is necessary to release the neurovascular bundle by performing lateral osteotomies with a small osteotome (Fig. 47.4). The periorbita is then elevated from the roof of the orbit bilaterally and to the level of the nasion in the midline. If traction sutures are placed in the scalp, they should be placed at the midline and lateral to the orbit to avoid inadvertent injury to the vascular supply to the pericranium. The scalp should be kept moist during the remainder of the surgery with moistened gauze.

The pericranium and its blood supply are now protected, and the surgical team can proceed with a craniotomy and tumor resection. If a subfrontal approach is performed, orbital osteotomies are performed, and the supraorbital bar is removed. Following repair of the dural defect with primary closure or a fascial graft, a pericranial flap is harvested (Fig. 47.5). The flap is dissected from the undersurface of the galea using sharp...
tenotomy scissors. The flap is dissected transversely so that the scissors do not perforate the flap. Constant traction on the pericranial flap using a moistened sponge helps maintain the proper plane of dissection. The flap should be retracted at 90 degrees from the plane of dissection to prevent perforation (“buttonholing”) of the flap. Laterally, the pericranium is incised vertically; the incision should be lateral to the vascular pedicle. Elevation of the flap continues to the frontalis muscle where the base of the pericranial flap merges with the galea. Dissection usually stops at this point unless additional flap length is needed. Branches of the nerves and vessels are at risk of injury in this area, and cauterization of bleeders should be done cautiously with bipolar electrocautery. If any perforations of the flap have occurred during elevation, they can be individually closed with 4-0 chromic sutures. For midline defects, bilateral vascular pedicles are usually preserved. This maximizes the blood supply but limits the mobility and reach of the flap. The pedicle of the flap can be sacrificed on one side without jeopardizing the vascularity of the flap (Fig. 47.6). The remaining pedicle should be at least 3 cm wide.

The pericranial flap should separate the nasal cavity from the bone flaps; otherwise, infection of the bone flap can occur. For this reason, the flap should be placed inferior to the supraorbital bar (Fig. 47.7). The flap is

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rotated posteriorly to cover the dura to the posterior margin of the defect. Small tacking sutures can be placed between the flap and the dura around the periphery of the flap to prevent migration and reinforce the dural closure (Fig. 47.8). In order to prevent compression of the flap, a 2- to 3-mm margin of bone is drilled from the inferior margin of the bone flap in the midline. This gap is undetectable at the level of the nasion and does not result in a cosmetic deformity. The flap pedicle should not be under tension since replacement of the scalp at the end of the operation may pull on the flap and disrupt the repair. The intranasal surface of the pericranial flap can be covered with fibrin glue or Gelfoam and supported with nasal packing (Merocel tampons or a Foley balloon catheter inflated with saline) if desired.

The scalp incision is closed in the usual manner following replacement of the craniotomy bone flap. A pressure dressing or gauze wrap is not placed on the scalp since this may further compromise the vascularity of a thinned scalp and contribute to scalp necrosis.

**POSTOPERATIVE MANAGEMENT**

No special care is necessary postoperatively. The intranasal surface of a pericranial flap is kept moist with saline nasal spray until mucosalization is complete. The patient is monitored for signs of a CSF leak or scalp infection.

**COMPLICATIONS**

Injury to the vascular pedicle of the pericranial flap can occur during dissection (laceration or cauterization) or from compression or torsion of the pedicle during placement. This can result in ischemic necrosis of the flap and delayed healing with CSF leak.

Complications of flap dissection include injury to sensory and motor nerves innervating the scalp, resulting in frontal hypesthesia and paresis of the frontalis muscle. Dissection in the wrong plane, superficial to the galeal layer, can also result in injury to hair follicles with hair loss and excessive thinning of the scalp. Devascularization of the superficial layers of the scalp, especially in patients who have received radiation therapy, can cause ischemic necrosis of the skin with exposure of cranial bone and hardware.

Failure to eliminate dead spaces and to maintain contact between the pericranial flap and underlying dura delays healing and provides a space for accumulation of fluids (hematoma, seroma, or subgaleal CSF collection). This, in turn, increases the risk of infection and CSF leak.

**RESULTS**

Pericranial flaps are the most frequently used flaps for reconstruction of defects of the anterior cranial base and have been used successfully for decades. An analysis of a large series of craniofacial resections reported a CSF leak rate of less than 10% using vascularized flaps for reconstruction.

A pericranial flap can also be used in endoscopic endonasal surgeries of the anterior cranial base by introducing it extracranially at the level of the nasion (see Chapter 46). In this situation, the flap is exposed with a bicornoral scalp incision, and a bone window is created at the level of the nasion. The pericranial flap is dissected in the usual manner and can be pedicled unilaterally or bilaterally. The flap is inserted through the bone defect below the level of the frontal sinus to cover the defect in the dura.
PEARLS

● The length of the pericranial flap can be extended by dissecting posterior to the bicoronal scalp incision in the subgaleal plane.
● A moist gauze provides gentle but secure traction of the pericranial flap during dissection without tearing the flap.
● The pericranial flap can be pedicled on one or both supraorbital arteries.
● The flap is dissected at the end of the surgery to avoid thinning and desiccation of the flap.

PITFALLS

● Damage to the blood supply to the pericranium may occur with excessive dissection or cauterization of the flap pedicle.
● Compression of the pericranial flap pedicle can occur unless additional bone is removed from the inferior margin of the bone flap.
● Compressive scalp dressings should be avoided postoperatively since they may compromise the vascularity of the frontal scalp.

INSTRUMENTS TO HAVE AVAILABLE

● Tenotomy scissors
● Bipolar electrocautery

SUGGESTED READING

INTRODUCTION

Due to the location and anatomic proximity to the central cranial–facial skeleton, the temporalis muscle and the associated fasciae have been studied extensively in the reconstruction of defects resulting from head and neck oncologic surgery, trauma, and skull base surgery. The flaps derived from this region include the temporal–parietal fascial flap, the temporalis muscle flap, the temporalis muscle calvarium osteomuscular flap, and the temporalis muscle pericranial flap. Each of the flaps has particular indications and utilities as they relate to reconstruction of malar, palatal–maxillary, auricular, temporal bone, intraoral, and cranial base defects. Although it lacks bulk, the thin and pliable temporal–parietal fascial flap can be used both as a pedicle flap and a microvascular free tissue transfer for limited soft tissue augmentation and as a scaffold for skin and/or cartilage grafts. Primarily used in auricular reconstruction, the temporal–parietal fascial flap has also been applied to the reconstruction of limited intraoral and pharyngeal mucosal defects, facial skin and contour defects, and orbital exenteration defects and obliteration of the mastoid cavity. The composite temporalis muscle-split calvarium flap has been used for the reconstruction of congenital, post-traumatic, and oncologic defects of the palate, orbital floor, and lateral orbital rim. The application of this flap is limited by the amount of bone that can be safely harvested and the availability of more reliable alloplastic material for orbital reconstruction. The temporalis muscle proper is broad and flat and fills the lateral (temporal) region of the head (Fig. 48.1). The consistently reliable bulk and arc of rotation of the temporalis muscle proper have led to its multiple applications in reconstruction of palatal, retromolar trigone, orbital exenteration, lateral temporal bone resection, and skull base defects. Additionally, the temporalis muscle has been used in the dynamic reanimation of the paralyzed face. This chapter will be limited to the applications of the temporalis muscle as a rotation flap for reconstruction of the central and paracentral skull base.

HISTORY

The temporalis muscle flap is not reliable in the setting of salvage cranial base surgery. The reduced muscle bulk and tenuous blood supply following prior surgery or radiation therapy make the muscle unsuitable in these situations. Therefore, patients should be carefully questioned regarding prior (1) surgical procedure for resection or attempted resection of cranial base tumors, (2) prior chemotherapy or radiation therapy, and (3) prior treatment for intractable epistaxis, which may have required embolization of the internal maxillary artery. In situations of reoperative or salvage surgery, reconstruction with microvascular free tissue transfer from another site should be considered.

Patients should also be questioned regarding prior trauma to the craniofacial skeleton, which may have altered the position of the zygoma or mandible.
PHYSICAL EXAMINATION

The physical examination should be directed at determining the size of the temporalis muscle with particular attention to temporal wasting indicating denervation atrophy. The temporal fossa should be palpated in the neutral position and with the teeth clenched to assess muscle bulk. The range of motion of the mandible should also be determined. Trismus may indicate fibrosis or scarring of the temporalis muscle further limiting its size or arc of rotation into the cranial base defect.

INDICATIONS

The principal indicator for the use of the temporalis muscle flap in cranial base surgery is the reconstruction of the floor of the central skull base following anterior–lateral skull base surgery with subtemporal craniectomy. Resection of neoplasms of the anterior and anterior–lateral cranial base, particularly those requiring a transcranial approach with subtemporal craniotomy, results in exposure of the temporal dura. The removal of bone and soft tissue required by either the surgical approach or the extirpation of the tumor may result in a surgical defect for which primary closure is not possible. Vascularized soft tissue augmentation of the resulting defect is necessary to (1) restore the anatomic separation and immune-competent barrier between the upper aerodigestive tract or paranasal sinuses and the epidural space to prevent meningitis and epidural abscess, (2) provide three-dimensional support and protection to the central nervous system, (3) reduce the probability of cerebrospinal fluid fistula, (4) provide vascular supply to dural reconstruction as needed, (5) enhance functional and aesthetic results by preventing contour deformities in the lateral orbit, and (6) maintain globe position and prevent enophthalmos or dystopia. Other indications for the temporalis muscle flap in extended head and neck and cranial base surgery include support for orbital contents following extended maxillectomy, obliteration of middle ear and mastoidectomy defects following temporal bone resection, and soft tissue augmentation of orbital exenteration defects.

CONTRAINDICATIONS

A common error in using the temporalis muscle is failing to realize the limitations of the size of the flap relative to the defect and not having satisfactory bulk to accomplish the reconstructive goals. Cranial base resection with either orbital exenteration or maxillectomy commonly results in a defect with significant exposure of the temporal lobe dura. This situation is frequently one in which the bulk of the temporalis flap is inadequate to match the defect, and a free tissue transfer is a more appropriate reconstructive option. Another error is not recognizing the need to sacrifice the blood supply to the temporalis muscle during the tumor resection.
CHAPTER 48  Temporalis Muscle in Skull Base Reconstruction

PREOPERATIVE PLANNING

Minimal additional preoperative planning is needed when considering using the temporalis muscle for cranial base reconstruction. A detailed history should be obtained regarding previous surgical or nonsurgical treatments of head and neck or skull base malignancy. Prior radiation treatment to this area renders the temporalis muscle flap unreliable, and alternative reconstructive methods should be considered. Standard presurgical imaging of the skull base often includes both CT and MRI studies. The MRI will provide superior detail regarding the size, thickness, and bulk of the temporalis muscle and the potential size of the expected cranial base defect. Dedicated vascular or other specific studies are not necessary prior to using this flap.

Surgical Technique (Fig. 48.2)

The successful application of the temporalis muscle flap begins with a clear understanding of the regional anatomy, various investing fasciae, and the vascular supply to the muscle. The temporalis muscle is usually approached through the same incision as the ablative procedure with either a hemi- or bicoronal scalp incision. With a hemi coronal incision, the apex of the incision should be taken to the vertex to expose the ipsilateral pericranium in the event additional tissue is needed in the reconstruction. The inferior aspect of the incision should be carried 1 cm below the tragus to facilitate safe exposure of the zygomatic root and eventually the zygomatic arch. The skin and subcutaneous tissue of the scalp are incised parallel to the hair follicles, and the subgaleal plane is developed anteriorly and posteriorly. Injury to the hair follicles and subsequent permanent alopecia can be avoided by maintaining a plane of dissection deep to the galea or superficial temporal fascia. Bipolar cautery should be used judiciously for hemostasis. The anterior limit of the exposure is the orbital process of the frontal bone and posteriorly the vertical plane of the mastoid tip. The posterior dissection is necessary to mobilize the entire temporalis muscle and gain the maximum arc of rotation.

The temporoparietal fascia (TPF) is attached superiorly to the galea aponeurotic and inferiorly to the superficial muscular aponeurotic system. The TPF is supplied by the frontal and parietal branches of the superficial temporal artery and has been extensively used as both a pedicle flap and a microvascular free tissue transfer for the reconstruction of limited-size head and neck defects. The TPF will need to be divided to fully mobilize the temporalis muscle; therefore, the identification and preservation are critical to maintain the integrity of this flap.

With the scalp reflected anteriorly, the surgeon will encounter the pale yellow temporal pad of adipose tissue deep to the TPF. The TPF is incised with a curvilinear incision approximately midway between the superior temporal line and the zygomatic arch preserving the superficial temporal artery system. A broad sharp periosteal elevator is used to mobilize the TPF inferiorly to the level of the temporal pad of adipose tissue. The pad of adipose tissue is located between the layers of the investing fascia of the temporalis muscle (deep temporal fascia). The deep temporal fascia is continuous with the pericranium (periosteum of the skull) superiorly and the parotid-masseteric fascia inferiorly. The more superficial layer of the deep temporal fascia

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that may be inseparable from the TPF is mobilized with the adipose tissue pad to preserve its blood supply. Mobilization of the pad of adipose tissue in this plane provides for protection of the frontal branches of the facial nerve. The deep layer of the deep temporal fascia should remain intact and be attached on the surface of the muscle. The thickness and strength of the deep temporal fascia are critical to hold sutures when securing the flap in the defect.
As the dissection proceeds inferior to the temporal pad of adipose tissue, the zygoma is palpated. The zygoma will be exposed by sharp dissection as a subperiosteal plane entered posteriorly on the arch. Beginning the dissection here and maintaining the subperiosteal plane will further protect the temporal and frontal branches of the facial nerve. The lateral dissection in the plane of the parotidomasseteric fascia proceeds until the superior most fibers of the masseter muscle are identified where they attach to the zygoma. The zygoma is skeletonized as far as the zygomatic root posteriorly, to the zygomatico-orbital suture anteriorly, and to the malar eminence inferiorly. Submillimeter holes for microplates or wires are drilled with the zygoma in situ. Osteotomies of the zygoma are carried out with a high-speed reciprocating saw and can either be left attached to the masseter muscle or be removed and replaced as a nonvascular autograft. Keeping the zygoma attached to the masseter muscle facilitates inferior retraction of the muscle and identification of the tendinous insertion of the temporalis muscle onto the coronoid process. The zygomaticofacial foramen is a consistent anatomic reference for the lateral extent of the maxillary antrum; placing the osteotomy posterior to it on the malar eminence will prevent entrance into the maxillary sinus. Anterior–inferior exposure can be safely facilitated by using the Cushing subtemporal blunt retractors, thereby avoiding direct injury to distal branches of the facial nerve.

Mobilization of the zygoma allows for complete visualization of the temporal fossa and the size and position of the temporalis muscle. The muscle originates from the squamous portion of the temporal bone at the level of the superior temporal line and the greater wing of the sphenoid bone; therefore, there is no fascia on the deep surface of the muscle. The only superior fascial attachments are those to the pericranium. Inferiorly, the muscle fibers condense into a dense tendon that inserts onto the medial and lateral surfaces of the coronoid process and the anterior aspect of the ramus of the mandible. The vertical height of the muscle is up to 12 cm from the superior origin to the insertion at the coronoid. The broad belly of the muscle is up to 2 cm thick and ranges from 12 to 14 cm in the anterior–posterior dimension. The motor and proprioceptive innervations of the muscle are from the anterior and posterior deep temporal nerve branches of the anterior division of the mandibular branch of the trigeminal nerve (V₂). These nerves enter the deep aspect of the muscle after passing superiorly to the lateral pterygoid muscle.

Once fully exposed, the muscle is now completely elevated from the temporal and sphenoid bones. If a pericranial extension is needed, the pericranium is marked and divided with electrocautery to access the subperiosteal plane, and sharp dissection proceeds broadly in a superior-to-inferior direction. Caution is needed when dissecting the attachments of the muscle to the superior temporal line to prevent shearing of the pericranium from the distant end of the temporalis muscle. If a composite osseous–muscle flap is to be used, the calvarium attached to the muscle is harvested at this point, preserving multiple microscopic perforating vessels to the bone. The dissection proceeds inferiorly separating the muscle from the greater wing of the sphenoid and lateral pterygoid plates. The deep temporal nerve will be encountered just medial to the lateral pterygoid plate. It is not necessary to routinely divide these nerves as their preservation results in some maintained muscle bulk. Extreme caution is needed when elevating the most inferior aspects of the muscle as to not injure the vascular supply. The muscle is supplied by the paired anterior and posterior deep temporal arteries and branches of the second or pterygoid division of the internal maxillary artery, and venous drainage is from the associated venae comitantes draining into the pterygoid plexus. The second (pterygoid or muscular) division of the internal maxillary artery courses anteriorly and laterally from the heads of the lateral pterygoid muscle and gives off branches to the temporalis, pterygoid, masseter, and buccinator muscles before becoming the third (pterygopalatine) segment as it enters the pterygopalatine canal. The anterior and posterior deep temporal arteries enter the temporalis muscle on the deep surface supplying the muscle and pericranium in a consistent pattern allowing for the safe partitioning of the muscles into discrete anterior and posterior components. To do this safely, the muscle should be divided sharply in its midportion in an anterior–posterior direction using meticulous bipolar electrocautery for hemostasis. To reliably preserve the vascular pedicle, the elevation of the muscle should terminate when the root of the lateral pterygoid is identified. Unless the muscle is to be harvested and used as a free tissue transfer, the routine identification of the vascular pedicle is not indicated (Fig. 48.3).

With the muscle completely elevated, it can be transposed medially into the defect in the paracentral skull base region. Although not always necessary, an additional 1 to 2 cm of rotation can be obtained by resecting the coronoid process of the mandible. The coronoid is approached from its anterior–lateral aspect distant from the deep temporal arteries. A sharp periosteal elevator is used to dissect the attachments of the temporalis from the mandible and expose the coronoid from the tip to the base at the level of the sigmoid notch of the mandible. A small reciprocating saw or rongeur is used to remove the bone using malleable retractors medially to protect the vessels. The muscle is then free to maximally rotate on the vascular pedicle into the defect (Figs. 48.4 and 48.5).

The muscle is sutured into the defect with absorbable sutures placed through the deep temporal fascia. Ideally, anchoring sutures in the defect are placed in small drill holes into the skull base. Even if the defect extends into the nasopharynx or paranasal sinuses, there is no need for a skin graft on the exposed muscle surface. Both the deep and lateral surfaces of the muscle tolerate exposure to the pharynx and will support the growth of the mucosa. The key principles in positioning the flap are to avoid tension, excessive angular rotation, and twisting and to ensure coverage of exposed major vessels and bone. If the defect is small, then the temporalis muscle can be split in the anterior–posterior dimension. The anterior component can be rotated inferiorly and medially into the defect in the paracentral skull base and the posterior component rotated anteriorly into the anterior portion of the donor site defect in the temporal fossa. The flap is secured anteriorly to the zygoma and orbital process of the frontal bone with absorbable sutures to small drill holes or the periorbita (Fig. 48.6).
FIGURE 48.3
Surgical defect prior to inset of temporalis muscle.

FIGURE 48.4
Schematic representation of split temporalis muscle reconstruction with anterior segment into skull base defect and posterior segment rotated anteriorly.
FIGURE 48.5
Split temporalis muscle in reconstruction. Anterior segment has been rotated anteriorly and inferiorly and cannot be seen while the posterior segment is rotated anteriorly and is visible in the temporal defect.

FIGURE 48.6
Schematic representation of medial inset of the temporalis muscle flap across a defect in the middle cranial base obliterating the sphenoid sinus and secured to the floor of the contralateral sphenoid sinus.
Transposition of the temporalis muscle will leave a depression at the donor site. Adipose tissue grafts have been used to eliminate this defect as have alloplastic materials. Women can minimize the cosmetic impact of this depression with appropriate hairstyling.

**POSTOPERATIVE MANAGEMENT**

At the completion of the procedure, the surgeon must be certain that there is complete separation between the upper aerodigestive tract and the (infra)temporal fossa. Following replacement of the zygoma, a medium-caliber suction drain (7-mm Jackson-Pratt) is inserted into the temporal fossa defect and placed to continuous wall suction. A tight circumferential dressing is to be avoided to prevent external compression of the flap. The eye should be carefully examined and lid function evaluated. If there is paresis of the upper divisions of the facial nerve, corneal protection protocols should be instituted. Temporary large-bore nasal airways can be used to maintain patency of the nasal cavity and nasopharynx and to support the medial portions of the temporalis flap. The nasal airway should be placed under direct vision with a sinus telescope to prevent disruption of the inset of the temporalis muscle flap.

**COMPLICATIONS**

Complications of the temporalis muscle flap occur in greater frequency in patients who have received prior radiation therapy to the temporal region and skull base; therefore, serious consideration should be given to reconstruction using free tissue transfer. The surgeons should always be cognizant of the blood supply to the muscle (see Surgical Technique section) and avoid excessive cautery on the deep surface of the muscle. A very generous tunnel should be created to avoid constricting the flap when transposing the muscle medially into the infratemporal fossa to reach the paracentral skull base, sphenoid, or carotid artery regions. Necrosis and loss of the flap can result in potentially devastating infectious complications such as epidural abscess, brain abscess, or meningitis. Loss of protection of the dura or dural reconstruction can lead to recurrent CSF leak.

Alopecia can develop when raising the scalp flap in too superficial a plane placing the hair follicles at risk. Injury to the frontal or temporal branches of the facial nerve may develop from incorrect placement of the incisions between the layers of the temporalis fascia (interfascial incisions), incomplete mobilization of the temporal pad of adipose tissue, or excessive retraction of poor placement of retractors on the anterior scalp and skin flaps.

The consequences of the temporalis muscle transfer include a mild insignificant mandibular drift to the contralateral side and the donor site deformity or temporal concavity. Patients will accommodate to the mild temporary mandibular crossbite, and no secondary procedures are indicated. Regarding the donor site deformity, autologous nonvascularized adipose grafts, alloplasts, and vascularized free tissue transfers have all been used in this situation. The use of nonvascularized adipose tissue and alloplasts carries a significant risk of infection and extrusion particularly when there is contamination from the oral cavity or paranasal sinuses. I prefer a delayed reconstitution of the temporal defect to allow for satisfactory healing of the primary cranial base defect, the timely initiation of adjuvant treatment as needed, and time for the definitive three-dimensional geometry of the defect to stabilize. Secondary reconstruction of the temporal defect can then be tailored to more specifically accommodate the final defect.

**RESULTS**

The temporalis flap, taken from a donor site not previously operated, traumatized, or radiated is a reliable flap for reconstruction of a defect in the floor of the central skull base. The bulk and arc of rotation of the temporalis muscle make it a reliable flap for a variety of reconstructive applications, including reconstruction of the palate, retromolar trigone, and buccal mucosa, orbital exenteration, and lateral temporal bone resections.

**PEARLS**

- Due to anatomic proximity, the temporalis flap has been useful in reconstructing defects of the central skull base.
- A complete history and physical examination are important to rule out previous trauma, surgery, or radiation to the donor site.
- The surgeon must have a thorough understanding of the surgical anatomy of the temporalis muscle, particularly the blood supply and the proximity to the frontalis branch of the facial nerve.
- The patient should be counseled preoperatively about the possible aesthetic changes, due primarily to the concavity of the donor site, which follows transposition of the temporalis muscle.
It is important to maintain the dissection in the proper plane to avoid injury to the frontalis branch of the facial nerve.

Dividing the insertion of the temporal muscle to the coronoid process of the mandible will increase its reach and arc of rotation.

**PITFALLS**

- Not recognizing the sacrifice of the blood supply to the temporalis flap during tumor resection may lead to flap necrosis.
- Preoperative embolization of the muscular branches of the internal maxillary artery will render the flap nonviable.
- Previous surgery, trauma, or radiation to the donor site may result in flap necrosis due to fibrosis or injury to the blood supply.
- Not dissecting in the proper plane may result in paresis or paralysis of the frontal branch of the facial nerve.
- Failure to counsel the patient about the possible aesthetic consequences, such as concavity of the temporalis fossa, may result in a dissatisfied patient.

**INSTRUMENTS TO HAVE AVAILABLE**

- Broad sharp periosteal elevator
- Narrow sharp elevator (Lempert type)
- Bipolar electrocautery
- Cushing subtemporal retractor
- Reciprocating saw with small blade
- Malleable retractors

**SUGGESTED READING**


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