Section 11 – CRANIAL BASE SURGERY

Chapter 100 – Surgery of the Anterior Cranial Base

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Anterior cranial base surgery has been the most conspicuous arena for cooperation between otolaryngologists and neurologic surgeons. From an otolaryngologist's perspective, the anterior cranial base is the region most commonly involved by extracranial neoplasms.[1–6] Most frequently they consist of neoplasms arising from the nasal cavity or paranasal sinuses. A wide variety of benign and malignant neoplasms may involve the anterior cranial base, as demonstrated in Table 100-1.[2]

Although some of these neoplasms have been associated with exposure to environmental carcinogens, the cause of the majority of neoplasms involving the anterior cranial base is unknown. Squamous cell carcinomas arising in the nasal cavity or paranasal sinuses, unlike those arising in other areas of the upper aerodigestive tract, are not associated with the use of alcohol or tobacco products. Squamous cell carcinoma of the paranasal sinuses, however, has been associated with exposure to nickel refining, softwood dust, leather tanning processing, chromium, soldering and welding, radium dial painting, and isopropyl oils. Hardwood workers have an increased incidence of adenocarcinoma.[4,6]

The symptoms and signs of neoplasms involving the anterior cranial base are nonspecific and are not useful in predicting a histologic diagnosis. These symptoms and signs do, however, reflect the location of the tumor and may be predictive of the extent of involvement of adjacent anatomic structures. Nonetheless, the clinical manifestations of the tumor may be identical to those of inflammatory sinus disease. Common symptoms include unilateral or bilateral nasal obstruction, recurrent epistaxis, rhinorrhea, and anosmia. Diplopia may be associated with invasion of orbital structures. Intracranial extension with significant involvement of the frontal lobes may occur without the production of any particular symptoms (Fig. 100-1). Because of this “silent” area of the brain, the first indication of invasion of the brain may be symptoms associated with elevated intracranial pressure, such as headache. On further questioning, patients and family members may relate subtle alterations in personality with disinhibition of emotions and inappropriate responses.

As a result of the location of these tumors there may be no external manifestations until the tumor reaches a large size. With slow-growing benign and malignant neoplasms, remodeling of bone with widening of the nasal dorsum may be seen (Fig. 100-2). Extension laterally into the orbit may result in periorbital swelling, proptosis, or restriction of extraocular movement and diplopia.[7] Visual loss is a late occurrence and is seen more often with tumors that originate close to the optic chiasm or orbital apex. Intracranial extension may be associated with signs of elevated intracranial pressure, such as papilledema. Evidence of frontal lobe involvement may be suggested by detecting abnormal reflex responses associated with frontal lobe release (glabella blink response, palmar-mental reflex).

Intranasal examination may be hindered because of deviations of the nasal septum, mucosal edema, or obstructing nasal polyps. Examination is greatly facilitated with the use of flexible or rigid fiberoptic endoscopes. The appearance and location of the tumor may suggest a histologic diagnosis. Origin of a tumor from the nasal vault, medial to the attachment of the middle turbinate, suggests an esthesioneuroblastoma (Fig. 100-3). Extension of a neoplasm from the maxillarysinus to the anterior cranial base may be evident. Posteriorly, involvement of the eustachian tube may be detected. This is important in explaining an associated middle ear effusion, as well as being a potential route of spread of tumor to the infratemporal skull base or carotid canal.

Table 100-1 -- TUMOR DIAGNOSIS AND PATIENT STATUS

		Disease Status (Follow-up: Months)			
Tumor	Total	NED	AWD	DOD	DOC
Benign Lesions					

		Disease Status (Follow-up: Months)			
Tumor	Total	NED	AWD	DOD	DOC
Meningioma	4	2 (48)	1 (31)	—	1 (36)
Ossifying fibroma	2	2 (27)	—	—	—
Cranial defect	2	1 (30)	—	—	1 (1)
Chondroblastoma	1	1 (45)	—	—	—
Fibrous dysplasia	1	—	1 (18)	—	—
Inverted papilloma	1	1 (22)	—	—	—
Pituitary adenoma	3	1 (44)	2 (26)	—	—
Subtotal	14	8	4	0	2
Low-Grade Malignancies					
Chordoma	7	4 (32)	2 (13)	1 (29)	—
Esthesioneuroblastoma	6	4 (27)	1 (13)	—	1 (22)
Adenoid cystic carcinoma	4	3 (31)	—	—	1 (24)
Chondrosarcoma	2	2 (27)	—	—	—
Subtotal	19	13	3	1	2
High-Grade Malignancies					
Squamous cell carcinoma	7	3 (33)	1 (23)	3 (7)	—
Undifferentiated carcinoma	2	—	1 (24)	1 (36)	—
Adenocarcinoma	2	1 (33)	—	1 (12)	—
Osteogenic sarcoma	2	2 (36)	—	—	—
Melanoma	1	—	1 (43)	—	—
Rhabdomyosarcoma	1	—	—	1 (10)	—
Malignant fibrous histiocytoma	1	1 (16)	—	—	—
Subtotal	16	7	3	6	—
Grand total	49	28	10	7	4

AWD, alive with disease; DOC, dead of other causes; DOD, dead of disease; NED, no evidence of disease.

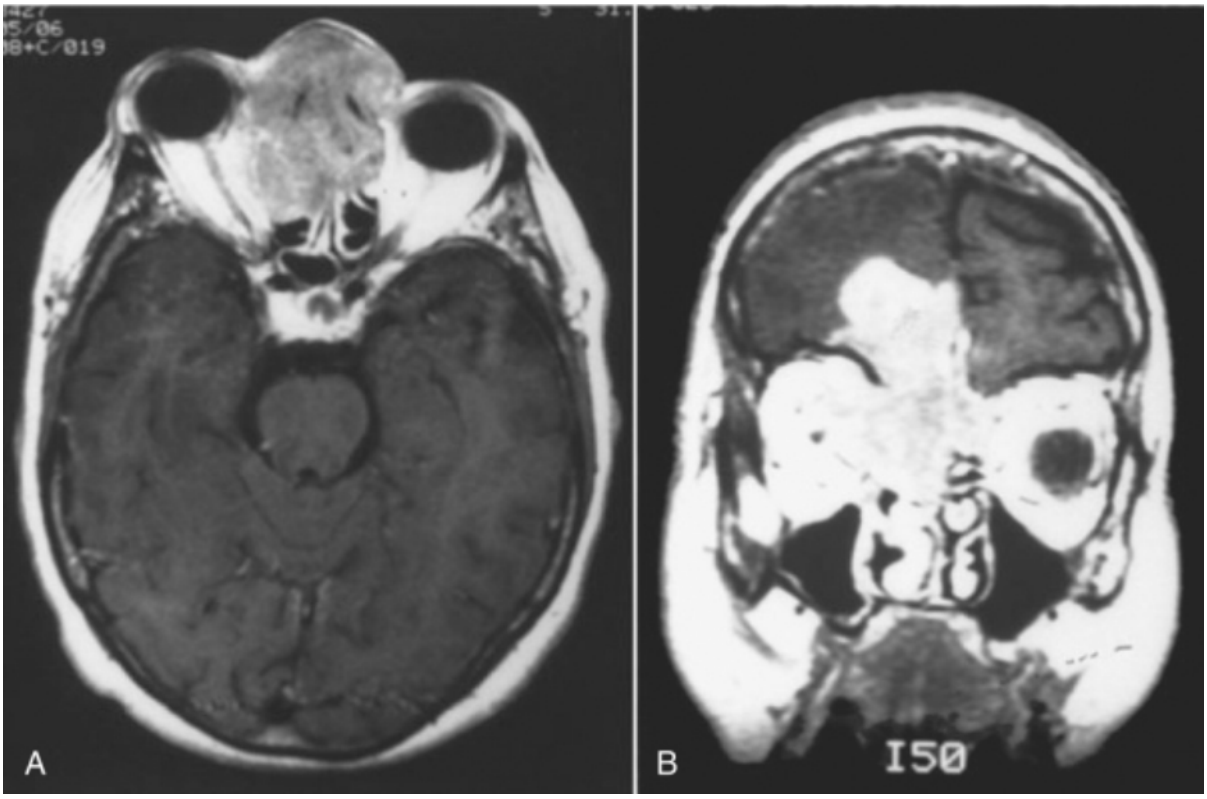

Figure 100-1 **A** and **B,** Magnetic resonance images demonstrating extensive neoplasm with erosion of the skull base and invasion of the right frontal lobe.

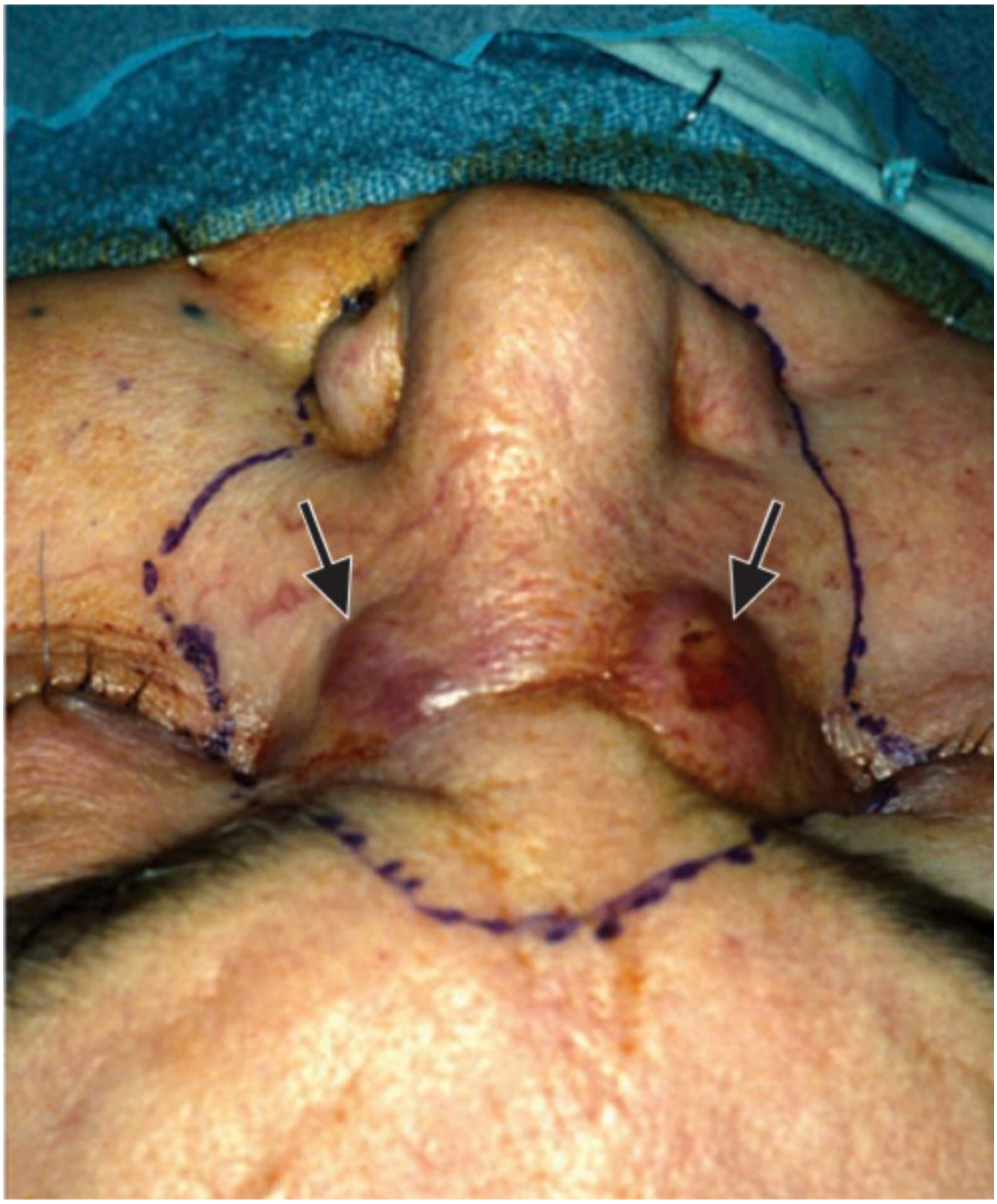

Figure 100-2 Widening of the nasal dorsum is evident with this neoplasm extending to and involving skin *(arrows)*.

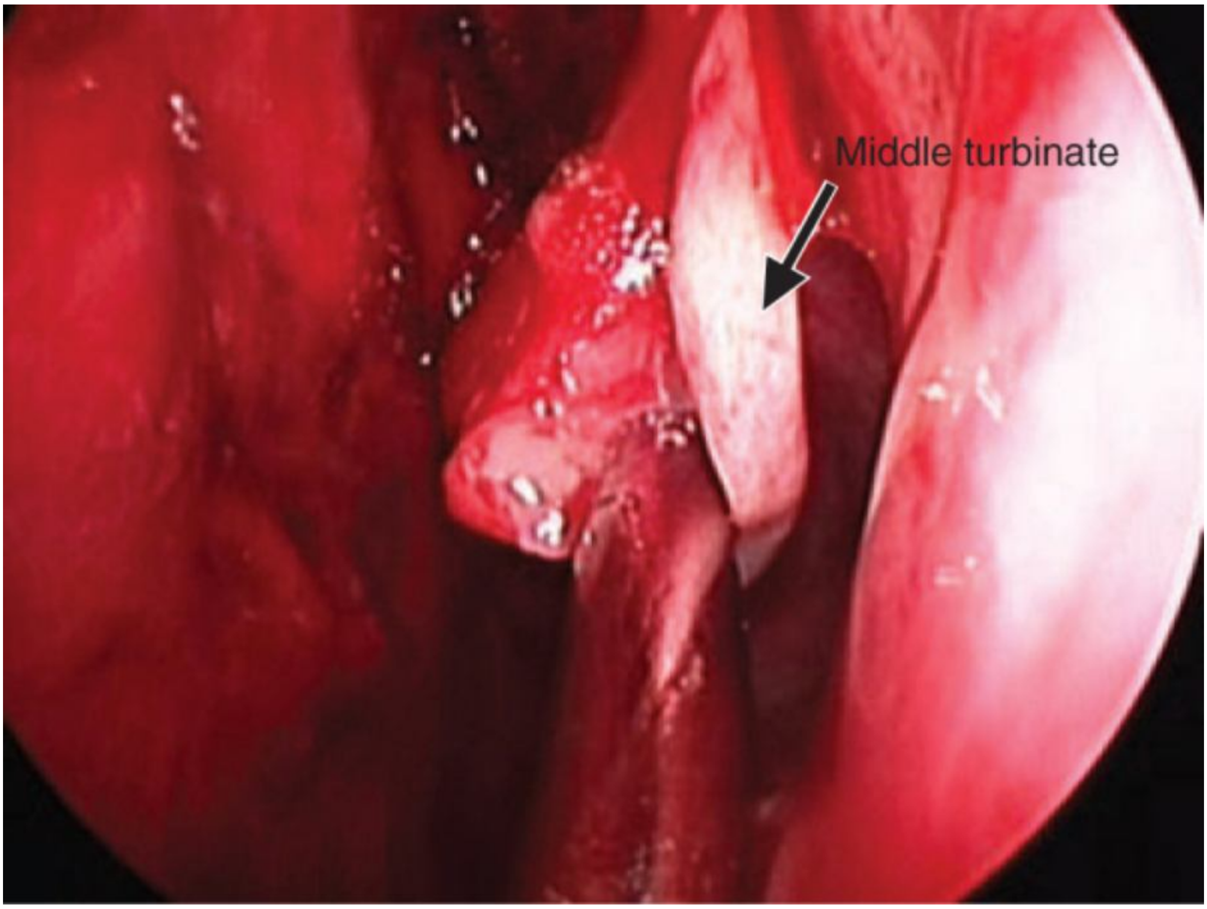

Figure 100-3 A mass is noted arising medial to the attachment of the middle turbinate in the left nasal cavity *(arrow)*. Biopsy confirmed an esthesioneuroblastoma.

PATIENT SELECTION

Some aspects of the physical examination have already been addressed. Endoscopic visualization of the nasal cavity and nasopharynx is considered a routine part of the examination that may provide useful information regarding the origin, extent, and vascularity of the tumor. Additional preoperative testing may include assessment of olfactory function with “scratch-and-sniff” panels and neuro-ophthalmologic examination, including visual acuity and visual field testing. Biopsy samples are not usually obtained in the office setting because of concern for bleeding and possible communication with cerebrospinal fluid (CSF) (Fig. 100-4). Additionally, biopsy may alter the magnetic resonance imaging (MRI) characteristics of the tumor. However, large fungating tumors that are easily visualized in the nasal cavity may undergo biopsy with minor risk in the office setting.

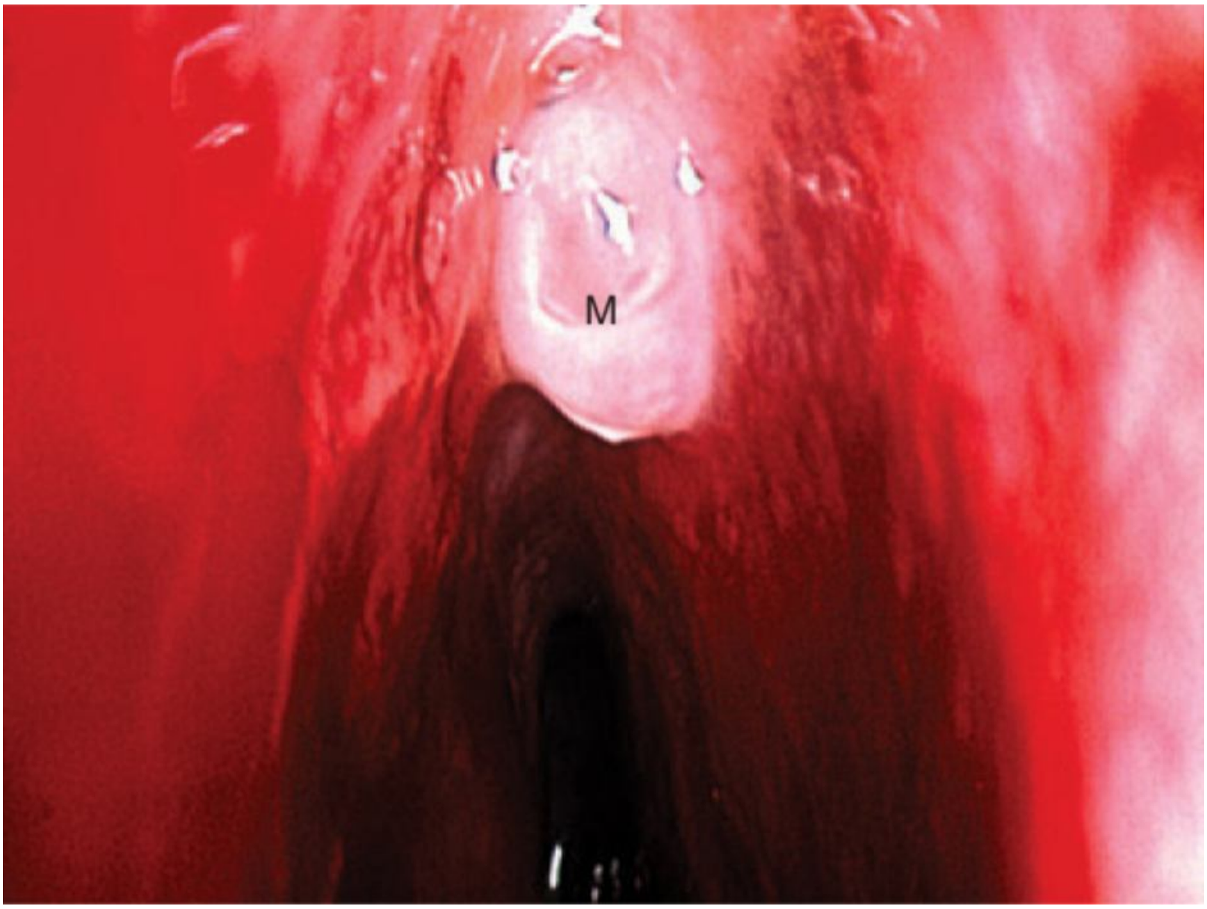

Figure 100-4 This patient had a history of unilateral nasal obstruction. Endoscopic examination revealed a meningocele (M) in the region of the cribriform plate.

Radiologic imaging is an essential part of the evaluation of these patients. Involvement of the orbit and intracranial extension may not be clinically apparent. Computed tomography (CT) of the paranasal sinus with contrast enhancement is the preferred initial examination. Images through the skull base are obtained at 1-mm intervals to achieve maximal resolution. CT provides excellent bone detail and is superior to MRI in detecting bony erosion of the anterior cranial base and paranasal sinuses. A contrast agent provides assessment of the overall vascularity of the tumor (Fig. 100-5). Coronal images of the anterior cranial base are superior to axial images in demonstrating intracranial extension. MRI provides much greater detail of soft tissue structures and is complementary to CT scanning in most patients. Bone detail is poorly visualized, however. MRI is particularly valuable for demonstrating dural involvement and invasion of the brain. MRI is also superior for demonstrating perineural extension of tumor (Fig. 100-6). Highly vascular tumors may be associated with flow voids within the tumor. When a sinus is opacified, a CT scan may not be able to differentiate tumorfrom retained secretions. In this case, the use of MRI with T1- and T2-weighted images allows differentiation of tumor and secretions (Fig. 100-7). When the sinus contains fungus, however, a signal void indistinguishable from air may give a false impression of a normal examination on T2-weighted images (Fig. 100-8).

Figure 100-5 Computed tomography scan demonstrating bone erosion of the anterior cranial base resulting from rhabdomyosarcoma of the left orbit.

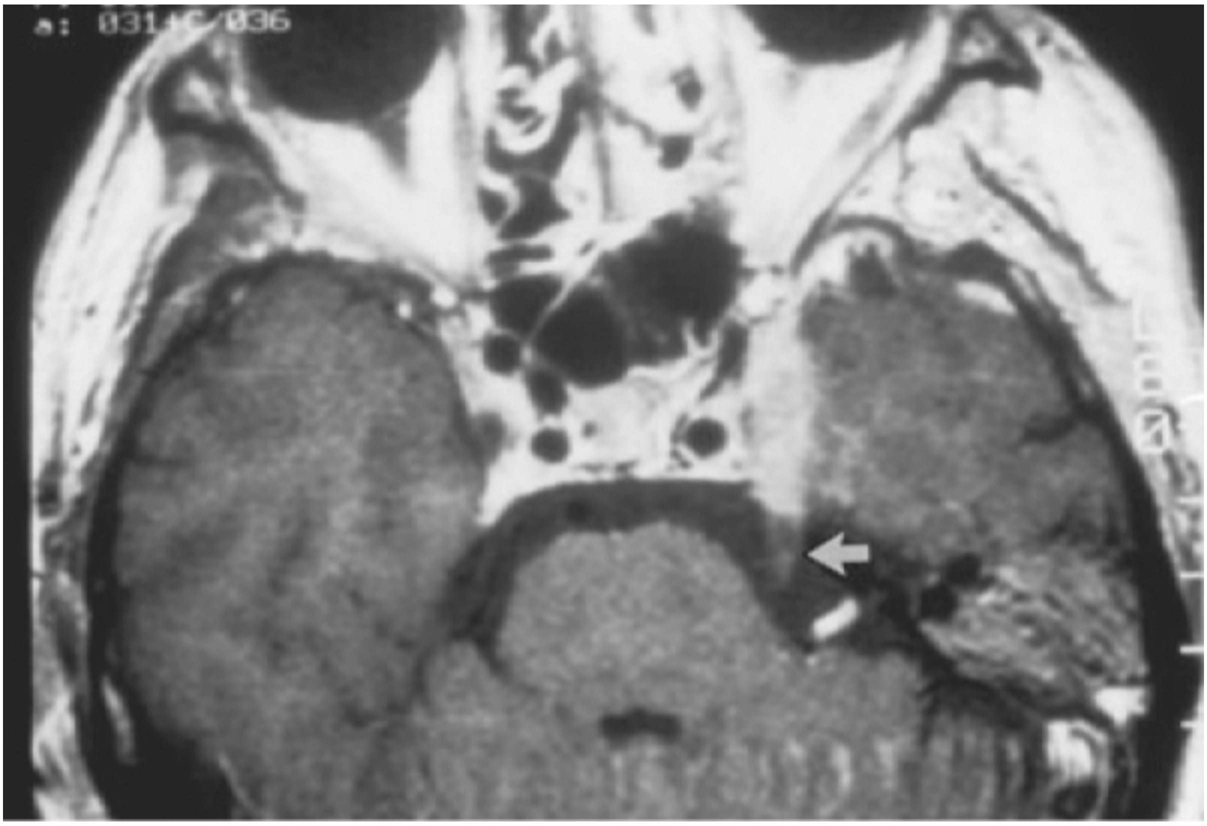

Figure 100-6 In this patient with a malignant neoplasm, magnetic resonance imaging demonstrates tumor involvement of the left cavernous sinus and perineural extension along the route of the trigeminal nerve *(arrow)*.

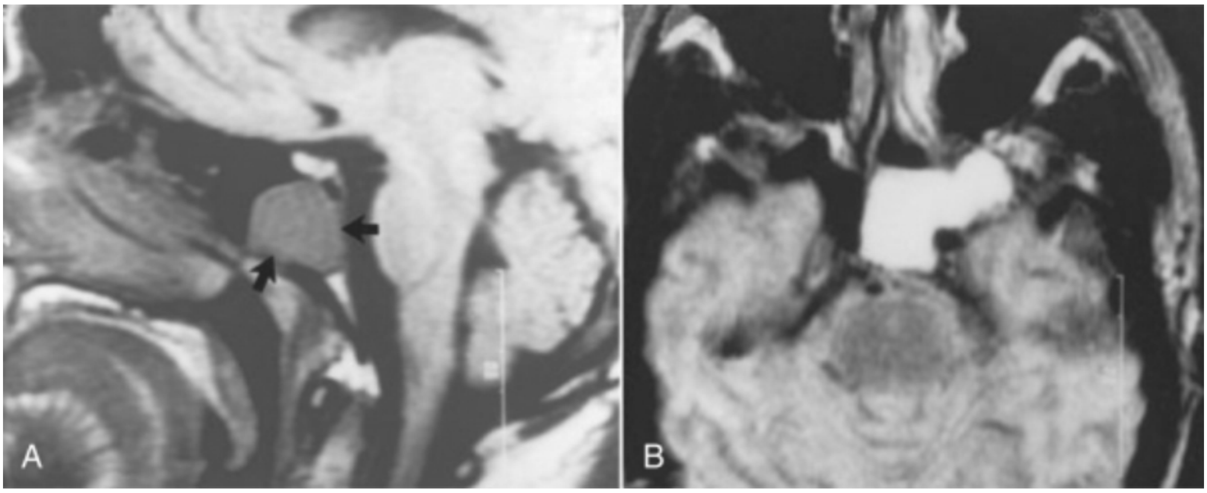

Figure 100-7 **A,** A T1-weighted magnetic resonance image demonstrates a sphenoid sinus mass *(arrows)* that is consistent with either a tumor or secretions. **B,** A T2-weighted image, however, demonstrates high signal intensity consistent with secretions from obstruction of the ostium of the sinus.

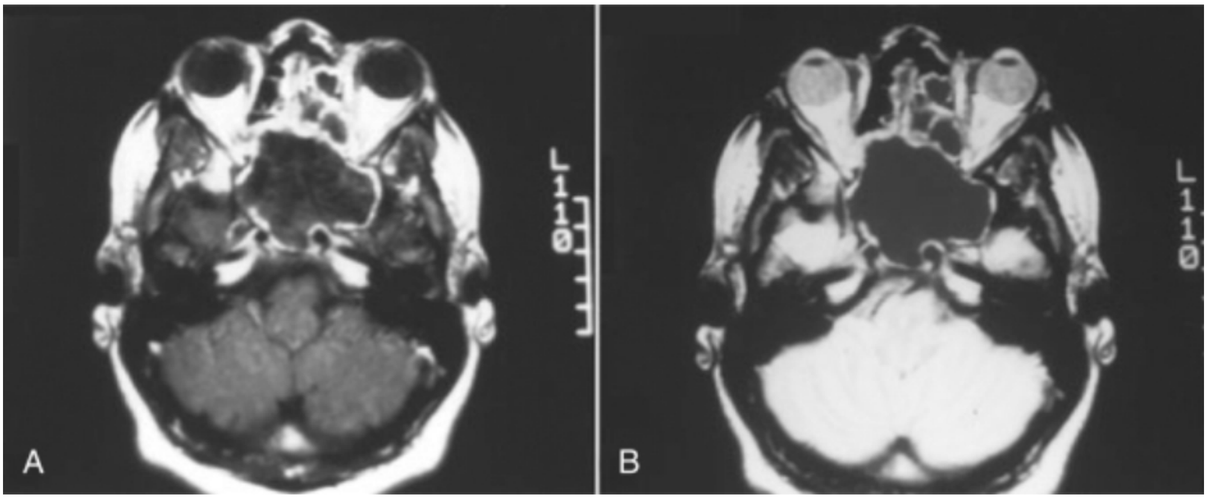

Figure 100-8 **A,** A T1-weighted magnetic resonance image demonstrates an extensive lesion of the sphenoid sinus with remodeling of bone and erosion of the cranial base. The variable-density pattern is consistent with fungal sinus disease. **B,** A T2-weighted image gives a false impression of a clear sinus. This patient was treated endoscopically for allergic fungal sinusitis.

Angiography is not necessary for neoplasms involving the anterior cranial base unless there is neoplastic involvement of the cavernous sinus or extensive extracranial involvement with extension of tumor to the infratemporal skull base. CT or MR angiography is usually adequate to establish the status of the vasculature in these areas. If the neoplasm is suspected to be highly vascular based on CT or MRI characteristics, angiography with preoperative embolization may be considered. Nevertheless, preoperative embolization is rarely necessary because the vascular supply to these tumors is usually accessible at the time of surgery.

The choice of therapy is dependent on the histology of the tumor and its expected biologic behavior, the tumor site, and involvement of critical anatomic structures. Surgical excision is the preferred treatment modality for the majority of benign and malignant tumors involving the anterior cranial base (Table 100-2). Complete removal of the tumor can be achieved in the majority of cases with contemporary surgical techniques. Because regional or distant metastases are unusual at the time of initial evaluation, the critical problem is that of local control. Rhabdomyosarcomas, melanomas, and adenoid cystic carcinomas, which are known to disseminate hematogenously, are an important exception to this concept. Sarcomas are not considered operable until the absence of distant metastases is confirmed by CT scanning of the lungs and liver and a bone scan.[8–10] We prefer the use of a fused positron emission tomography (PET)/CT study to evaluate for metastasis.

Table 100-2 -- CHOICE OF TREATMENT OF TUMORS OF THE ANTERIOR CRANIAL BASE

Neoplasm	Treatment
Benign	Surgery
Low-grade malignancy	Surgery ± radiotherapy
High-grade malignancy	Surgery + radiotherapy ± chemotherapy Radiotherapy + chemotherapy ± salvage surgery

Cytologic examination of the spinal fluid is recommended for some tumors with intracranial extension, such as sarcomas or other high-grade malignancies. Positive cytology may indicate the need for combined therapy to prevent intracranial dissemination. The role of preoperative chemotherapy in the treatment of high-grade malignancies with intracranial extension has not been adequately addressed in the adult population. Strong consideration should be given, however, to the use of chemotherapy postoperatively in these patients.

Orbital involvement by a malignant neoplasm may require orbital exenteration to achieve complete tumor removal. Orbital exenteration is recommended when there is soft tissue involvement of the orbit by malignant neoplasms.[7] Surgical therapy may be contraindicated in patients with malignant neoplasms invading the soft tissue of the orbit who adamantly refuse orbital exenteration. The orbit can usually be spared when there is involvement by benign neoplasms.

Intracranial extension of malignant neoplasms is not necessarily a contraindication to surgery. If it appears that the neoplasm is extradural, the dura may be excised as the margin (Fig. 100-9). Adequate surgical margins may also be obtained if there is minimal involvement of the frontal lobes (Fig. 100-10). However, when dealing with aggressive neoplasms such as squamous cell carcinoma or adenoid cystic carcinoma, which have a predilection for extending great distances beyond the observable margin of the tumor, the likelihood of achieving local control with surgery is slim. Significant palliation, however, may be achieved with the addition of postoperative chemoradiotherapy. Additionally, given the insidious natural history of adenoid cystic carcinoma, tumor recurrence may not become evident for 5 to 10 years despite incomplete tumor excision.

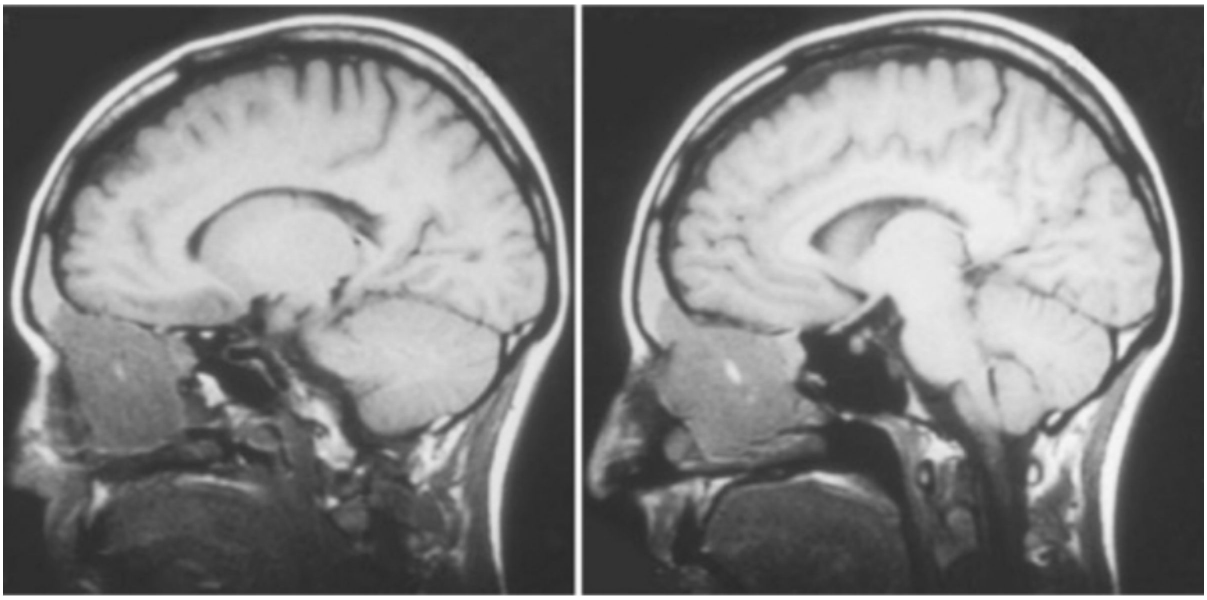

Figure 100-9 This patient has an extensive neoplasm involving the nasal cavity and paranasal sinuses. Magnetic resonance imaging demonstrates protrusion of tumor into the inferior portion of the frontal sinus. There is evidence of tumor extension through the bone of the anterior cranial base with possible involvement of the dura.

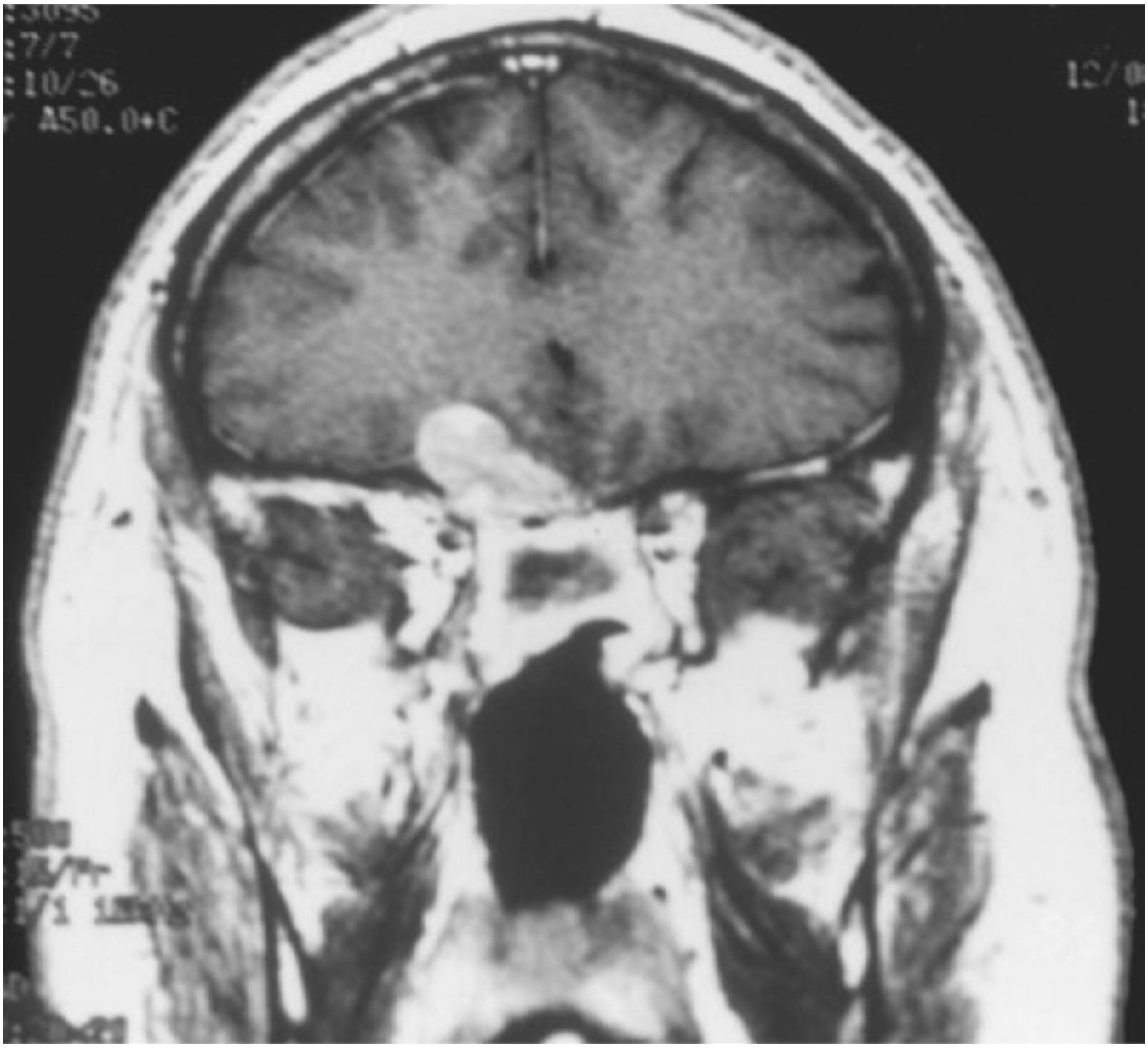

Figure 100-10 In this patient, squamous cell carcinoma developed in an inverting papilloma. Magnetic resonance imaging demonstrates minimal tumor invasion of the right frontal lobe.

Adequate exposure of the anterior cranial base for excision of neoplasms traditionally requires a combined intracranial and extracranial approach. The choice of an extracranial approach depends on the site and extent of the tumor and aesthetic considerations, as well as the experience of the surgeon with particular approaches. For most neoplasms arising from the nasal cavity or paranasal sinuses, lateral rhinotomy provides excellent exposure when combined with an intracranial approach (Fig. 100-11). This approach allows complete resection of the medial wall of the maxilla and the orbit and nasal septum. Excellent exposure of the ipsilateralnasopharynx is also possible. Access to lesions that extend bilaterally, however, is limited. In addition, patients object to the facial scars. A midfacial degloving approach avoids external scarring and provides improved access to bilateral lesions (Fig. 100-12). It is also possible to resect some tumors limited to the cribriform plate and superior ethmoid air cells through an intracranial approach exclusively. Most tumors that were previously managed by lateral rhinotomy combined with a transcranial approach or by a degloving approach may be removed by endoscopic or endoscopic-assisted resection. Endoscopic or endoscopic-assisted approaches will obviate the need for facial scars and have been our favored approaches for the past 10 years.

Figure 100-11 Lateral rhinotomy affords excellent exposure of the ipsilateral nasal cavity and paranasal sinuses.

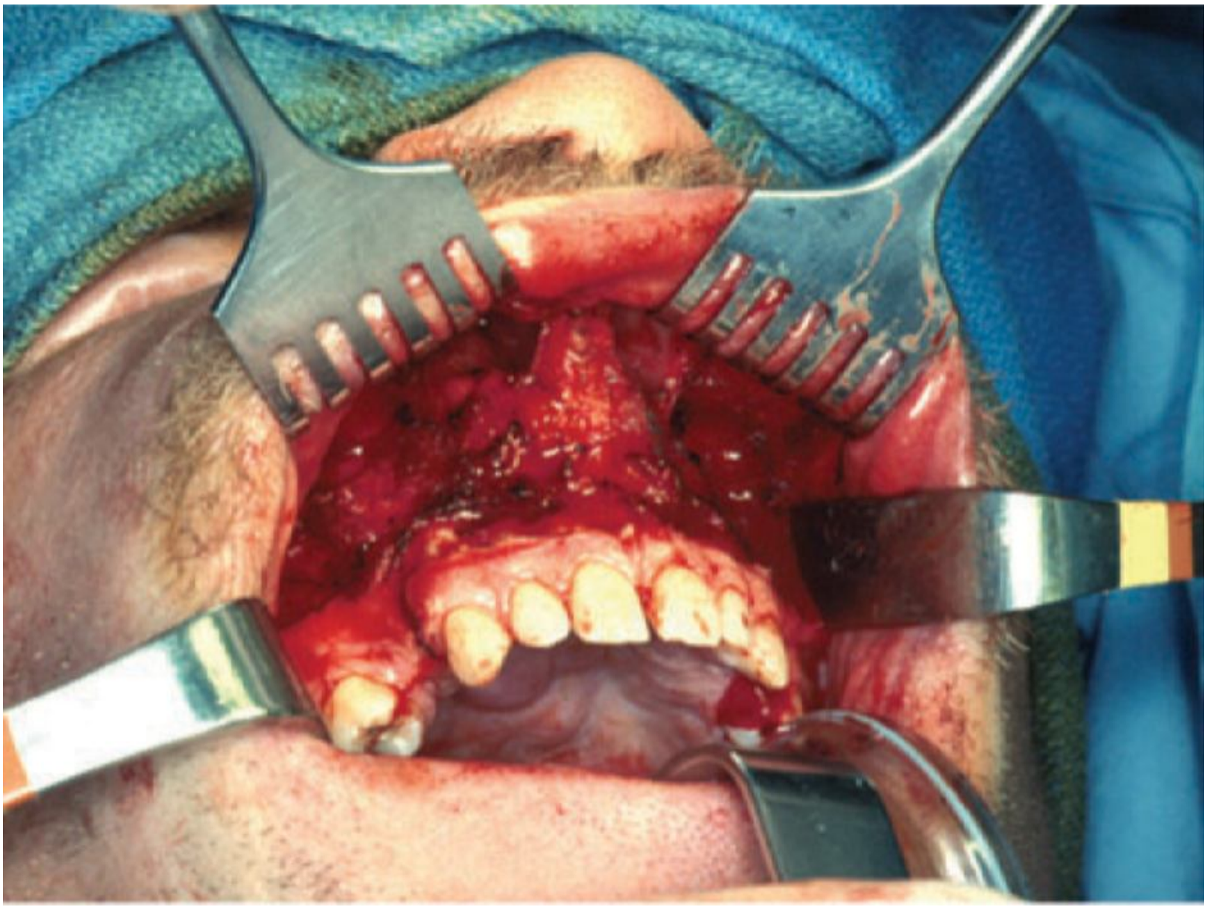

Figure 100-12 A midfacial degloving approach is useful for tumors involving the sinonasal cavity bilaterally.

Preoperative informed consent includes discussion of the various treatment options, as well as the sequelae and potential risks associated with the surgery. For patients undergoing anterior craniofacial resection, standard discussion of risks includes possible brain injury, hemorrhage, infection, CSF leak, stroke, and visual loss. Patients are informed that anosmia is a sequela of the operation.

PREOPERATIVE PLANNING

Special consideration must be given to perioperative and intraoperative management of these patients. As a result of the prolonged nature of the surgery, these patients are at risk for the development of deep venous thrombosis (DVT). Since anticoagulation is contraindicated in these patients because of the risk of intracranial hemorrhage, DVT prophylaxis is best achieved with sequential pneumatic compression stockings intraoperatively and in the postoperative period until ambulation is possible.

Anterior craniofacial surgery necessarily results in contamination of the intracranial space by bacterial flora of the upper aerodigestive tract. These are considered clean-contaminated cases, and perioperative antibiotic prophylaxis is indicated. Broad-spectrum antibiotics are recommended to provide adequate coverage of the flora of the sinuses *(Streptococcus pneumoniae, Haemophilus influenzae, Branhamella catarrhalis)* and skin *(Staphylococcus aureus).* Previous studies have demonstrated that the use of a single agent such as a broad-spectrum cephalosporin may provide adequate protection. Antibiotic prophylaxis is instituted at least 2 hours before the skin incision and is continued through the second postoperative day. Antibiotic prophylaxis for 24 hours or less is associated with a significant increase in local infections.[11,12] Such infections may be due to transient CSF leaks postoperatively with potential contamination of the intracranial cavity. Antibiotic prophylaxis for more than 48 hours may be associated with an increased risk for infection by resistant organisms.

To minimize the need for retraction of the brain, which may lead to contusion and the development of encephalomalacia, it is desirable to minimize intracranial pressure with various anesthetic techniques, including removal of CSF by lumbar puncture, as well as using a balanced anesthetic technique to maintain adequate cerebral perfusion while minimizing intracranial pressure. Hyperventilation to produce hypocapnia usually provides adequate relaxation of the frontal lobes. If significant frontal lobe retraction is necessary, a lumbar spinal drain is placed preoperatively and approximately 50 mL of spinal fluid is removed. Because these drains tend to malfunction intraoperatively, it is best to remove additional CSF at the time of catheter placement. Additional CSF may be removed intraoperatively or postoperatively to minimize intracranial pressure and decrease the risk for a postoperative CSF leak. In most cases, the spinal drain can be removed in the recovery room after surgery. Relaxation of the brain may be enhanced intraoperatively with the use of osmotic diuretics such as mannitol. The surgical approach is designed to minimize frontal lobe retraction through the use of a subfrontal approach.

The patient is positioned on a Mayfield horseshoe head holder to improve access to the face and scalp areas. Because frequent repositioning of the face and head is necessary with a combined intracranial and extracranial approach, head tongs or pins are not generally used. Since access to the airway is limited intraoperatively, the endotracheal tube is additionally secured by placement of a wire around a mandibular or maxillary molar. Wiring of the tube to the maxilla is preferred, when feasible, because such wiring provides greater stability. If the patient is edentulous, a circum-mandibular wire is placed for anchoring of the endotracheal tube.

An additional concern for the anesthesiologist is the development of an air embolus intraoperatively. This risk is minimized by operating with the patient in a supine position. A precordial Doppler probe is used to detect significant air embolism. A central line is also placed preoperatively to allow advancement into the right atrium for aspiration of an air embolus should it occur.

Most approaches to the anterior cranial base require exposure of the intracranial structures via frontal craniotomy. Before proceeding with the skin preparation, the eyes are protected by suturing the lids closed with 6-0 silk suture. This allows inclusion of the eyes within the surgical field and decreases the risk of corneal abrasion. The tarsorrhaphy suture may be placed through the lids at the tarsal line. Pledgets soaked in 0.05% oxymetazoline nasal solution are placed intranasally with the strings attached. To allow adequate time for the vasoconstrictive effects of a local anesthetic, the proposed incision line is infiltrated with 0.5% lidocaine (Xylocaine) with 1 : 200,000 epinephrine at this time. On average, approximately 20 mL of local anesthetic is infiltrated. The skin is then prepared with a povidone-iodine solution. It may be used around the eyes, although it is advisable to rinse the eyes with balanced saline solution to prevent chemical irritation. The povidone-iodine solution should be allowed to dry for it to be most effective.

SURGICAL TECHNIQUES

Open Technique

To provide access to the right and left frontal areas, a bicoronal scalp incision is made over the vertex of the scalp. Laterally, the incision extends to the superior attachment of the auricle. When additional lateral exposure is necessary, the incision is extended into a preauricular crease. The incision may be extended as necessary with a parotidectomy incision (Fig. 100-13). If lateral exposure is not necessary, small anterior backcuts are made at the ends of the incision in the temporal hair-bearing scalp (Fig. 100-14). This increases the arc of rotation of the scalp flap without the need for extending the incision inferiorly. The incision is made over the vertex of the scalp to maximize the length of any potential scalp flaps used for reconstruction. For this reason, incisions that follow the hairline or that have a V-shaped peak projecting anteriorly in the midline are to be avoided. Because of placement of the incision high over the vertex of the scalp, an acceptable cosmetic result is achieved even in bald persons. If there is any loss of hair along the incision line, it is well hidden.

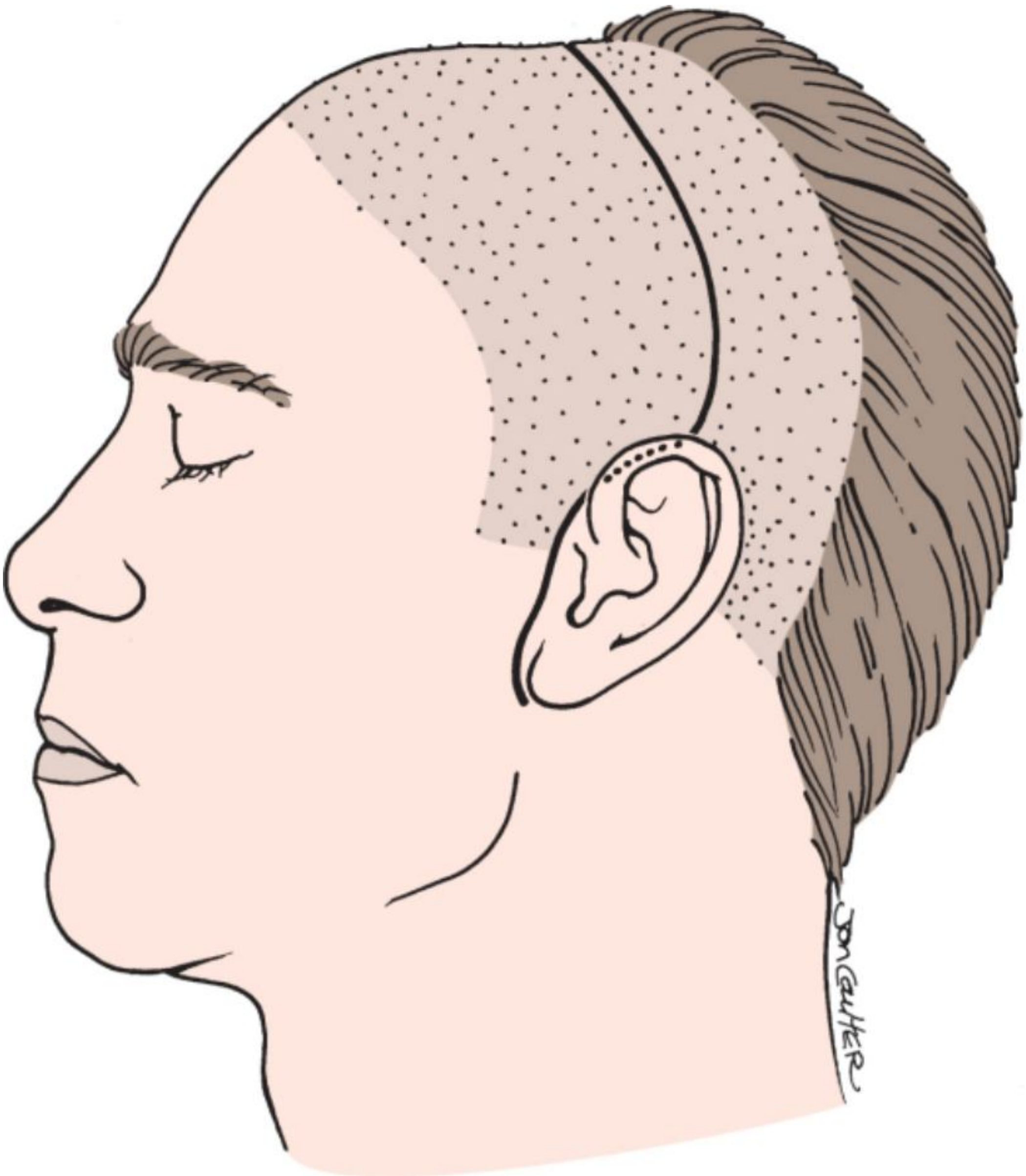

Figure 100-13 The coronal scalp incision may be extended in a preauricular skin crease to provide additional lateral exposure.

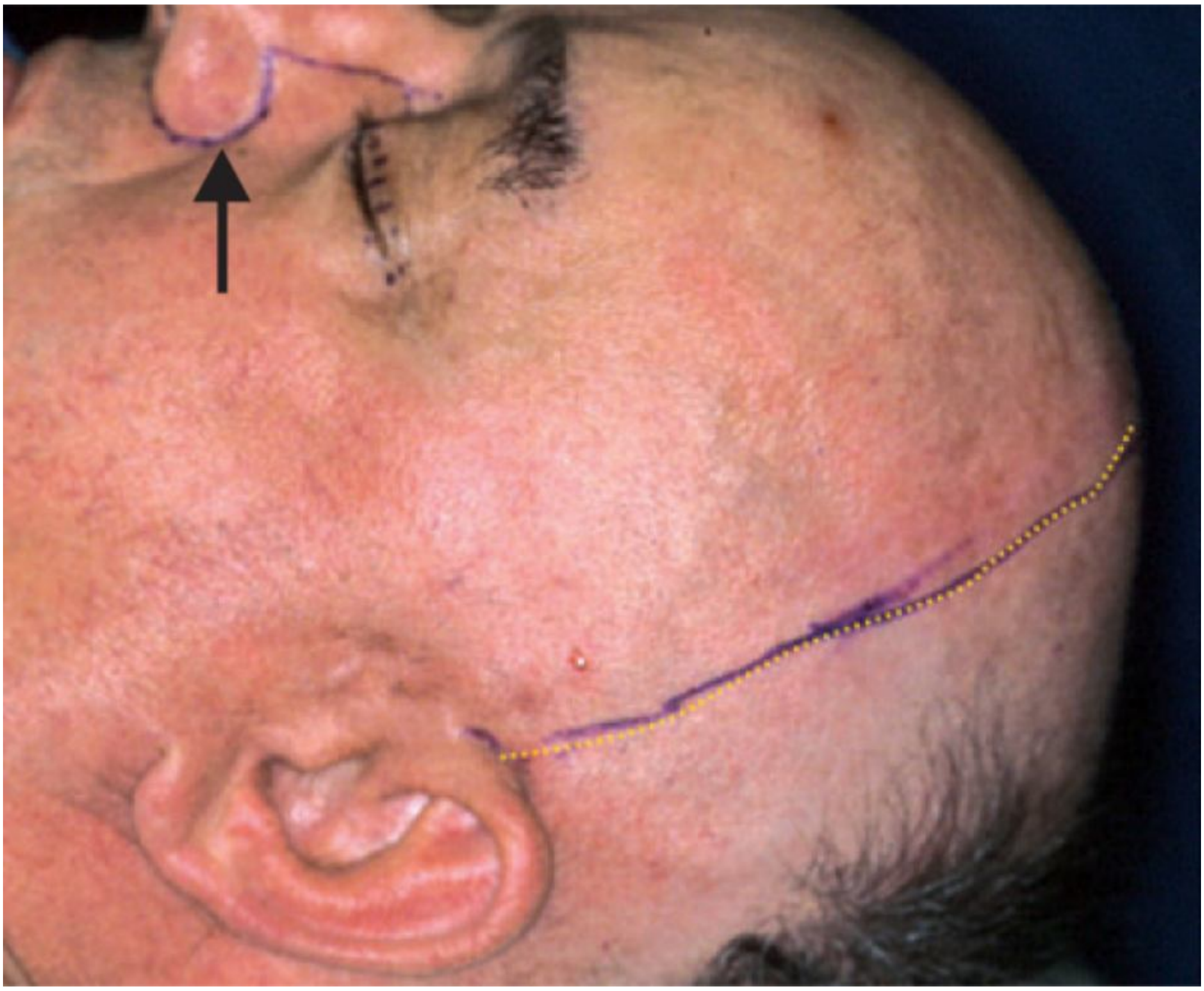

Figure 100-14 As an alternative to extending the incision inferiorly, a short angulation of the incision anteriorly increases the arc of rotation of the scalp flap and provides adequate frontal exposure. This patient has also been marked for a lateral rhinotomy.

Superiorly, the incision extends through all layers of the scalp, including the pericranium. Laterally, the incision extends to the level of the deep temporalis fascia. The lateral dissection is more meticulous to avoid injury to the superficial temporal artery. The branching pattern of this artery is variable, but in 85% of patients it divides into major anterior and posterior branches. By placing the scalp incision in line with the ear, the posterior branches are divided with preservation of the anterior branch. Preservation of the superficial temporal artery is not essential for viability of the scalp in most patients, but it may be important in patients who previously have undergone surgery or who have received radiation therapy. Additionally, if a galeal-pericranial scalp flap is used for reconstruction, collaterals from the superficial temporal artery are important to provide adequate circulation to the overlying skin.

The edges of the scalp are elevated with a broad periosteal elevator, and Raney clips are placed along the skin margins of the incision to provide hemostasis. The pericranium is not separated from other layers of the scalp at this time to prevent desiccation of the flap during a prolonged procedure. The scalp is then elevated, deep to the pericranium, with a periosteal elevator and blunt dissection with gauze. Laterally, this requires separation of the pericranium from the deep temporalis fascia at the origin of the temporalis muscle. The thin fascial layers overlying the deep temporalis fascia are easily elevated with a wide periosteal elevator. Bleeding from perforating veins of the frontal bone is controlled with bone wax or electrocautery.

As the scalp is elevated and reflected inferiorly, care is taken to avoid injury to the supraorbital and supratrochlear vessels. The supraorbital vessels and nerve are usually found in a notch along the medial half of the superior orbital rim (Fig. 100-15). With a sharp elevator such as a Cottle instrument, the vessels and nerve can usually be elevated from the bony notch without injury. Occasionally, however, the nerve and vessels may be completely encompassed by a bony foramen. In such cases, the inferior portion of the foramen can be mobilized with a 2- to 3-mm osteotome (Fig. 100-16). If the neurovascular bundle is found to exit through a foramen more than 1 cm from the orbital rim, it may be sacrificed. If a bifrontal craniotomy is performed without a subfrontal approach, it is not necessary to elevate the periorbita. A basal subfrontal approach is generally preferred, however, to provide additional exposure of the anterior cranial base posteriorly and to minimize retraction of the frontal lobes.

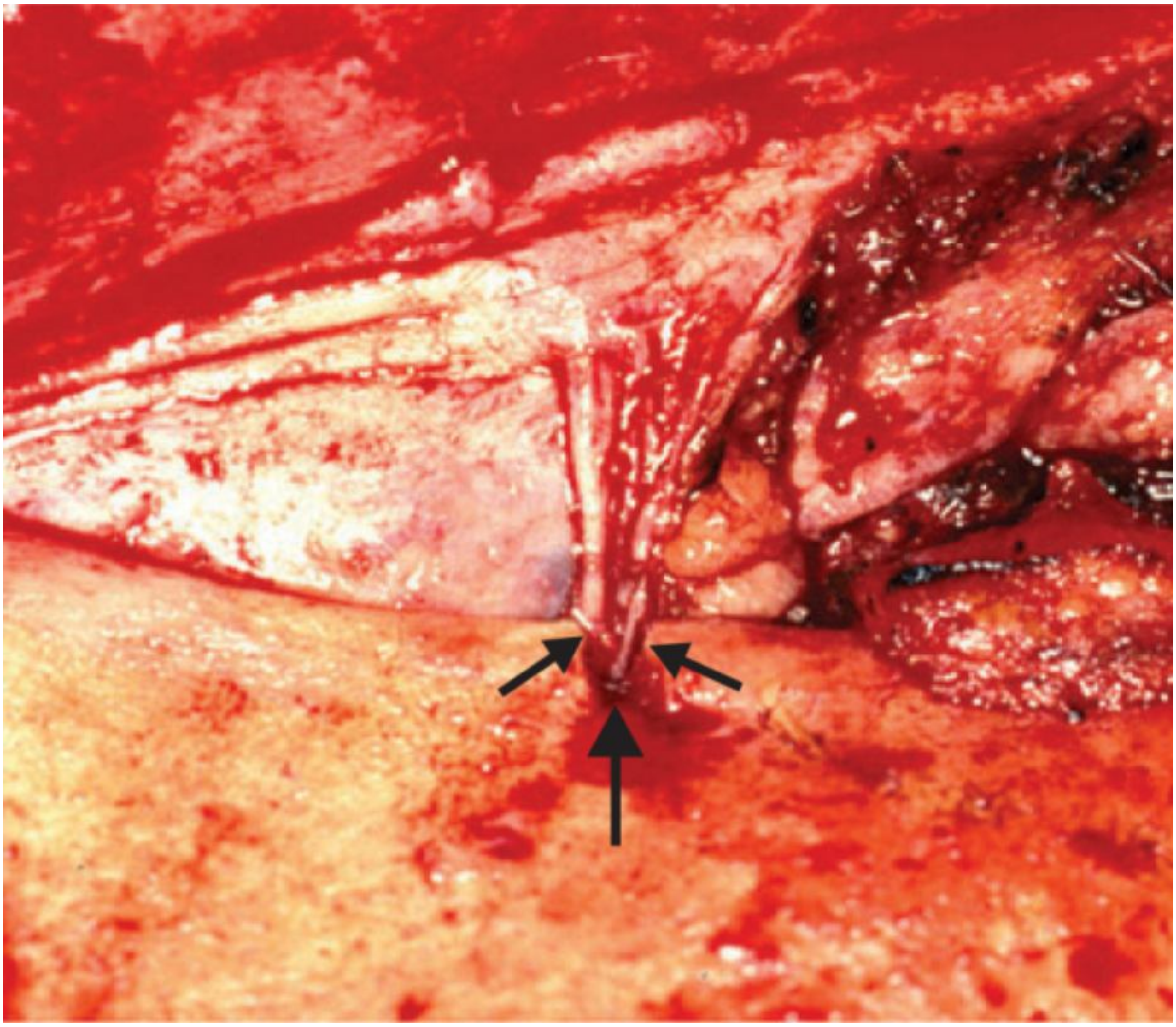

Figure 100-15 Subperiosteal elevation of the frontal scalp reveals the supraorbital nerve exiting from a completely enclosed bony foramen *(arrows).*

Figure 100-16 When the supraorbital nerve is enclosed by bone, it may be released by making angled bone cuts with an osteotome on both sides of the nerve through the supraorbital rim.

The periorbita is then elevated from the medial, superior, and lateral walls of the orbit with an Adson, Freer, or Penfield elevator. The supraorbital nerve runs along the surface of the orbital tissues. The globe is retracted with a malleable ribbon retractor to provide adequate visualization. Pressure on the globe may result in an ocular reflex, with resultant bradycardia and hypotension. This usually recovers quickly once pressure is released. Violation of the periorbita frequently occurs and results in herniation of orbital fat. Though a nuisance for visualization, it is not necessary to repair the periorbita. Medially, elevation of the periorbita continues as far inferiorly as the anterior ethmoid artery and the frontoethmoid suture.

During elevation of the scalp laterally, it is important to avoid injury to the temporal branches of the facial nerve. Injury to these nerves is unlikely with a strictly anterior approach because dissection to the level of the zygomatic arch is not usually necessary. The temporal branches of the facial nerve are found in the superficial temporal fascia layer (superficial muscular aponeurotic system [SMAS], galea). These branches can be elevated with the scalp flap and protected from injury by developing a plane of dissection deep to the outer layer of the deep temporal fascia. The deep temporal fascia splits into superficial and deep layers 1 to 2 cm above the zygomatic arch. This space contains fatty tissue that can be elevated from the deep temporal fascia and muscle by blunt dissection with a broad periosteal elevator (see Chapter 101).

The anterior origin of the temporalis muscle is then elevated from the temporal fossa by electrocautery. A 3- to 4-mm margin of fascia is left intact to allow resuturing of the muscle after replacement of the craniotomy bone flap. Alternatively, the muscle may be sutured to holes drilled at the temporal line or to a titanium plate placed over the temporal line. Tractionsutures are placed along the anterior border of the temporalis muscle and in the scalp anteriorly, and rubber bands are used to facilitate exposure of the operative site (Fig. 100-17). The rubber bands are looped over Allis clamps, which are then attached to the surgical drapes. A unilateral or bifrontal craniotomy is then performed. The lateral burr hole is placed in the region of the pterion where the temporalis muscle is elevated. Small burr holes may be placed on each side of the sagittal sinus to facilitate dissection of the sinus from the calvaria and avoid laceration of the sinus (Fig. 100-18). After elevation of dura from the cranium with Adson elevators, the craniotomy bone flap is removed with a craniotome (Fig. 100-19). The inferior osteotomy is placed just superior to the prominence of the supraorbital rims and glabella. The anterior and posterior walls of the frontal sinus are frequently transgressed by the craniotomy. After removal of the bone, dural “tack-up” sutures are placed through drill holes at the margin of the craniotomy to prevent postoperative epidural dissection by blood or fluid. In older individuals, the dura is very thin and adherent to bone, and lacerations of the dura frequently result. They may be repaired primarily or with the use of a pericranial graft. If pericranium is used, it is harvested from the posterior aspect of the scalp incision to preserve anteriorly based scalp flaps for later reconstruction.

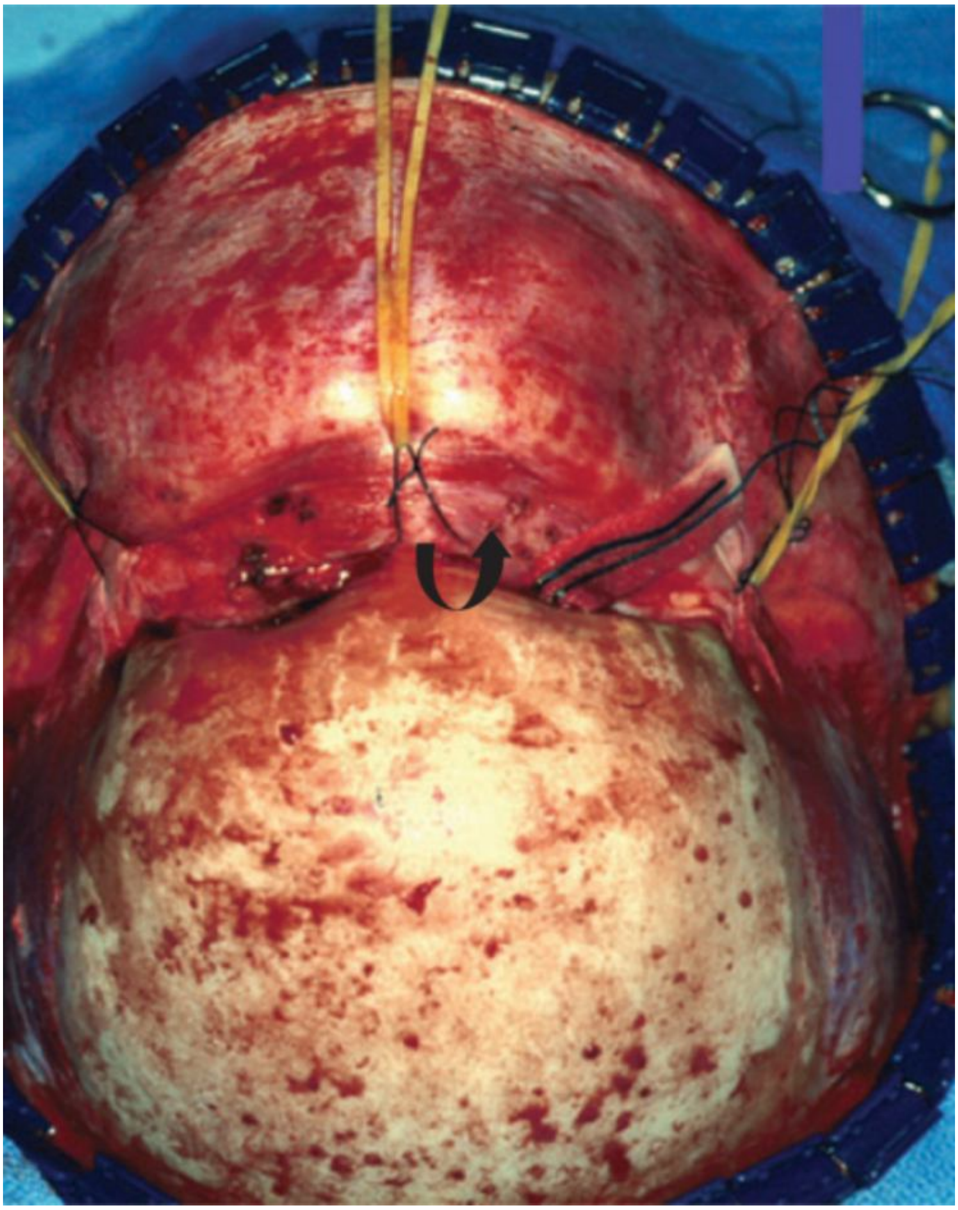

Figure 100-17 The scalp over the frontal bone has been rotated inferiorly *(curved arrow)*. The periorbita has been elevated from the superior and medial orbital walls. The anterior attachments of the temporalis muscles have been released.

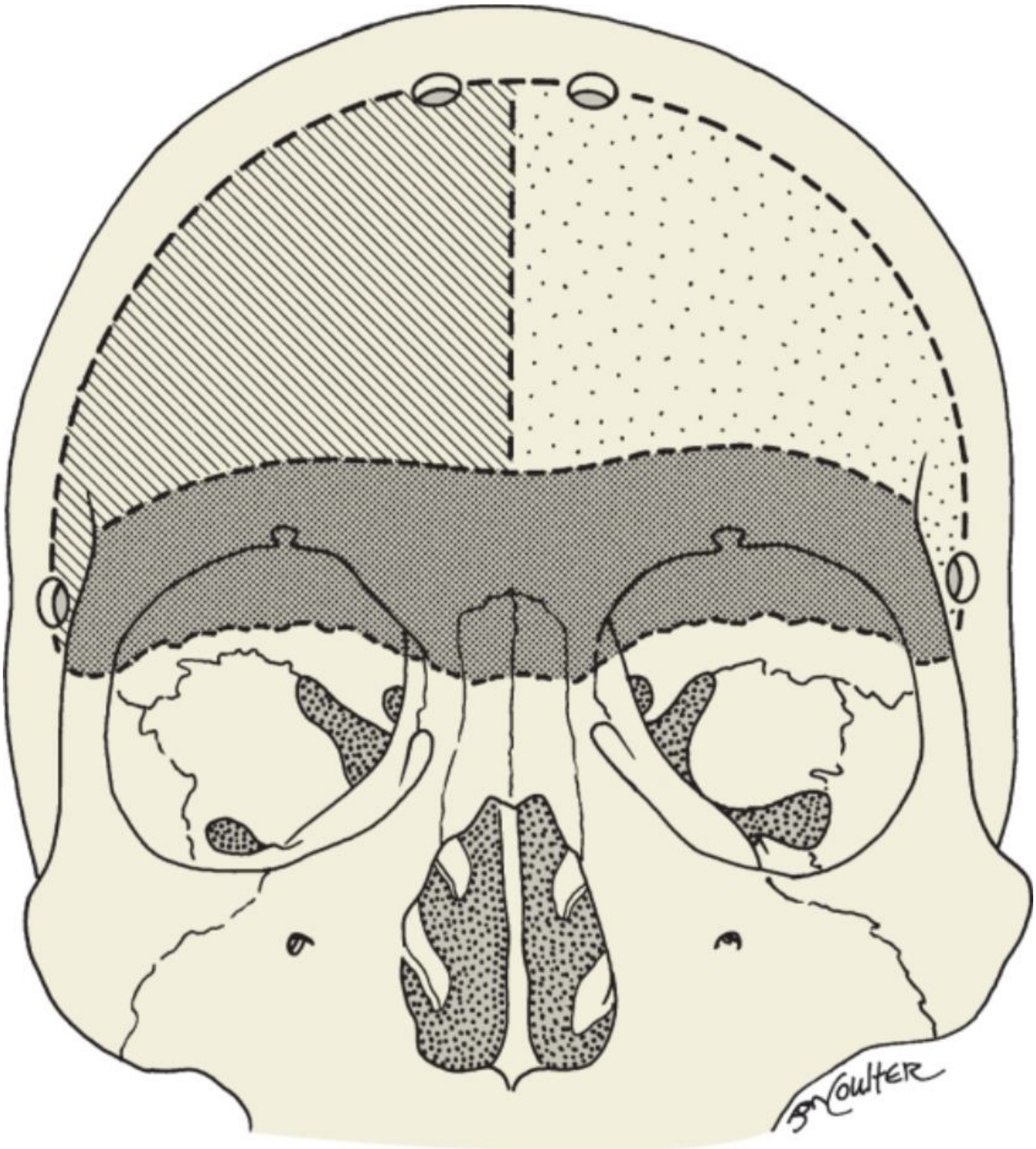

Figure 100-18 Various segments of the frontal bone and supraorbital rims may be removed to provide adequate exposure of the anterior cranial base.

Figure 100-19 This patient required a bifrontal and left temporal craniotomy. The left orbital rim and zygomatic arch were removed as a single unit to provide additional subfrontal and anterolateral exposure.

The frontal lobe dura is then carefully elevated from the roof of the orbits and the crista galli and cribriform plates. Because of perforations of the olfactory nerves, multiple dural lacerations in the region of the cribriform plate necessarily result. It may be necessary to incise the dura along the crista galli. If there is intracranial extension of tumor with potential involvement of dura, a patch of dura is incised and left attached to the tumor specimen. In rare instances it may be necessary to resect a portion of one or both frontal lobes to obtain an adequate tumor margin. To maximize additional exposure while minimizing frontal lobe retraction, the supraorbital rims and nasion are removed as a single bone segment (Fig. 100-20). While the brain and orbit are protected by malleable retractors, a reciprocating saw with a long blade is used for osteotomies through the orbital rims at approximately the supraorbital notch. The cuts are beveled laterally to allow greater stability of the bone segment at the time of closure. Osteotomies through the orbital roof are made with reciprocating or oscillating blades (Fig. 100-21). An attempt is made to remove a large portion of the orbital roof as a single unit to avoid postoperative problems with enophthalmos because of loss of the orbital walls or pulsating exophthalmos because of contact of the brain with the soft tissues of the orbit. Near the midline, the osteotomy is necessarily directed to the anterior margin of the cribriform plate. A horizontal osteotomy is then made through the nasion superior to the level of the frontoethmoid suture line. The tip of the saw blade is placed approximately 2 cm deep to the nasion for this cut. This osteotomy usually transgresses the nasofrontal ducts superior to the ethmoid labyrinth. The entire bone segment, including both orbital rims and orbital roofs, can then be further mobilized, if necessary, with an osteotome.

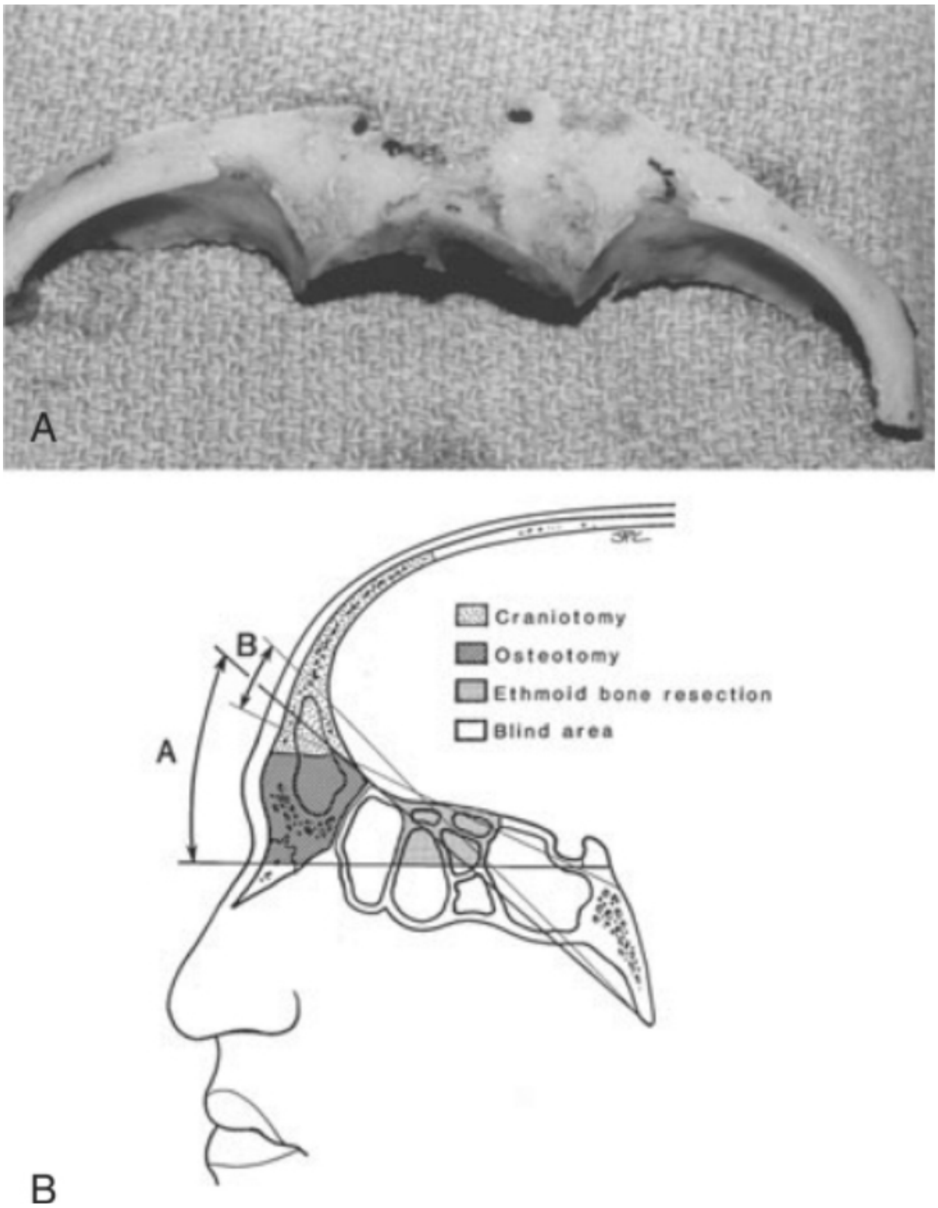

Figure 100-20 **A,** The superior orbital rims and nasion may be removed as a single bone unit to provide additional subfrontal exposure. **B,** This provides additional access to the limits of the anterior cranial base (arc A) with decreased need for frontal lobe retraction (arc B).

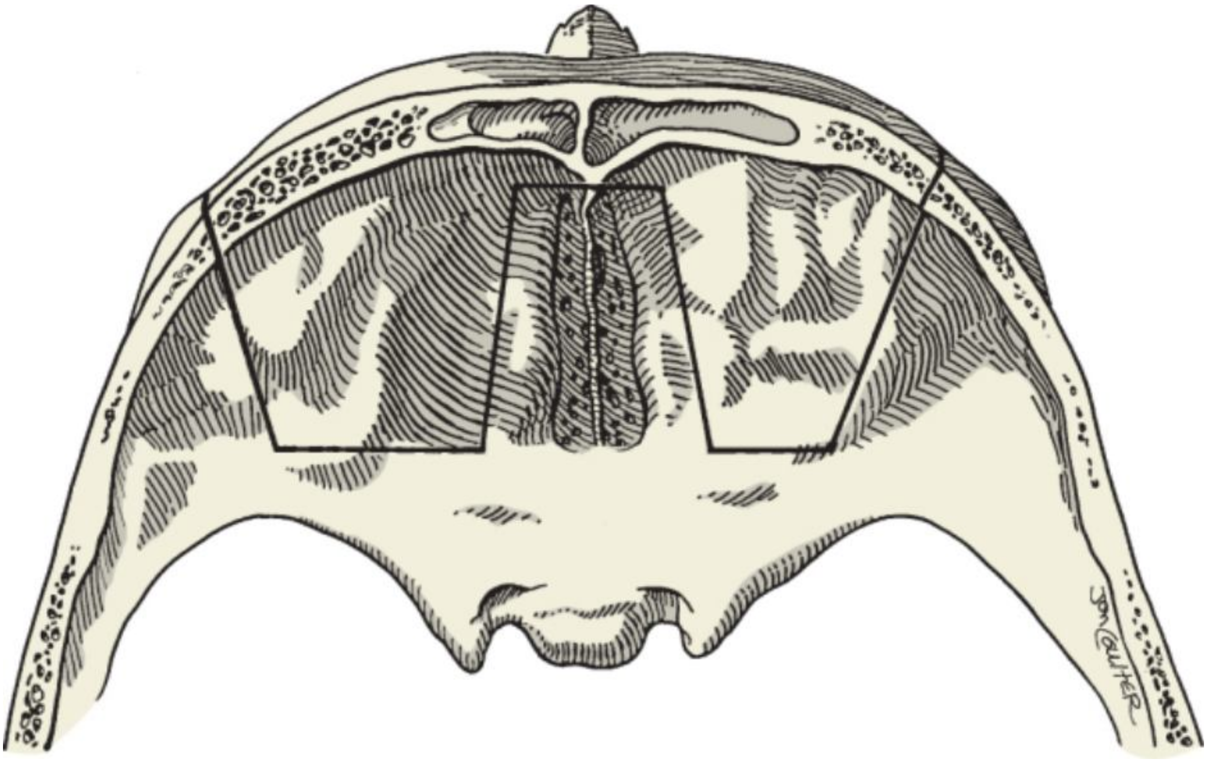

Figure 100-21 The sphenoid sinus is opened in the region of the planum sphenoidale. Osteotomies are then made anteriorly and laterally through the roof of the orbit or fovea ethmoidalis. Anteriorly, an osteotomy is made anterior to the crista galli.

Additional elevation of frontal lobe dura can then be performed with minimal brain retraction. After iden tification of the planum sphenoidale posterior to the crista galli and cribriform plates, the anterior clinoid processes and optic canals are identified bilaterally. In patients with tumor in proximity to the orbital apex, the optic canal is carefully decompressed with Kerrison rongeurs. Decompression is performed to prevent an entrapment syndrome postoperatively as a result of edema of the optic nerves. An opening is next made through the planum sphenoidale into the sphenoid sinus with cutting burrs. The sinus may then be inspected for evidence of tumor involvement. Bone removal from the roof of the sphenoid sinus continues anterolaterally on both sides toward the orbit (Fig. 100-22). If tumor does not involve the ethmoid sinus, the bone cut extends through the ethmoid air cells. When there is involvement of the sinus, the medial orbital wall is included to provide an adequate resection margin (Fig. 100-23).

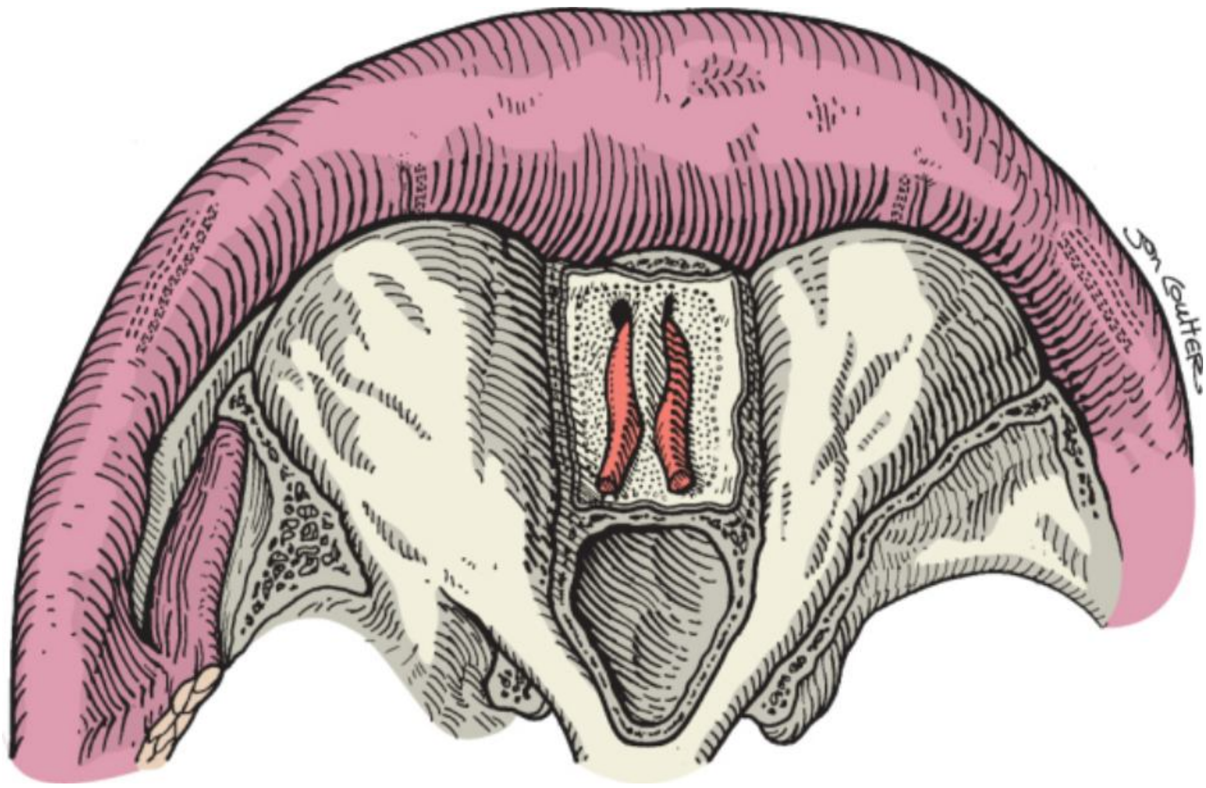

Figure 100-22 Depending on the extent of the tumor, the medial wall of the orbit may be included with the ethmoid sinus to provide an adequate tumor margin.

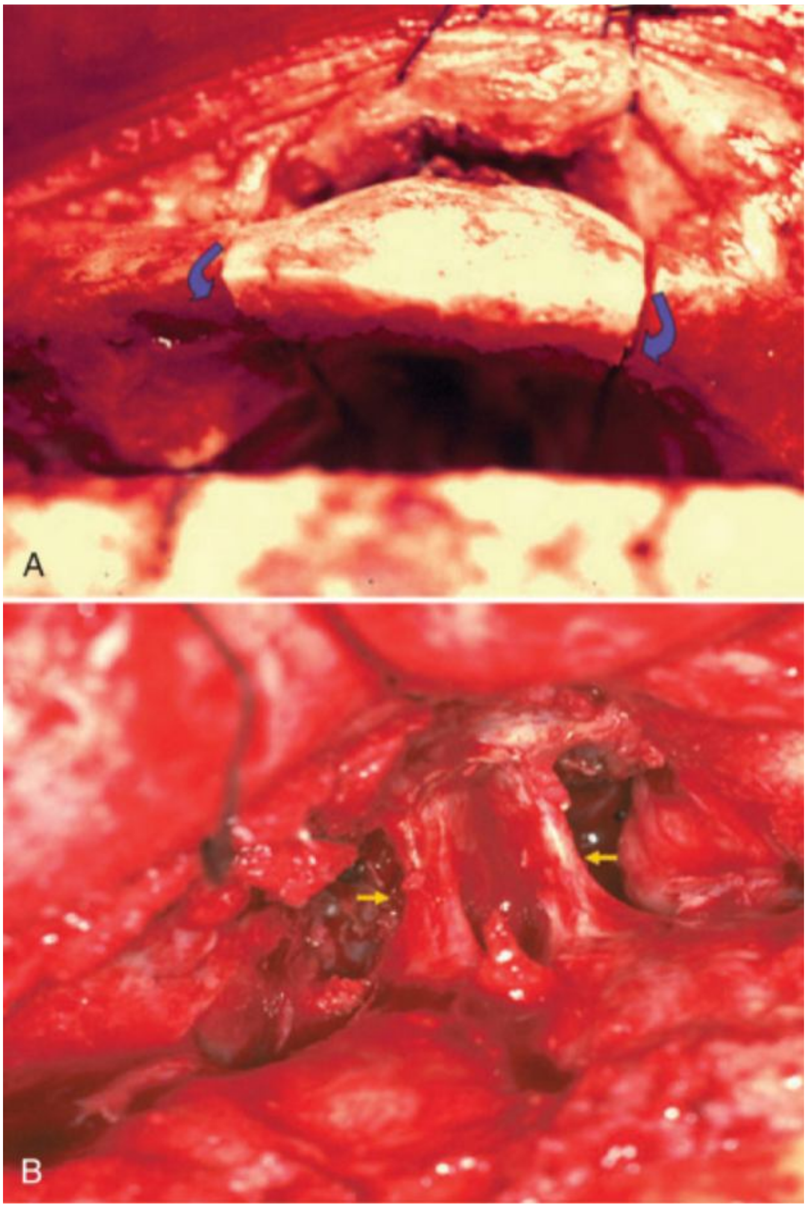

Figure 100-23 **A,** In this patient with a malignant neoplasm of the nasal cavity, it was necessary to remove only a short segment of the nasion *(curved arrows).* **B,** After removal of this bone segment, additional osteotomies were made through the fovea ethmoidalis bilaterally and across the roof of the sphenoid sinus posteriorly *(arrows).*

Extracranial exposure of the neoplasm is now obtained with a lateral rhinotomy or midfacial degloving approach or with an endoscopic-assisted approach (see Chapter 10). Resection of the medial orbital wallis facilitated with this approach. The intracranial exposure allows en bloc removal of the anterior cranial base with direct visualization of the optic nerves and the lateral walls of the sphenoid sinus with the internal carotid artery. An osteotome, drill, or Mayo scissors may be used to transgress the anterior wall of the sphenoid sinus, thus separating the specimen from its attachment inferiorly. Transection of the nasal septum from below is necessary to mobilize the specimen. This cut extends from the nasion anteriorly and superiorly to the posterior edge of the nasal septum inferior to the rostrum of the sphenoid.

After removal of the specimen, the defect is examined and additional bone or soft tissue margins can be obtained under direct visualization from above. A large defect frequently results in direct communication between the cranial cavity and the nasopharynx (Fig. 100-24).

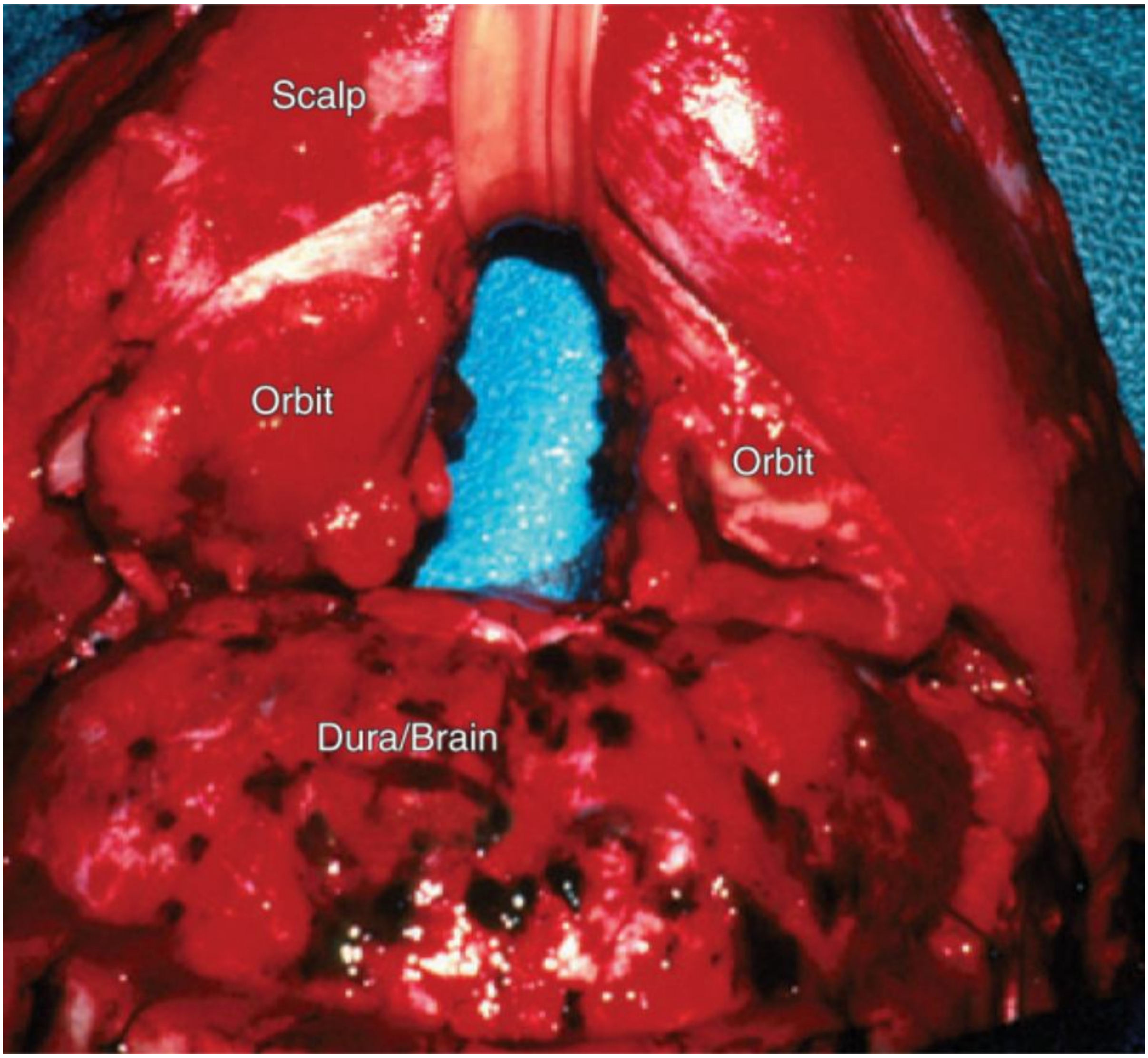

Figure 100-24 After resection of the neoplasm, a large defect of the anterior cranial base remains and communicates with the paranasal sinuses.

Open Reconstruction

Every attempt should be made to attain a watertight closure of the dura to minimize the risk of a postopera tive CSF leak and resultant meningitis. Small lacerations of the dura may be closed primarily. Larger defects of the dura may require the use of a fascial graft. Suitable materials include fascia lata harvested from the lateral aspect of the thigh or cadaveric dura. It is not necessary to remove all the mucosa from the sphenoid sinus unless a pericranial flap is used to obliterate the sinus.

Defects of the anterior skull base, including the cribriform plate, planum sphenoidale, and roof of the sphenoid sinus, can be reconstructed with a vascularized pericranial scalp flap. The flap is designed as an inverted U based on the supraorbital neurovascular bundles (Fig. 100-25). The primary blood supply of the flap comes from the supraorbital and supratrochlear vessels, although the anterior branches of the superficial temporal artery can also be included. The pericranial layer is easily dissected from the galea, beginning at the edge of the bicoronal scalp flap. The layer is elevated with tenotomy scissors down to the level of the supraorbital rim (Fig. 100-26). It is important to dissect close to the undersurface of the galea to maximize the thickness of the pericranial flap. As one approaches the base of the flap, it becomes more difficult to separate the galeal and pericranial layers, and extra care is needed to avoid injury to the vessels at this point. If necessary, the arc of rotation of the flap can be increased by incising its base on one side. A unilateral blood supply has proved to be adequate for survival of the flap.

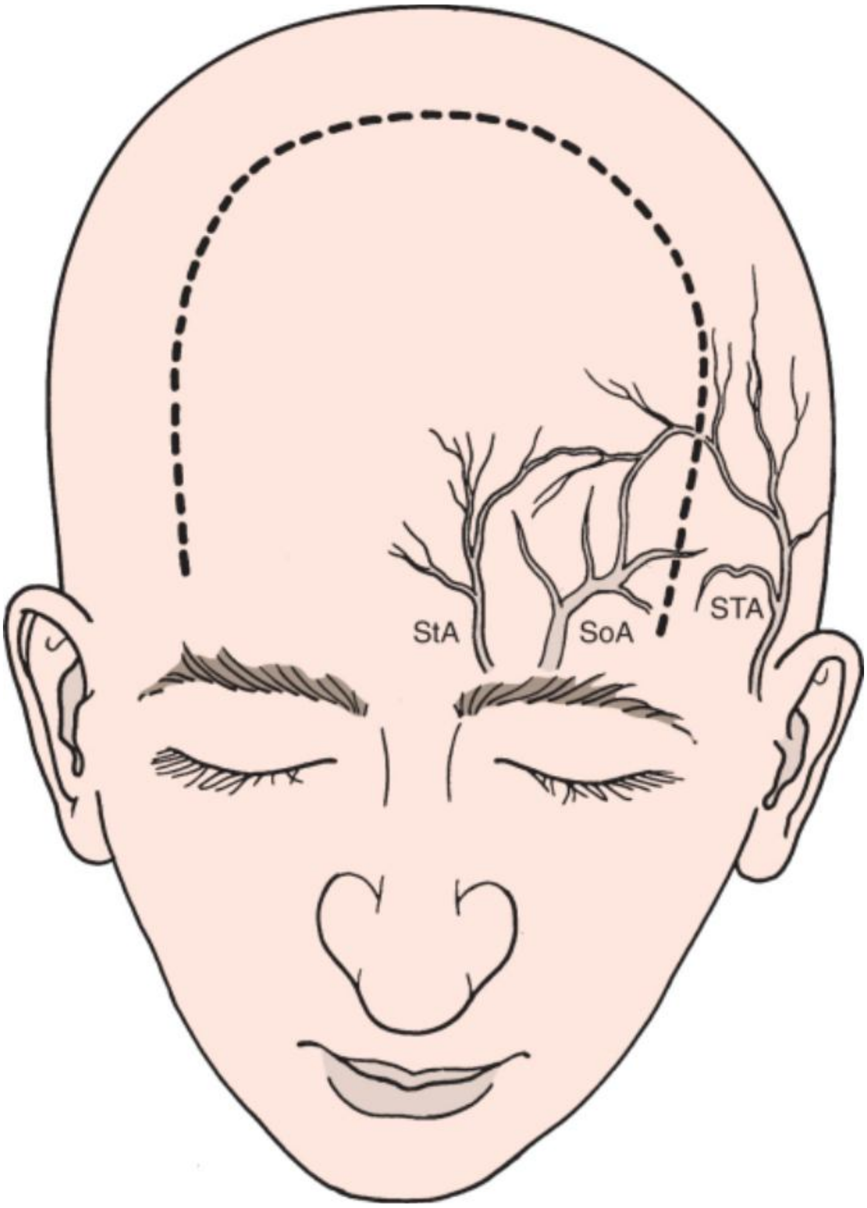

Figure 100-25 An anteriorly based pericranial flap receives its blood supply from the supratrochlear (StA) and supraorbital (SoA) vessels. The superficial temporal artery (STA) also contributes to the vascular supply of the galeal layer.

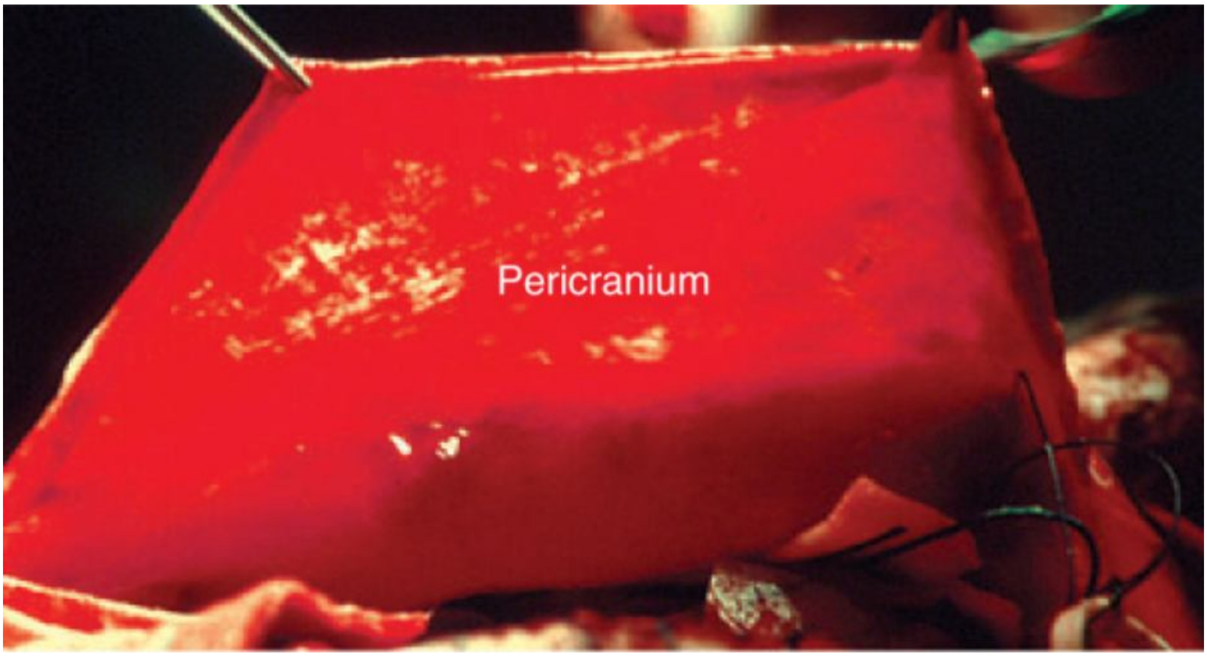

Figure 100-26 The pericranial flap is dissected from the galea by sharp dissection to the level of the orbital rim.

The pericranial flap may be transferred into the defect above or below the supraorbital bone graft. The latter is preferred to increase the reach of the flap and to separate the supraorbital bone graft from the nasal cavity. The distal edge of the pericranial flap is sutured to the dura at the posterior limit of the cranial basedefect (Fig. 100-27). In elderly patients with thin dura, this may be quite difficult because of tearing of the dura. In such cases it may be necessary to place small drill holes at the posterior margin of the defect for suturing of the pericranial flap. Laterally, the pericranial flap is sutured to the periorbita.

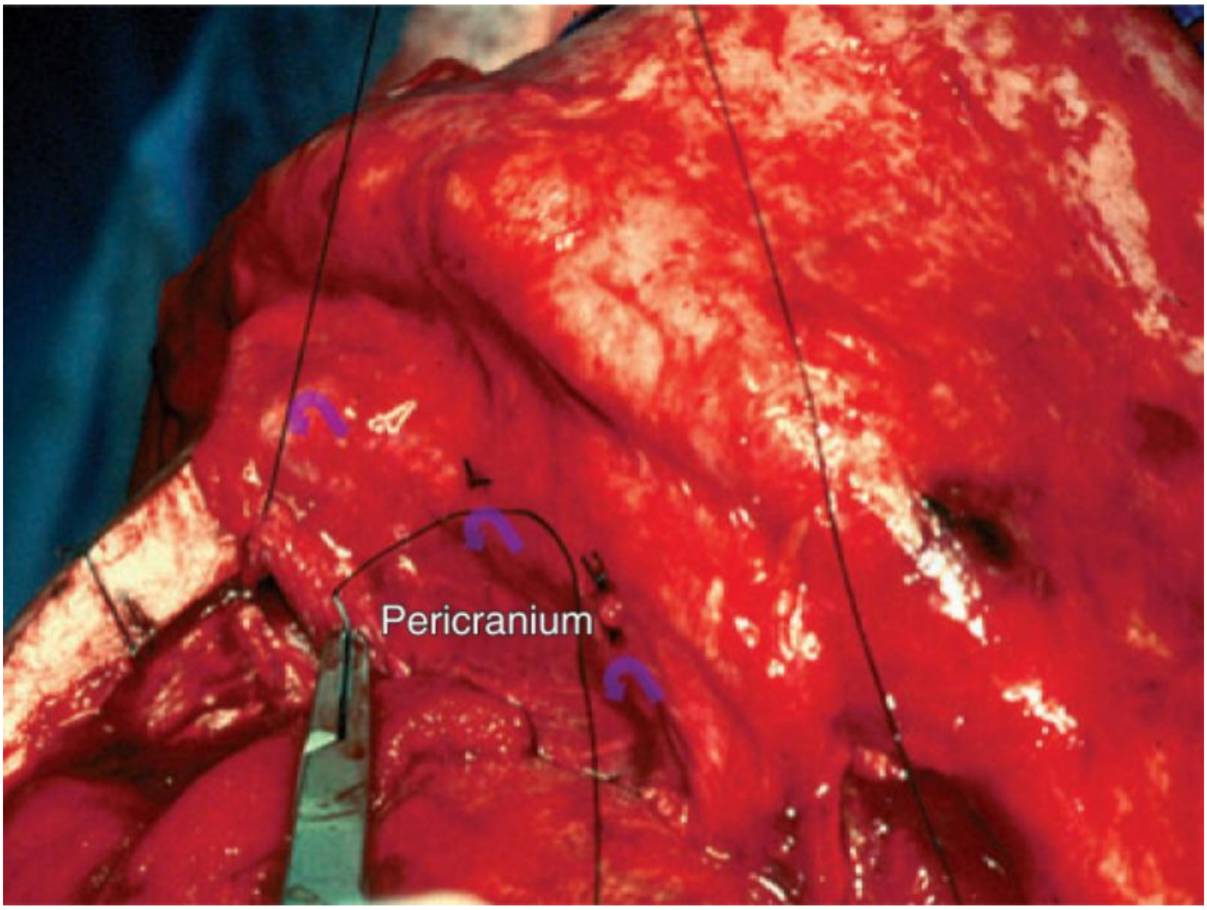

Figure 100-27 The pericranial flap is rotated posteriorly and sutured to bone, mucosa, or dura at the posterior margin of the surgical defect. Laterally, the pericranial flap is sutured to the orbital tissues to provide watertight separation of the nasopharynx from the cranial cavity. This step is performed before replacement of the supraorbital and craniotomy bone flaps.

A galeal-pericranial flap is preferred for larger defects or when the vascularity or integrity of the pericranium is in question. The flap requires dissection of the galeal-pericranial layer from the skin at a plane between the frontalis muscle and the hair follicles. The thickness and vascularity of this flap are superior to that of the pericranial flap, but at the expense of the vascularity and thickness of the bicoronal scalp flap. In cases in which the pericranium is not available, the galea may still be used as a flap. Rarely, the galeal and pericranial flaps may be used separately to cover different defects.

The use of free bone grafts in conjunction with these flaps does not appear to contribute to support of the brain and is associated with a higher incidence of infection and osteoradionecrosis. The use of nonvascularized tissue is avoided as much as possible to decrease the risk of wound infection. Placement of a nonvascularized fat or bone graft against a nonvascularized dural graft may interfere with vascularization of the dura. The pericranial flaps are rapidly mucosalized on the nasal surface. Therefore, skin grafting is not recommended. (For anterolateral defects, see Chapter 101.)

Before replacement of the bone flaps, it is necessary to remove all mucosal remnants from the frontal sinus to prevent postoperative mucocele formation. The frontal sinus is cranialized by removing the posterior table of the frontal sinus with rongeurs or a saw. The mucosa is then stripped from the sinus with an elevator. Removal of mucosal remnants in deep crevices is facilitated by the use of a cutting burr. The mucosa is also stripped from the nasofrontal ducts, and the ducts are obliterated with Surgicel or soft tissue plugs.

The craniotomy and supraorbital bones are then replaced superior to the pericranial flap. Care is taken to avoid compression of the vascular supply of the flap by the bone. It may be necessary to remove an additional 2 to 3 mm of bone in the midline to prevent compression. The bones are held in place with multiple 2-0 braided nylon sutures through drill holes in the margins of the bone or with microplates. Titaniummicroplates are currently preferred because of greater stability of the bone flap, rapid repair, and the ability to cover small bone defects. This affords adequate stabilization of the bones with excellent healing and bony union. Steel wire and nontitanium plates are not generally used because of the potential for scatter artifacts on postoperative radiologic imaging. Bone dust and chips are used to fill defects surrounding the craniotomy bone flap. Titanium burr hole covers may also be used to cover burr holes when adequate autologous bone is not available (Fig. 100-28). Alternatively, the inner cortex of the bone flap or the posterior wall of the frontal sinus may be used for bone reconstruction. Larger defects may be covered with titanium mesh.

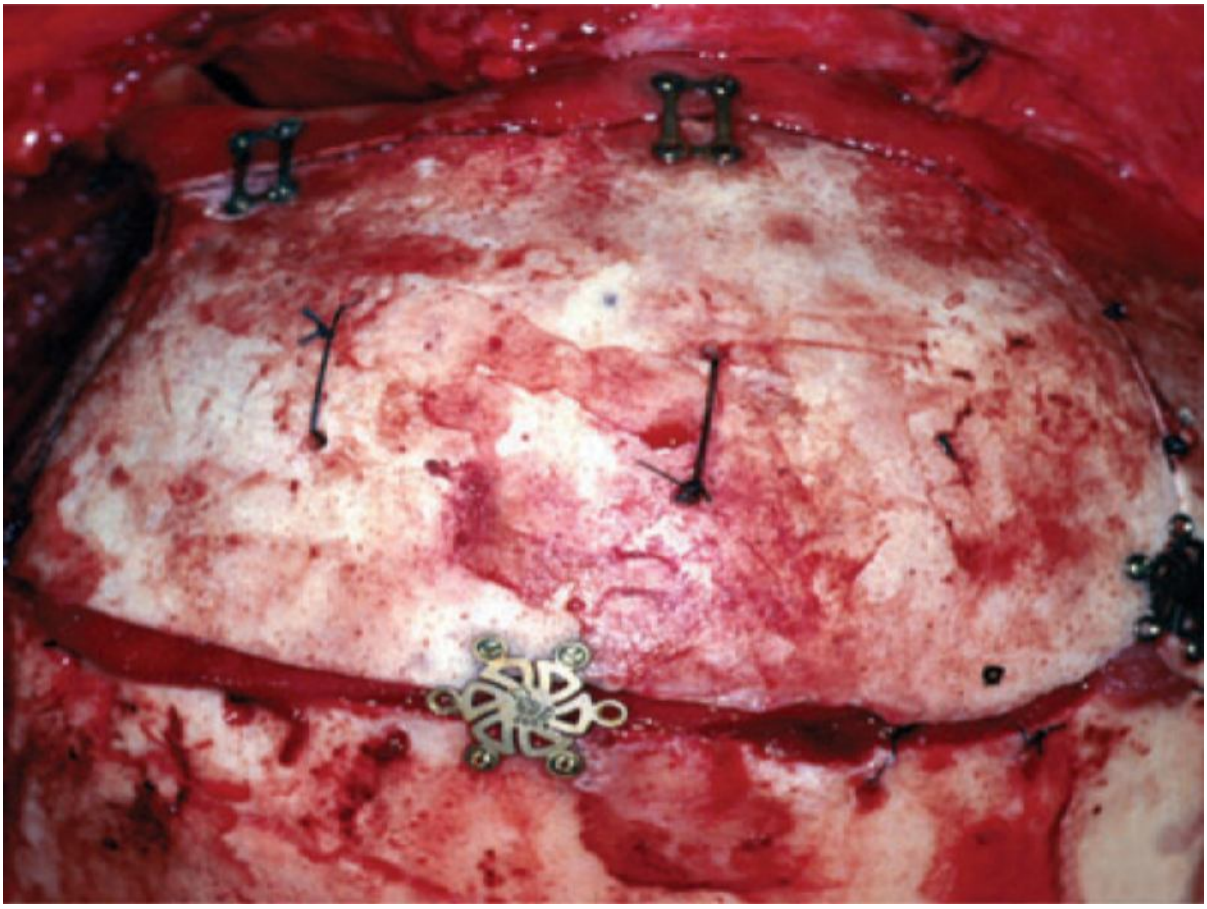

Figure 100-28 Bone defects may be covered with titanium burr hole covers to prevent a postoperative deformity.

A Jackson-Pratt drain is use for drainage of the wound. The exit wound is placed posterior to the incision line to avoid potential compromise of the vascular supply to the anterior portion of the scalp. Whenever there is the potential for a CSF leak, the drain is placed to empty by gravity with the use of a bile bag. There are potential risks of excessive CSF drainage or sudden cardiac arrest as a result of changes in intracranial pressure if high suction is applied to the drains. The anterior margins of the temporalis muscle are then sutured to the cranium to prevent a cosmetic defect, and the scalp incision is closed with interrupted 2-0 Vicryl or Dexon sutures. Staples are used for skin closure. Telfa coated with povidone-iodine ointment is applied to the suture line, and a standard neurosurgical gauze compressive dressing is applied. It is important to make sure that there are no compressive points anteriorly that might compromise anterior scalp vascularity.

Endoscopic Technique

We have described several endoscopic "modules" based on exposure and control of key anatomic structures. Although this chapter addresses resection of the anterior skull base for the specific indication of sinonasal tract malignancies, we consider this approach to be part of an encompassing modular system that provides endoscopic exposure of the entire anatomy of the sinonasal tract and the anterior and middle skull base and clival region.[13–18]

Patients are positioned supine on the operating table with the head in neutral position and fixed by a three-pin head holder with the neck slightly rotated to the right side. If exposure of the frontal sinus (endoscopic Lothrop or Draf III procedure) will be required, the head is extended mildly. Video monitors are positioned directly in front of the surgeons.

The nasal cavity is decongested with cottonoids soaked in 0.05% oxymetazoline and then examined with 0- and 45-degree endoscopes. One percent lidocaine with 1 : 100,000 epinephrine may be infiltrated into the lateral nasal wall, middle turbinates, posterior nasal septum, and rostrum of the sphenoid sinus for additional hemostasis. Infiltration must be avoided in areas involving the vascular pedicle for a nasoseptal flap if one is to be harvested. The operation begins with debulking of the tumor or with exenteration of the anterior paranasal sinuses, depending on the origin, extent, position, and bulk of the tumor. The tumor is debulked with a microdébrider to increase exposure of the skull base. Dissection of the paranasal sinuses follows a technique similar to that used for the management of inflammatory disease. The dissection can be unilateral or bilateral, depending on the extent of the tumor. Uncinectomy is followed by identification and widening of the natural ostium of the maxillary sinus in a posterior and inferior direction. A wide middle meatal antrostomy helps define the inferior and medial walls of the orbits and exposes the posterior wall of the antrum, thereby facilitating control of the sphenopalatine and posterior nasal arteries. Completion of anterior and posterior ethmoidectomies and exposure of the nasofrontal recess will define and expose the paramedian anterior skull base, including the fovea ethmoidalis, the vertical and horizontal lamellae of the cribriform plate and its olfactory fila, and the anterior and posterior ethmoidal artery canals. The middle turbinates may also be removed to create more room for intranasal instrumentation.

At this point, if a vascularized nasoseptal flap is required for reconstruction and the oncologic principles of resection can be respected, it is harvested from the nasal septum. Until recently, options for endoscopic reconstruction of the skull base were limited to the use of nonvascularized tissue. This resulted in CSF leak rates of 20% to 30% and became a major obstacle to widespread acceptance of these techniques. Recently, the Haddad-Bassagasteguy flap (HBF), or nasoseptal flap, has proved to be a versatile, robust vascularized flap for the reconstruction of expanded endonasal approaches defects.[19] Since adopting this technique, our CSF leak rates have dropped to numbers that compare with those of traditional techniques (around 5%). The advantage of this flap as a reconstructive option is that a second approach or incision is not necessary and the flap can be harvested endoscopically. The major drawback of the HBF is that its need must be anticipated before embarking on resection because the vascular pedicle to this flap is frequently compromised during the sphenoidotomy and posterior septectomy portion of the procedure. In addition, if a revision procedure is necessary, the flap may have been used previously or the pedicle previously damaged.

Design of the flap should be based on the expected size of the defect. This point is counterintuitive to most reconstructive surgeons because the flap is harvested before the resultant defect is created; thus, one can be left with a flap that is inadequate. As a result of this potential flaw, we tend to harvest a larger flap. The first incision is the most critical and involves the use of electrocautery along the free edge of the choana from the lateral nasal wall toward the nasal septum. This incision is exceedingly difficult to perform once the flap has been elevated, so extra time and patience are warranted to ensure a full incision down to the level of the sphenoid floor. Two longitudinal incisions are then created in a posterior-to-anterior direction. The most inferior incision is placed along the maxillary crest; however, it can be extended inferiorly and laterally to harvest the mucoperiosteum of the nasal floor. The superior incision is created 1.0 to 1.5 cm inferior to the cribriform plate to preserve olfactory function. It then crosses the rostrum of the sphenoid at the level of the sphenoid sinus os. This leaves approximately a 1- to 2-cm width of pedicle across the anterior face of the sphenoid. Both these incisions are joined anteriorly with a vertical incision at the level of the anterior end of the inferior turbinate. Once all the incisions are completed, the flap is elevated in a subperichondrial and subperiosteal plane back to its pedicle on the sphenopalatine foramen. The flap can then be “stored” for the duration of the resection in the nasopharynx or inside the antrum through a wide maxillary antrostomy.

In the event that a flap cannot be harvested because of oncologic margins or because the blood supply has been compromised from previous procedures, the nasal septum is separated from the sphenoid rostrum via a transfixion incision with a Cottle elevator. A similar vertical transfixion incision is performed at a level just posterior to the nasofrontal recess (this is modified to include the anterior extent of the tumor). A third septal transfixion incision, horizontal and parallel to the floor of the nose, connects these two vertical transfixion incisions and leaves the bony nasal septum attached to the cribriform plate. Bilateral wide sphenoidotomies to remove the entire rostrum help define the posterior limit of the tumor (planum sphenoidale) and further delineate the position of the skull base. At this point in the surgery the skull base from orbit to orbit and from frontal sinus to sella turcica, as well as the base of the tumor, is completely exposed and the resection can begin. The lamina papyracea may be removed as a lateral margin or as part of an endoscopic medial maxillectomy (unilaterally or bilaterally according to the necessary resection), with care taken to preserve the periorbita while identifying the anterior and posterior ethmoidal arteries at their entry into their respective canals at the skull base. Gentle curettage or drilling helps remove the bone over the canal, thereby exposing the arteries, which can then be dissected and controlled with clips or bipolar electrocautery.

Using a high-speed drill with a 2- to 3-mm coarse diamond hybrid burr, a horizontal osteotomy is made at the planum sphenoidale, parallel and anterior to the sphenoid rostrum. Another horizontal osteotomy is made just posterior to the frontal sinus posterior wall. These osteotomies are then connected by bilateral osteotomies performed lateral to the cribriform plate and running parallel to the superomedial wall of the orbits, thereby forming a rectangle surrounding the tumor and adjacent structures such as the nasal septum, the entire cribriform plate, and the planum sphenoidale. The resection then proceeds in an anterior-to-posterior direction. The olfactory nerves are identified and transected after bipolar cauterization. If the tumor extends to the dura, its anterior surface is coagulated with bipolar cautery and then incised. Dural incisions that match the previously described osteotomies facilitate removal of the specimen with adequate control of the dural margins. It is critical to establish the completeness of the resection with the use of intraoperative frozen section analysis. Any positive margin mandates additional resection.

The crista galli is most often fractured from the rest of the resected skull base. It must nonetheless be removed to improve visualization and facilitate the reconstruction. It should be noted that the crista galli can extend for a variable depth into the intracranial cavity, so removal of it involves drilling internally until it becomes eggshell thin so that it can be fractured. Meticulous hemostasis completes resection of the anterior cranial base.

This resection may be combined with other approaches such as a Draf III or endoscopic Lothrop, with or without endoscopic medial maxillectomy. As previously stated, the resection can be unilateral to preserve the contralateral turbinates and possibly the olfactory fibers.

Endoscopic Reconstruction

Currently, we use a subdural inlay graft (between the brain and dura) of collagen matrix (Duragen, Integra Life Sciences) to help obliterate the dead space.[15,17,19] Its pliability and texture allow manipulation around neurovascular structures. This subdural graft should extend beyond the dural margins, ideally by 5 to 10 mm in all directions. Closely adherent skull base and dura around the resection margins are dissected. A subsequent inlay graft of acellular dermis is placed in the epidural space (between the dura and skull base). Occasionally, the bony ledges are not adequate to support an inlay graft; in this case the acellular dermis graft is placed extracranially (at the nasal side of the defect) as an onlay graft (Fig. 100-29). All the edges of the defect should be denuded of mucosa to allow revascularization of the graft and avoid the formation of mucoceles. Alternatively, this graft can be sutured to the dura with nitinol U-clips (Medtronic U-Clips, Memphis, TN).

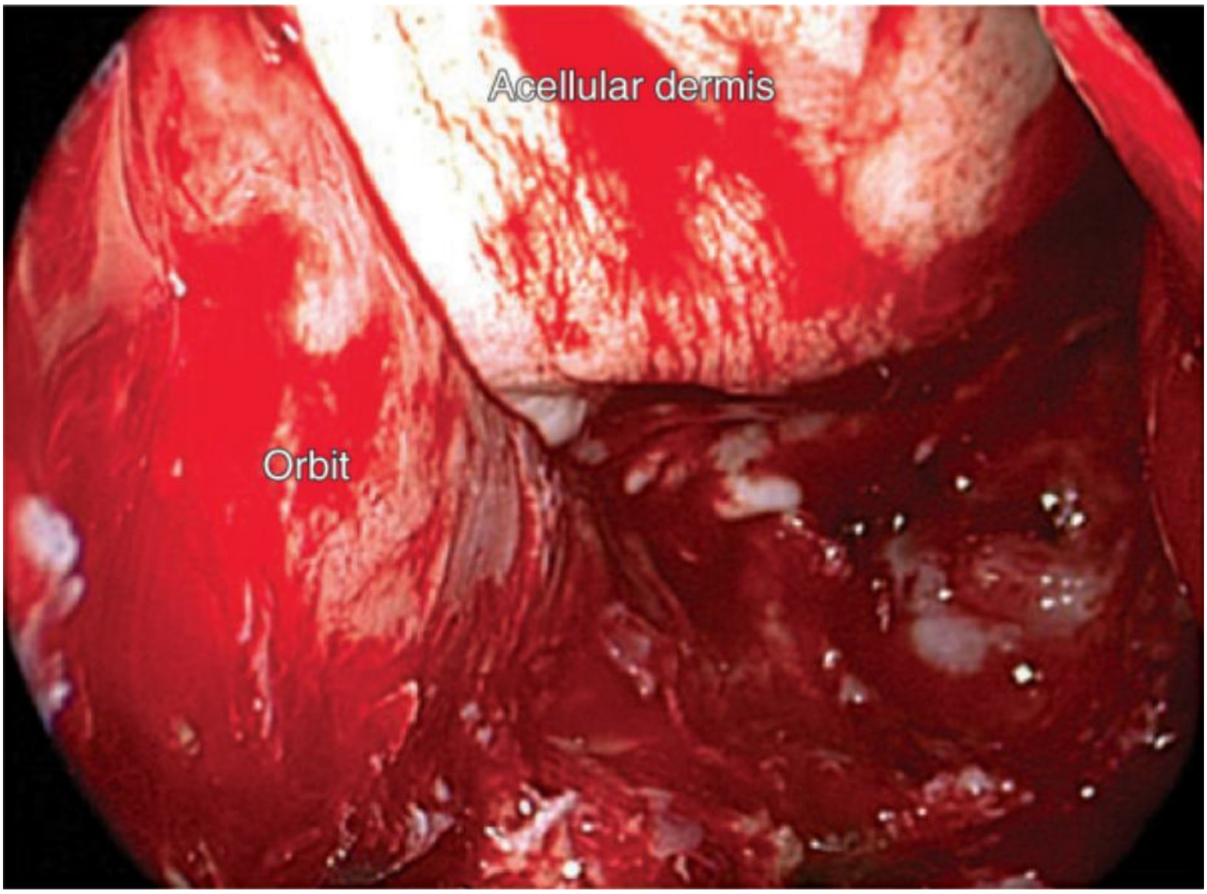

Figure 100-29 Endoscopic appearance of acellular dermis used for skull base reconstruction after endoscopic anterior craniofacial resection.

Although this is an off-label indication for acellular dermal grafts, we found that its handling characteristics, its availability (i.e., no need for harvesting from a distant site), ingrowth of the patient's own tissue, and rapid epithelialization are advantages that outweigh its cost. It is important that a single graft with dimensions that will extend beyond the defect margins in all direction be used and that the graft be adequately hydrated in normal saline solution before insertion. It is our experience that medium-thickness grafts (0.30 to 0.70 mm) offer the best combination of tissue handling and “take.”

According to the contour of the skull base and how anterior the extent of the resection is, the acellular matrix is supported by free abdominal fat or nasal packing (Fig. 100-30). An abdominal free fat graft harvested through a periumbilical incision acts as a biologic dressing and applies pressure to reduce any early brain herniation that may lead to migration of the underlying grafts and a subsequent CSF leak. Nasal packing ([1]–2-inch strip gauze impregnated with Bacitracin ointment) is preferred if the resection involves the convexity of the posterior wall of the frontal sinus because the packing can accommodate for this curvature better than the globular shape of a free fat graft can. Another alternative is to harvest the fat in a wedge or teardrop shape that will match the contour of the skull base more effectively. Recently, we have adopted the use of a pedicled vascularized flap based on the posterior nasoseptal artery. The technique for harvest was described earlier. When a vascularized nasoseptal flap is available for reconstruction, it is used as an onlay flap over top of the inlay collagen matrix and acellular dermis graft. It is critical to separate the grafts from the packing with some type of nonadherent material such as Gelfoam or Gelfilm because this will prevent traction on the grafts when the packing is removed. In addition, shifting of the underlying inlay/onlay grafts may occur during placement of the fat graft or the packing, so the surgeon must be vigilant and the graft should be placed under direct visualization with the endoscope. Fibrin sealants are applied only after the final tissue barrier has been placed.

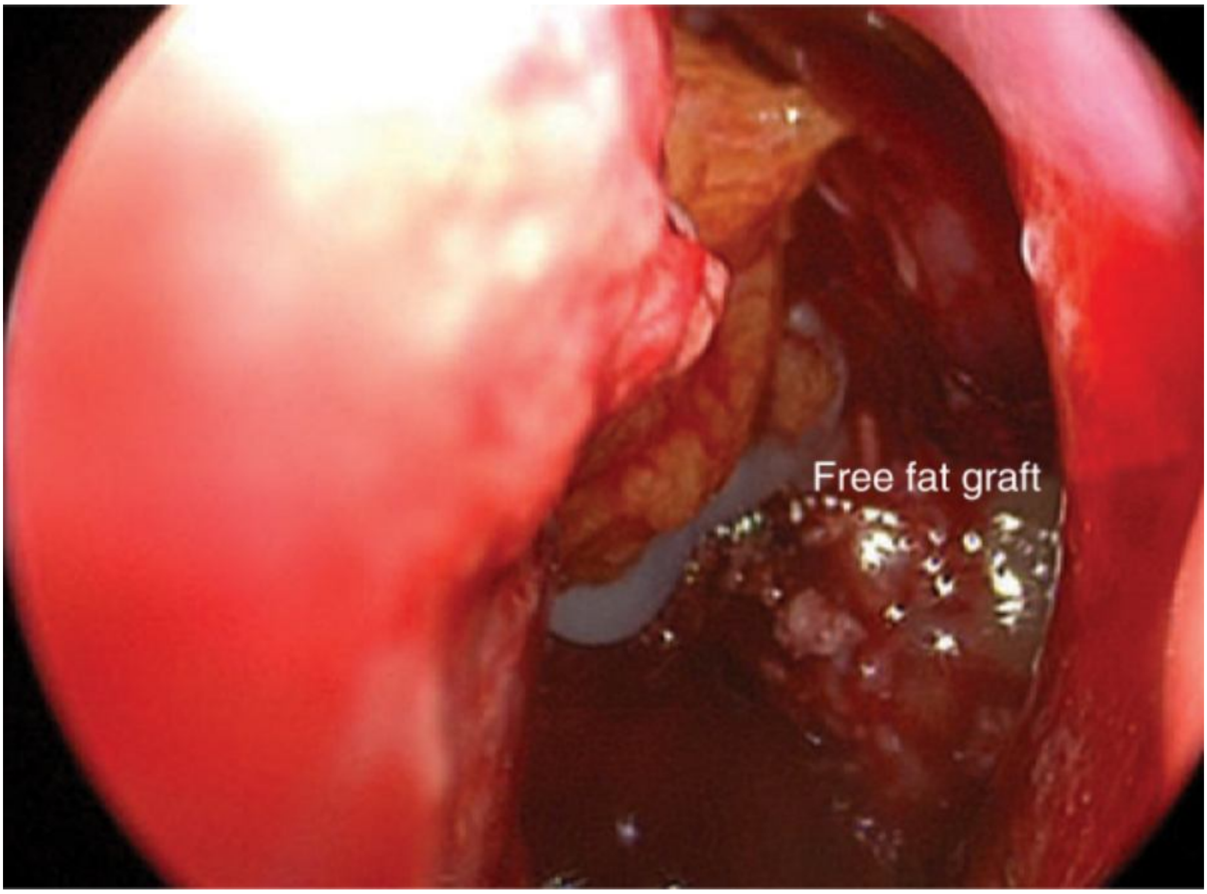

Figure 100-30 Endoscopic appearance of a free fat graft used to support the endonasal skull base reconstruction.

We then use the balloon of a 12F Foley catheter to splint the fat graft or packing, which in turn will stabilize the inlay/onlay grafts and thus further prevent early brain herniation. The balloon is fixed in position by threading the Foley catheter through a Doyle splint, advancing it to the desired position, and then securing the Doyle splint to the septum with 4-0 nylon. Placement plus inflation of the balloon catheter with 5 mL of saline is also performed under endoscopic vision. Overinflation may result in compressive effects over the intracranial structures. Any nasal packing or balloons are removed 3 to 5 days after resection.

POSTOPERATIVE MANAGEMENT

Most patients can be extubated in the recovery room. After extubation, it is important to avoid external mask ventilation because air may be forced intracranially through the anterior cranial base defect. Similarly, all instrumentation of the nose, including passing of tubes, should be avoided. A nasal dressing is useful to absorb any drainage and also to prevent the patient from nose blowing.

If the patient has a spinal drain and watertight closure of the dura was achieved intraoperatively, the spinal drain is usually removed in the recovery room. This avoids excessive CSF drainage and decreases the risk of infection. If closure of the dura is tenuous, physiologic drainage of CSF is generally continued for 3 to 5 days. Intermittent drainage of CSF is performed (approximately 50 mL every 8 hours). This is preferable to leaving the lumbar drain open to gravity because excessive CSF drainage may occur with changes in patient position. Intermittent clamping of the drain also allows the patient to begin early ambulation.

On the first or second postoperative day, a follow-up CT scan of the head without contrast enhancement is obtained to acquire information about any intracranial complications such as hemorrhage or pneumocephalus. This scan also serves as a basis for future examinations should neurologic symptoms develop.

Early ambulation is encouraged, and an oral diet can usually be instituted on the first postoperative day. Patients are instructed to not blow their nose. A saline nasal spray may be used to gently irrigate the nasal cavity during hospitalization. This spray is continued after discharge from the hospital. Most patients can be discharged within 5 to 10 days.

During the month after surgery, excessive instrumentation of the nasal cavity is avoided. Gentle suctioning of the nasal cavity under endoscopic visualization is performed while taking care to avoid instrumentation of the reconstructed cranial base defect. Mucosalization of the pericranial flap occurs within 6 to 8 weeks. Depending on the original pathology, patients are seen at periodic intervals to screen for recurrent disease or complications of surgery. For any patient with a malignant neoplasm, baseline CT or MRI is performed at approximately 3 months after surgery to allow adequate time for healing of the surgical site and resolution of edema or fluid collections. It serves as a baseline for future examinations to look for recurrent disease. Patients may require lifelong nasal hygiene to remove excessive crusts, especially after radiation therapy. Patients are instructed to irrigate the nasal cavity with saline solution via a Water-Pik with a nasal adaptor. An alkalol solution may be helpful in loosening crusts. Because of the loss of olfactory function, patients should be counseled about the need for in-home monitors to detect natural gas leaks. Similarly, the home should be equipped with smoke detectors.

COMPLICATIONS

Metabolic

The fluid and electrolyte balance of patients undergoing skull base surgery should be monitored closely. Postoperative hyponatremia is generally the result of inappropriate fluid balance in the operating room, but the syndrome of inappropriate antidiuretic hormone (SIADH) secretion may develop in patients with cerebral edema or contusion. Excessive antidiuretic hormone (ADH) secretion leads to water retention with a serum sodium concentration of usually less than 130 mg/dL. The syndrome is generally self-limited and may be treated by restriction of fluid to less than 1000 mL/day. If the patient shows signs of disorientation, seizures, or muscle irritability, 3% saline solution is administered intravenously.

In contrast, ischemia or trauma to the hypothalamus may lead to insufficient production of ADH and result in diabetes insipidus. During diabetes insipidus the patient loses the ability to concentrate urine, which leads to increased free water loss and hypernatremia/hypovolemia. Serum sodium is usually higher than 145 mg/dL, and urine specific gravity is less than 1.002. Careful replacement of fluids is necessary because urine output can be greater than 2 L/hr. Aqueous ADH may be replaced initially (2.5 units intramuscularly every 4 hours). Iatrogenic SIADH, through overuse of parenteral ADH, should be avoided.

Hyperglycemia is very common in patients receiving steroids and should be ruled out in any patient with increased diuresis and hypernatremia. It is treated by a sliding scale of regular insulin titrated to glycemia. Other electrolyte disorders such as hypomagnesemia (<1.8 mg/dL), hypophosphatemia (<2 mg/dL), and hypocalcemia (<8.0 mg/dL) are common in patients after skull base surgery, especially if the patient requires replacement of significant blood loss (>5 units of packed red blood cells). These disorders can add to the postoperative delirium and diminished mental state. Hypocalcemia and hypomagnesemia increase muscle irritability and can lead to confusion. Calcium is replaced as 10% calcium gluconate administered intravenously at a rate slower than 1 mL/min. Phosphates are replaced intravenously as a solution containing 10 to 15 mmol phosphate in 250 mL of 5% dextrose solution administered over a period of 6 hours. Magnesium may be replaced intravenously as 4 g in 100 mL normal saline solution given over a 30-minute period.

Vascular

DVT is prevented with the use of sequential compression stockings. Heparin is contraindicated because of the risk of postoperative intracranial bleeding. If DVT occurs, an inferior vena cava filter is recommended to prevent pulmonary embolism. In selected patients at high risk for DVT or pulmonary embolism, the filter is placed preoperatively.

Coagulopathies may be induced by rapid bleeding and blood replacement temporarily exhausting the coagulation factors. This is treated by replacing the coagulation factors with fresh frozen plasma.

Central Nervous System/Skull Base

Seizures secondary to frontal lobe trauma are rare. Nevertheless, in the presence of significant brain contusion or when parenchymal resection is necessary, seizure prophylaxis in the form of phenytoin (Dilantin) is recommended.

Treatment of a grand mal–type seizure consists of diazepam (Valium), 10 mg intravenously, and ventilatory support, followed by phenytoin in a 15-mg/kg loading dose and 5-mg/kg/day maintenance dose. It is essential to rule out electrolyte or acid-base imbalances, as well as an intracranial space-occupying lesion or inflammation as a cause of the seizures.

CSF leaks that occur in the immediate postoperative period are managed with a lumbar spinal drain. The drain bag is kept at shoulder level, and 50 mL is drained every 8 hours. This approximates the physiologic production of CSF in 24 hours. Overdrainage may lead to pneumocephalus. High-flow or persistent CSF leaks (beyond 1 week) require surgical repair. The site of the leak may be identified by means of a CT-cisternogram. Repair of the leak usually involves repair of the dural defect and the use of a vascularized flap to separate the leak from the upper aerodigestive tract. Patientsin whom hydrocephalus develops require a ventriculoperitoneal shunt.

A small amount of pneumocephalus is frequently seen in the early postoperative period. It generally resolves spontaneously over about 1 week. Persistent or substantial pneumocephalus implies a CSF leak and may be managed conservatively, as described previously. Tension pneumocephalus, which is the accumulation of intracranial air under pressure, may compress brain tissue and cause impairment of the sensorium or focal neurologic deficits (Fig. 100-31). Although the mechanism of the increased air pressure is poorly understood, it may result from forceful expiration through the nose when there is an incompletely sealed defect in the anterior cranial base. The pneumocephalus is treated by needle aspiration when neurologic changes or evidence of increasing pressure is noted. Recurrent tension pneumocephalus may require repair of the dura. A tracheotomy may be used to bypass ventilation.

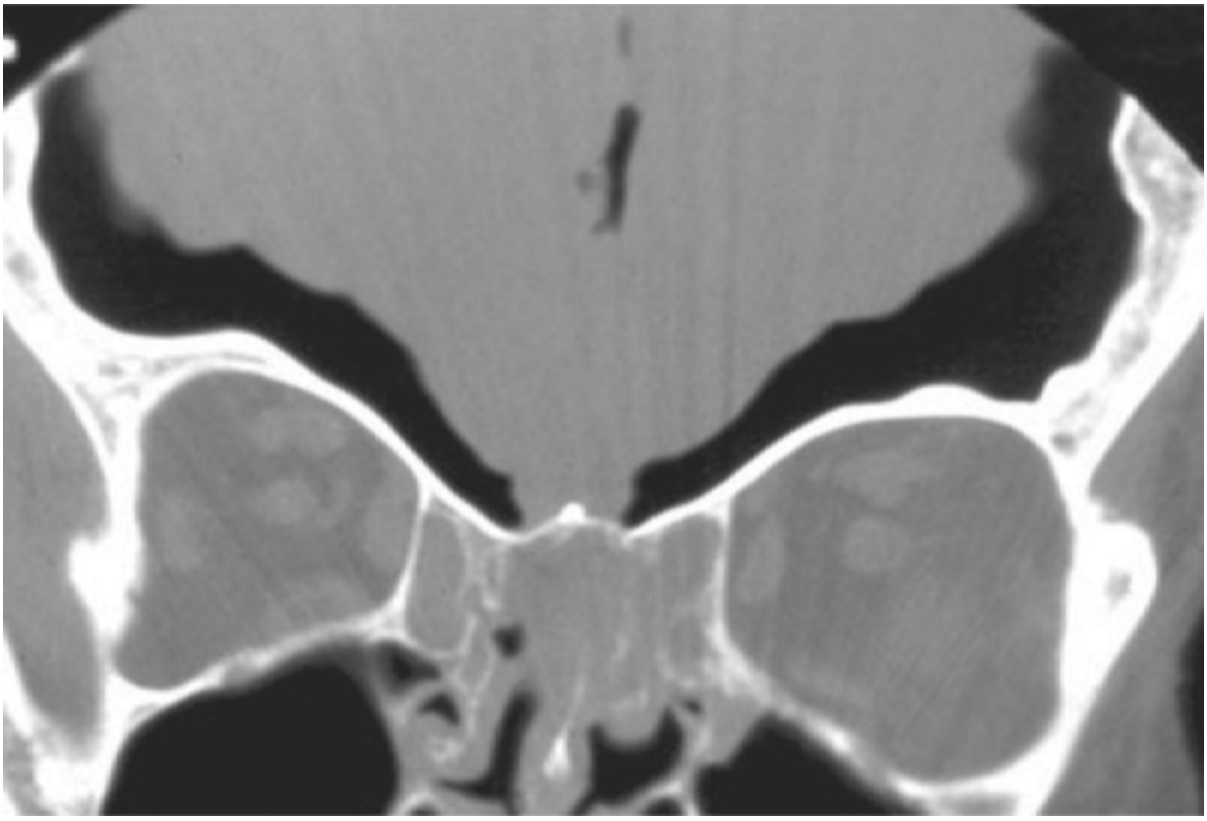

Figure 100-31 Mental status changes developed in the postoperative period. Computed tomography demonstrated a tension pneumocephalus that required aspiration to relieve frontal lobe compression.

Wound infection and meningitis are rare complications of anterior cranial base surgery and are usually the result of faulty surgical technique. An epidural dead space often results from cranialization of the frontal sinus and may increase the risk for a postoperative wound infection. Antibiotic therapy is directed by Gram stain or culture and the ability to achieve adequate CSF penetration. Involvement of bone grafts by the infection may require their removal. If the bones are not mobile (repaired with rigid fixation), they can be salvaged by using a suction irrigation system for the delivery of local antibiotics. It is essential that separation of the cranial cavity from the upper aerodigestive tract be achieved. When bone flaps are removed because of infection, the soft tissues are allowed to collapse onto the underlying tissues (dura or flap). Reconstruction is typically delayed for 6 months to avoid the risk of osteomyelitis.

Dissection of a galeal-pericranial or galeal scalp flap may compromise the vascularity of the superficial scalp layers, especially in patients who have previously received radiation therapy. A constrictive head dressing should be avoided because it may compromise the remaining vascularity. With thinning of the scalp, bone irregularities may become more apparent. Reabsorption of bone chips may result in depressions at the site of burr holes. Patients who require postoperative radiation therapy may also experience additional bone reabsorption.

Encephalocele and pulsatile exophthalmos rarely occur as late postoperative complications. They are corrected by reoperation and reconstruction of the dural and bone defects. Loss of medial orbital support and imprecise realignment of the medial canthus may result in ocular asymmetry and a disconjugate gaze. Whenever possible, large orbital defects should be recon-structed.

PEARLS

- Because of the location of anterior cranial base pathology, the initial clinical symptoms may be subtle and are often very similar to chronic inflammatory sinus symptomatology.
- Preoperative confirmation of histopathology is critical because of the wide variety of pathology of the anterior cranial base and the treatment options available.
- Care must be taken when raising a bicoronal flap to not compromise the blood supply from the supraorbital and supratrochlear vessels to the pericranial flap.
- A basal subfrontal approach is preferred to avoid excessive retraction of the frontal lobe.
- If undertaking endoscopic resection of anterior cranial base pathology, oncologic principles should never be compromised and the same resection must be achieved endoscopically as would be through a traditional technique.

PITFALLS

- Elevation of the bicoronal flap must occur in a plane deep to the superficial layer of the deep temporal fascia to avoid injury to the frontal branch of the facial nerve.
- Failure to preserve the superficial temporal vessels may forfeit the use of a temporoparietal flap for reconstruction.
- All frontal sinus mucosa should be drilled away to avoid late complications related to retained mucosal function.
- Lack of a watertight barrier separating the intracranial contents from the paranasal sinuses may lead to CSF leakage or infection.
- Early postoperative manipulation of endonasal reconstruction could lead to an iatrogenic CSF leak.