



Charles Dahlgreen. *Sunlight in Brown County*. Oil on canvas, 32" × 39".  
The Hainsworth Collection. Photo credit: R. H. Love Galleries, Chicago, Illinois.

*Progress has been made in treating nasal cavity and paranasal sinus cancer with surgery combined with radiation therapy and chemotherapy.*

## Malignant Tumors of the Anterior Skull Base

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**Background:** Cancers of the paranasal sinuses or nasal cavity are the most common malignant tumors of the anterior skull base. Several types of tumors occur in this location, including cancers of endodermal, mesodermal, and epidermal origins. Although anterior skull base surgery is a relatively recent approach in treating these tumors, widespread changes have already occurred in procedural methods and treatment goals.

**Methods:** We review the tumor types that occur in the anterior skull base and discuss the current treatment options, including multimodal therapy and the team approach to surgery. Surgical techniques are also described.

**Results:** Management of anterior skull base cancer is complex due to the anatomic detail of the region and the variety of cancers that occur in this area. Currently, the "gold standard" for surgery is the anterior craniofacial approach. Combined with adjuvant radiation therapy, 5-year disease-free survival rates have increased to 50%, with some tumors such as adenocarcinomas and esthesioneuroblastomas reaching up to 80% 5-year survival rates. Potential complications include cerebrospinal fluid leakage, meningitis, abscess formation, and pneumocephalus.

**Conclusions:** Treatment of anterior skull base cancer is complex due to the significant anatomic detail of the region and the variety of cancers that occur in this area. Multimodal therapy through a team approach is the optimal management approach for these tumors.

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### Introduction

Cancers of the paranasal sinuses or nasal cavity are the most common malignant tumors of the anterior skull base. A wide variety of tumors occur in this location, such as cancers of endodermal, mesodermal, and epidermal origins, including squamous cell carcinoma, melanoma, lymphoma, sarcoma, hemangiopericytoma, malignant giant cell tumor, basal cell carcinoma, plasmacytoma, adenoid cystic carcinoma, mucoepidermoid carcinoma, malignant meningioma, and metastatic malignancies. Historically,

these tumors were treated primarily by a lateral rhinotomy approach that, in most cases, resulted in subtotal tumor resection. Surgery was followed by adjuvant radiation therapy. This combined treatment yielded overall poor results, with a 5-year survival rate of less than 25%. In 1954, Smith and colleagues<sup>1</sup> published an anterior craniofacial resection of a cancer of the frontal sinus. In 1959, Malecki<sup>2</sup> presented an anterior craniofacial resection for a cancer of the ethmoid sinuses. However, Ketcham and colleagues<sup>3,4</sup> were the first to address cure rates and 5-year survival rates in patients with paranasal sinus cancers. They demonstrated that a team approach involving neurosurgeons and otolaryngologists could improve outcomes. Current combined approaches with adjuvant radiation therapy have increased 5-year disease-free survival rates to at least 50%, with certain tumors (eg, adenocarcinomas and esthesioneuroblastomas) demonstrating 5-year

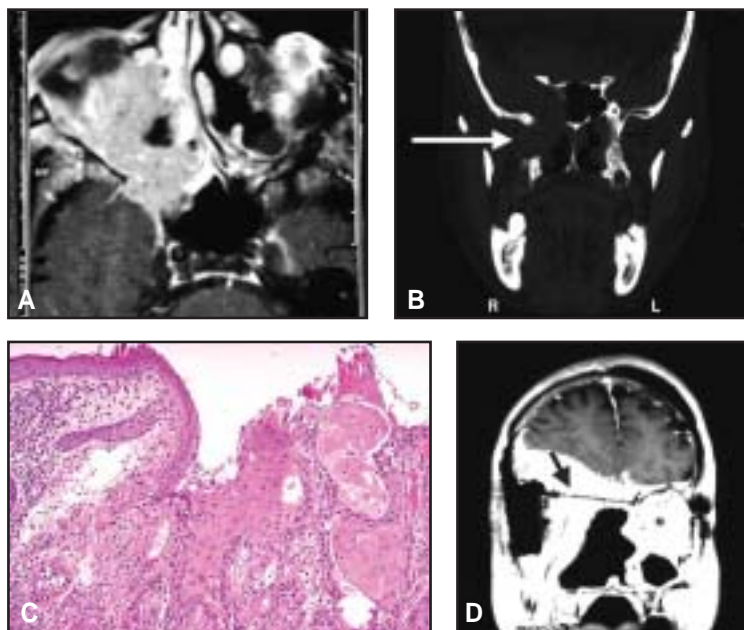
survival rates of up to 70% to 80%. The approach to managing a selection of these tumor types is presented.

## Paranasal Sinus and Nasal Cavity Cancers

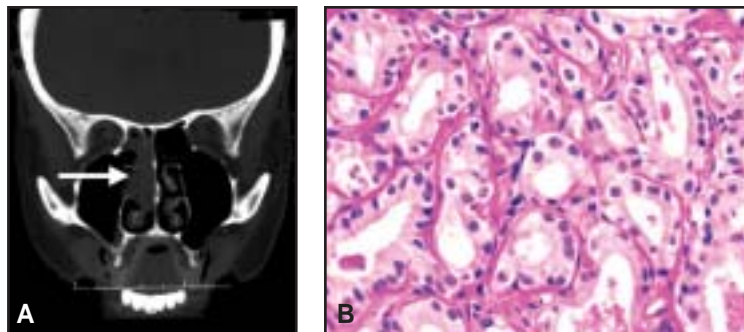
Nasal/paranasal sinus cancers are rare tumors, comprising approximately 3% of all head and neck cancers and having an annual incidence of 1 to 3 cases per 100,000 people per year.<sup>5</sup> They affect patients primarily between 60 and 70 years of age, and there is a slight male preponderance that may reflect occupational risks and exposure.<sup>6</sup> Incidence of this cancer is high in Asia, particularly in Japan. Most common sites include the maxillary sinus (60%), the nasal cavity (20%), and the ethmoid sinuses (16%).<sup>7</sup> Predisposing factors include exposure to occupational hazards such as nickel, wood, dust, and asbestos.<sup>6</sup> In addition, smoking and using snuff have been a source of increased incidence of paranasal sinus cancers and have been implicated in the pathogenesis of head and neck cancers in general. Although unclear at this point, chronic sinusitis or nasal polyps probably do not contribute to the incidence of this disease. These tumors present most commonly with nasal obstruction, epistaxis, and/or nasal discharge. In addition, they can present with facial pain, proptosis, diplopia, and anosmia. Because of the similarity in presentation with sinusitis, it is imperative that these symptoms in patients over 50 years of age who present with these symptoms for over 6 weeks' duration be investigated by an otolaryngologist.<sup>6</sup>

Histologically, the majority of nasal/paranasal sinus cancers are squamous cell carcinomas (50%), which tend to arise primarily in the maxillary antrum (Figs 1A-D). These tumors are more common in the Asian continent. Adenocarcinomas occur in approximately 35% and primarily arise in the ethmoid sinuses or in the upper nasal cavity (Figs 2A-B). Approximately 11% of tumors in this region are adenoid cystic carcinomas arising from minor salivary glands.<sup>7</sup> They are known for their diffuse infiltration and their propensity for perineural extension. Less than 1% of paranasal sinus cancers arise in the sphenoid or frontal sinuses.

Nasal/paranasal sinus cancers are predominantly locally invasive tumors, with only 8% of tumors involving the regional cervical lymph nodes.<sup>6</sup> Distant metastasis occurs in 5% to 10% of cases, usually to lung, liver, or bone. Numerous classification systems exist for tumors in this area, but the most commonly used is the TNM system. Standard management includes surgical



Figs 1A-D. — Squamous cell carcinoma involving (A) the right orbit, pterygoid processes, and (B) anterior cavernous sinus (white arrow). (C) shows typical histopathology of the tumor. (D) demonstrates a postoperative coronal magnetic resonance image after a gross total tumor resection through a combined anterior/lateral skull base approach. An orbital exenteration was performed. A titanium mesh was used to reconstruct the floor of the anterior cranial fossa (black arrow) to avoid an encephalocele.



Figs 2A-B. — (A) Adenocarcinoma of the right nasal cavity involving the septum, middle turbinate, and ethmoid air cells (white arrow). (B) shows typical histopathology with back-to-back glandular structures.

resection followed by radiation therapy and possibly chemotherapy. Overall, the 5-year disease-free survival rate is 50%. It is better for adenocarcinoma (70% to 80%) and worse for squamous cell carcinoma (30% to 40%). Prognostic factors vary among studies since most studies consist of a small number of patients, include different pathologies, and differ in the surgical technique and overall management.<sup>8</sup> However, certain prognostic factors appear to be major predictors of recurrence: tumor grade (especially for esthesioneuroblastoma), orbital involvement, and sphenoid sinus involvement.<sup>9</sup> Transdural involvement is associated with poor survival. McCaffrey et al<sup>10</sup> examined 54 patients with malignant anterior cranial fossa tumors and found that only tumor grade and orbital involvement were independent variables associated with decreased survival. This was similar to the findings of Van Buren et al<sup>4</sup> that orbital involvement reduced survival from 50% to 30%. In contrast, Danks and Kaye<sup>6</sup> reported that sphenoid sinus involvement was the only major predictor for recurrence. Initially, most surgeons recommended sacrificing the orbit in the event of radiographic tumor involvement. In 1998, Perry et al<sup>11</sup> presented 41 cases in which they preserved the eye when possible. They either peeled tumor from the medial orbital wall or removed the periorbita using frozen section guidance. They reported no recurrences in the orbit using this technique. Thus, our recommendation is to attempt to preserve the orbit in all possible cases. If there is invasion of the cavernous sinus or orbital apex, or orbital involvement with preexisting poor (nonusable) vision, an orbital exenteration is recommended.

Other critical structures include the brain and dura. In many cases, a good cleavage plain between the tumor and the frontal lobe can be obtained. Similarly, clival and nasopharyngeal involvement is usually not a limiting factor in resecting these tumors. The principal limiting factor from a surgical standpoint is the presence of tumors in the cavernous sinus and infratemporal fossa (pterygoid plates). In these cases, the anterior craniofacial approach is combined with a lateral approach to resect the tumor in that location. Also, sphenoid involvement is not amenable to complete excision without overwhelming morbidity and possible death. The most serious situation is tumor infiltration into the wall of the carotid artery at the skull base (cavernous sinus). In these cases, a preoperative balloon test occlusion is recommended. Currently, there is no safe test to predict the ability to sacrifice the carotid artery in the event that it is involved by tumor. Bypass surgery using saphenous vein grafts has been utilized, but this approach is associated with significant morbidity and should be considered only in cases where the carotid artery involvement is the only factor that prevents an

otherwise oncologically meaningful resection in a young patient. Most skull base surgeons consider carotid involvement to be a contraindication to surgery because of the associated poor prognosis and high morbidity and possible mortality associated with carotid sacrifice.

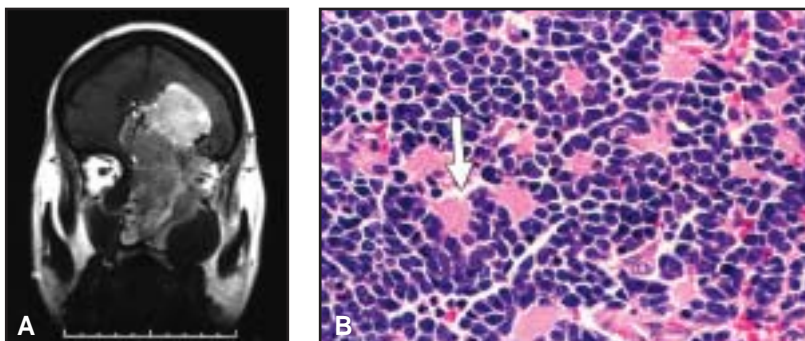
## Tumor Types and Current Treatment

### *Esthesioneuroblastoma*

Esthesioneuroblastomas are also known as olfactory neuroblastomas (Figs 3A-B). They comprise 3% of intracranial tumors and arise from the olfactory epithelium.<sup>12</sup> Because of their origin, they are similar to other tumors arising from the neural crest, such as primitive neuroectodermal tumors, small-cell lung carcinomas, and neuroblastomas. They have a bimodal distribution, primarily affecting patients in the second and fifth decades of life, and are slightly more common in men. Neck metastasis occurs in 8% to 10% of patients.<sup>13</sup> Presentation is similar to paranasal sinus cancer, with nasal obstruction, epistaxis, anosmia, pain, and mass effect. Pathologically, the tumors are characterized by the presence of pseudorosettes and discrete lobules of small, round cells. The histologic grade of the tumor is an important variable for predicting survival. High-grade tumors show mitoses, nuclear pleomorphism, and necrosis, but no Homer-Wright rosettes.<sup>12</sup> Recurrence rates for esthesioneuroblastomas range from 51% to 55%, and the 5-year survival rate is 70%. Treatment includes resection, usually followed by radiation therapy and chemotherapy in certain cases. Chemotherapy usually involves cyclophosphamide, vincristine, doxorubicin, and cisplatin.<sup>13</sup> Chemotherapy is indicated in high-grade tumors, but its role is unclear in tumors of lower grades.

### *Squamous Cell Carcinoma*

Squamous cell carcinomas are the most common malignancies of the nose and paranasal sinuses. They have a male predominance, and age at diagnosis tends to be 50 years or more. The maxillary antrum is most frequent pri-



Figs 3A-B. — (A) Large esthesioneuroblastoma with bilobular extension intracranially and intranasally. The tumor arises from the cribriform plate. (B) shows typical rosette formation (black arrow) and hyperchromatic cells.

mary site, followed by the nasal cavity, ethmoid sinus and, rarely, frontal or sphenoid sinus.<sup>14</sup> They metastasize regionally in approximately 10% of patients and distantly in 10% of patients. Treatment for low-stage lesions usually involves surgery or, less commonly, radiation, while higher-stage lesions are often treated with combined modalities with surgery followed by radiation. Because of the low (10%) incidence of regional metastases, the clinically negative neck is usually not treated.

### **Adenoid Cystic Carcinoma**

Arising in sinonasal minor salivary gland tissue, adenoid cystic carcinomas tend to be slow but steady-growing lesions that are destructive and have a high propensity for perineural spread. Trigeminal nerve involvement is most common in nasal/paranasal sinus tumors. Regional lymphatic spread is rare, while distant metastasis is more common, averaging 40%.<sup>15</sup> Bone and/or lungs are frequently involved. Systemic metastasis is most often secondary to failure of local control. Recurrence can occur as late as 10 to 20 years following treatment. Primary treatment is surgical, usually followed by radiation treatment in higher stage lesions.

### **Malignant Melanoma**

Sinonasal melanoma is the most common mucosal melanoma site but represents only 1% to 2% of all melanomas.<sup>7</sup> It arises in the fifth to eighth decade and occurs equally in men and women. Treatment consists of complete excision. Radiation therapy and chemotherapy are of limited value. The 5-year survival rate is poor, ranging from 0% to 30%.

### **Chordoma**

Chordomas arise from remnants of the notochord.<sup>16</sup> They represent 1% of intracranial tumors and occur in the third to fifth decades with equal distribution among men and women. Symptoms include headache, diplopia, facial pain, and various cranial nerve deficits. Histology shows physaliferous cells (epithelioid cells with vacuolated cytoplasm). Treatment is primarily surgical. Incomplete resection is common due to adjacent vital structures and the infiltrative nature of the tumor. High-dose radiation therapy and photon-beam therapy is believed to provide some benefit, with a control rate of 60% in 5 years. Local recurrences are common, but systemic metastases are unusual.<sup>16</sup>

### **Sarcoma**

Sarcomas are rare sinonasal malignancies.<sup>6</sup> They carry a worse prognosis than other head and neck sarcomas due to late diagnosis and their proximity to vital structures, thus making en bloc resection difficult. Low-grade tumors

may be treated with surgery, and high-grade tumors are treated with surgery and/or radiation. Rhabdomyosarcomas comprise 75% of pediatric head and neck sarcomas, with 70% involving the orbits. Small lesions are best treated with surgery, whereas radiotherapy is used for larger lesions. Chemotherapy is recommended for high-grade tumors and many times for low-grade tumors.

### **Histiocytosis X**

Histiocytosis X is an idiopathic pediatric disease consisting of lesions composed of eosinophils, lymphocytes, granulocytes, and Langerhans' histiocytes.<sup>7</sup> Rarely occurring in the nose, it is more commonly found in the temporal bone. Histiocytosis X is divided into eosinophilic granuloma, Hand-Schüller-Christian disease, and Letterer-Siwe disease. Localized disease is treated with surgery and radiotherapy, and disseminated disease is treated with chemotherapy.

### **Sinonasal Lymphoma**

Also known as lethal midline granuloma syndrome,<sup>6</sup> sinonasal lymphoma is an angiocentric, sinonasal, T-cell lymphoma that is a non-Hodgkin's lymphoma. It has an association with the Epstein-Barr virus, and it presents as a midfacial destructive lesion with nasal obstruction, epistaxis, dark drainage, intranasal ulceration, odor, fever, chills, and weight loss. Examination shows a friable, gray-white, necrotic lesion of the septum and palate. Histologic evaluation is difficult due to necrosis. Common findings are mixed angiocentric and angiodestructive cellular infiltrates. Sinonasal lymphoma is best treated with radiation after a biopsy is obtained.

### **Sinonasal Undifferentiated Carcinoma**

A rare and aggressive malignancy,<sup>6</sup> sinonasal undifferentiated carcinomas are usually diagnosed late and commonly involve the orbits, multiple sinuses, and anterior cranial fossa. Resection followed by radiotherapy is preferred, although the prognosis is poor. Some surgeons will not consider resection secondary to the poor prognosis. Unresectable tumors are treated with chemotherapy and radiation.

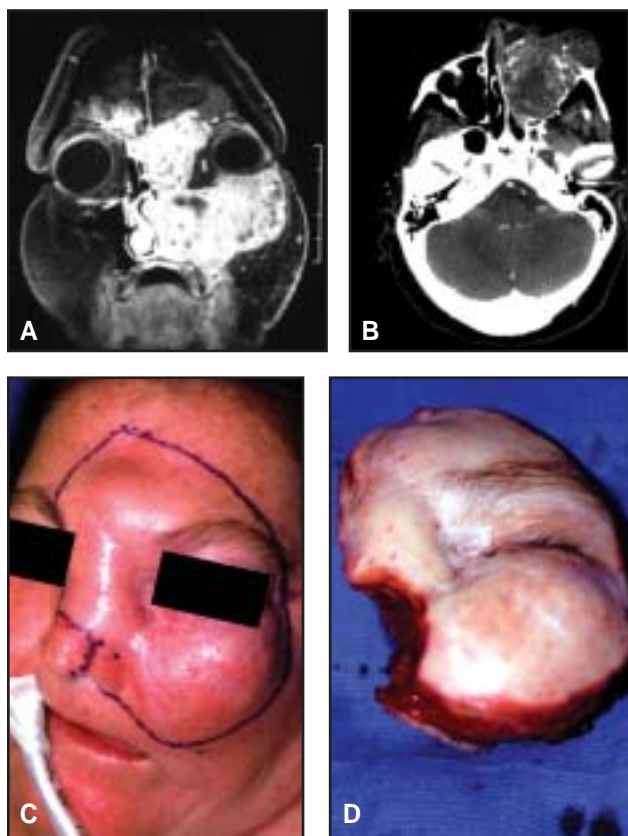
## **Surgical Technique**

Surgery carries certain innate difficulties due to the location of critical neurovascular structures (eg, olfactory nerves, optic nerves, trigeminal nerves, carotid arteries, brain, cavernous sinuses, eyes) in the anterior cranial fossa. In addition, as the tumor infiltrates or approximates the dura of the anterior cranial fossa, resection of the tumor involves a violation of the sterile cerebrospinal fluid (CSF) space as well as exposure to the contaminated nasal cavi-

ty.<sup>17-21</sup> Therefore, the surgery begins by "planning the closure."<sup>22</sup> It should be kept in mind that surgery must be safe and oncologically sound, with maximal preservation of critical structures, in order for patients to benefit from such a complex surgical intervention.<sup>23</sup>

Craniofacial surgery was revolutionized 35 years ago when Tessier<sup>24</sup> performed facial osteotomies in children with congenital abnormalities, proving several principles: (1) intracranial and extracranial exposures could be combined without undue risk of infection, (2) orbital osteotomies could be performed and the globes retracted without causing blindness, and (3) the facial bones could survive after being stripped of periosteum, transected, and repositioned.<sup>25</sup> Currently, the "gold standard" for surgery is the anterior craniofacial approach. This typically includes a bifrontal craniotomy and a lateral rhinotomy. It can be combined with a maxillotomy or maxillectomy or a lateral skull base approach.<sup>26</sup> The subcranial approach or the facial degloving approach could also be used for these tumors.<sup>27,28</sup>

Raveh and colleagues<sup>29</sup> designed and popularized the subcranial approach, which combines a bifrontal craniotomy with naso-orbital osteotomies for broad exposure to the anterior fossa, nasal cavity, and paranasal sinuses.



Figs 4A-D. — (A-B) Large recurrent basal cell carcinoma involving the frontal sinuses, nasal cavity, left maxilla, and left orbit. The patient has had 5 prior subtotal resections and had no useful left eye vision. The patient underwent an en bloc tumor resection with free margins using a combined team of neurosurgeons, ear-nose-throat specialists, and plastic surgeons. The tumor is outlined (C) and resected (D).

They proved that this approach offers no frontal lobe retraction, shorter distance to the tumor, and possible unilateral olfactory nerve preservation.<sup>29,30</sup> En bloc tumor resection is facilitated as removal of the supraorbital bar and frontal sinus allows broad exposure to the orbits, ethmoid roof bilaterally, cribriform areas, and planum sphenoidale. Removal of the nasal bones permits broader exposure to the anterior nasal cavity and nasofrontal duct areas that are not well exposed in the traditional craniofacial approach. The cranial approach also obviates the need for facial incisions, unnecessary maxillary bone removal, and unnecessary nasolacrimal duct and medial canthus sacrifice.

The surgical technique for an anterior craniofacial approach, designed by Johns et al<sup>31</sup> in 1981, involves a bicoronal incision, with the scalp being reflected anteriorly.<sup>32</sup> A large pericranial flap, measuring 10 cm in width and at least 15 cm in length, is raised from posterior to the incision to the orbital rims. It is raised as a separate layer and is then folded and sutured to the scalp to keep it moist. This graft receives vascular supply from the supraorbital and supratrochlear vessels (branches of the ophthalmic artery) and has decreased the risk of CSF leakage and meningitis that follows a craniofacial approach. Subsequently, a free bifrontal bone flap is removed. The bone flap should not be excessive in size as this may increase the risk of infection. Any dural lacerations at this point are primarily repaired. Subsequently, the frontal sinus is cranialized, which provides adequate working space for the tumor resection. An extradural dissection proceeds in a lateral to medial direction. The cribriform plate is defined, and the crista galli is removed. If there is no tumor involvement of the cribriform plate, one can transect the dura and suture the defect primarily. Usually, however, involvement of the cribriform plate is uncertain, and therefore it is resected with the specimen. Removal of the plate leaves a dural defect that is replaced with either temporalis fascia, excess pericranium, dural allograft, or fascia lata. To minimize the incidence of meningitis, it is important to create a watertight dural closure at this stage before the lateral rhinotomy incision is made. Minimizing the time that the intracranial contents are exposed to the "contaminated" nasal contents is also critical. In unilateral cases, an attempt can be made at olfactory preservation on the uninvolved side by leaving the olfactory bulb intact and attached to the cribriform, performing osteotomies around it, and reflecting it superiorly.<sup>33,34</sup> The head and neck surgery team then proceeds with a subcranial approach or lateral rhinotomy and ethmoidectomy, with possible maxillectomy and maxillotomy as required.<sup>26,35</sup> They define the extent of the tumor in the nasal cavity and the involvement of the maxilla, nasal septum, palate, and nasopharynx. Subsequently, osteotomies are performed from above, and ideally the whole specimen is removed as one piece (Figs 4A-D). The specimen involves

the basal dura, bone, tumor, and paranasal sinuses. In most cases, the inferior turbinate is preserved. Margins are checked pathologically on frozen section, if possible. The goal is for an en bloc resection, but in certain cases where the tumor is especially large, an internal debulking is acceptable and necessary.<sup>36</sup> Piecemeal excision of the tumor is avoided where possible.

Reconstruction is an important part of the operation to avoid the risks of meningitis and abscess formation. If the cranialized frontal sinus leaves a large dead space, a fat graft is indicated. Avoiding overestimation of the size of the dead space is important; the dead space is frequently exaggerated by the drainage of spinal CSF and possible use of mannitol. The most important reconstruction step involves the placement of the pericranial flap to separate the nasal cavity from the cranial cavity. The graft is folded in two layers and is sutured loosely to the planum sphenoidale bone, as far posteriorly as possible. Generally, suturing it to the dura is not recommended since CSF can leak through the suture holes. In addition, the dura in the area of the planum is attenuated and easy to damage. The pericranial flap as it is folded can be brought either over the dura of the frontal lobes or into the nasal cavity. Occasionally, fibrin glue can be used to reinforce the closure. In cases where an orbital exenteration has been performed, it is important to provide support to the anterior cranial fossa. Typically, the roofs of the orbits support the frontal lobes if they can be preserved. Additional support must be provided to avoid encephalocele if the roofs of the orbits are removed. For this purpose, the inner table of the bone flap or an anterior table cranial bone graft or titanium mesh can be utilized.<sup>37,38</sup> In some cases, an osteopericranial flap can be used in which a 4 × 4-cm outer table of the frontal bone is removed together with the pericranium graft and is utilized for reconstruction of the floor of the anterior cranial fossa.<sup>38</sup> However, this procedure is cumbersome and, in our opinion, does not provide more support than a titanium mesh, which can be easier to place.

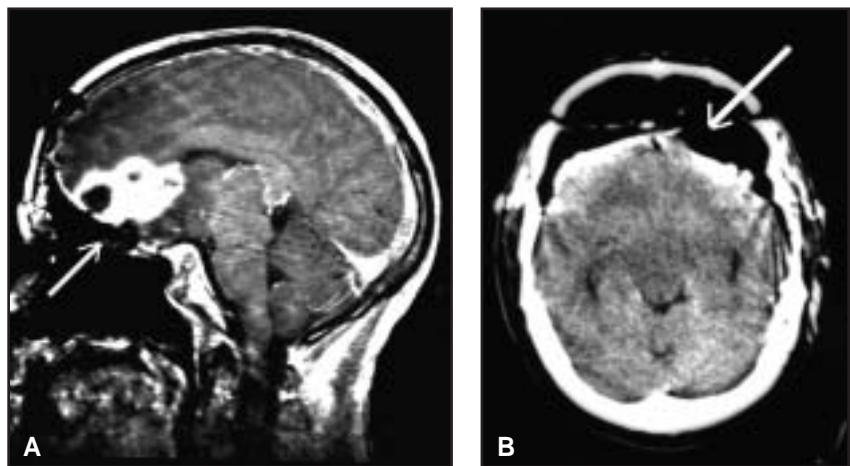
Careful approximation (ie, bringing tissue edges into the desired apposition for suturing) of the medial canthal ligaments is secured with permanent suture if the canthus has been separated. If the bony attachment of the medial canthus had been resected, then the ligament is secured with any remaining bony structures or to the medial canthus of the opposite side, taking into account that the intercanthal distance is equal to the length of one eye. Overcorrection is usually required as the canthal reconstruction tends to loosen over time. The lateral rhinotomy incision, if made, is carefully closed. Nasal packing is applied, and a subgaleal drain

can be placed. The nasal packing remains in place for 5 to 7 days. Nasal trumpets can be used to decrease the risk of pneumocephalus and provide a nasal airway. These are usually removed on day 3 following surgery. A palatal prosthesis should be placed and secured at the time of closure for patients with palatal defects. In the event of an orbital exenteration, a vascularized temporalis muscle flap can be used to close the defect. A lumbar drain is usually avoided. However, if the closure is tenuous or if the patient has undergone previous irradiation or reoperation for recurrent tumor, a lumbar drain is placed. It is important to avoid overdrainage, which could lead to pneumocephalus. A fixed amount of CSF drainage is recommended for 5 to 7 days.

In recurrent tumors, reconstruction is more difficult since the pericranium graft has already been used. In these cases, bilateral or unilateral galeal frontalis flaps can be used that are based on the superficial temporal vessels on either side.<sup>39</sup> Alternatively (or in addition), vascularized temporalis muscle flaps can be utilized.<sup>40</sup> These flaps can be brought into the anterior part of the anterior cranial fossa through the sphenoid wing or through the floor of the middle cranial fossa to cover defects in the sphenoid sinus. If none of these flaps are available, free omentum or vascularized rectus abdominus flaps have traditionally been used for the closure.<sup>41</sup> More recently, radial forearm fascial or fasciocutaneous flaps or lateral arm flaps have increased in popularity. These avoid compromise of the abdominal wall and are associated with less flap atrophy compared with denervated muscle flaps. A lumbar drain is paramount in these cases.

## Complications

Potential complications include CSF leakage, meningitis, abscess formation, and pneumocephalus (Fig 5A).<sup>42,43</sup> The presence of pneumocephalus is pathognomonic for the



Figs 5A-B. — (A) Cerebral abscess arising in a delayed fashion 2 years after surgery and radiation therapy for a squamous cell carcinoma (white arrow). The patient was treated successfully with surgery and antibiotics. (B) shows an example of pneumocephalus with mass effect to both frontal lobes.

presence of a CSF leak (Fig 5B). In our opinion, it implies a higher risk of meningitis and should be corrected surgically. The risk of meningitis is 20% to 30% in the presence of a CSF leak.<sup>43</sup> Re-exploration and closure of the defect is usually the treatment of choice. Other complications include frontal lobe contusions, cranial nerve injuries, internal carotid artery injuries, poor facial cosmesis, vision loss, diplopia, enophthalmos, and palatal dysfunction.

## Recurrent Tumors

Patients need to be followed for the possibility of a recurrent tumor for at least 5 years and usually for life. Most recurrences occur 2 to 5 years after the original resection and treatment. In the event of a recurrent tumor, a complete re-staging is imperative to determine if the tumor is local or regional or has distant metastases. If local and/or regional metastasis is present, reoperation can be considered, given the patient's overall functional status and age, especially for slow-growing tumors such as esthesioneuroblastomas and adenocarcinomas. Levine et al<sup>44</sup> reported a 5-year disease-free survival rate of 40% for recurrent tumors treated aggressively with surgery.

## Radiation Therapy

Radiation therapy is usually given in doses of 6,000 to 8,000 cGy fractionated over 6 weeks, depending on critical structures. It offers additional benefit after tumor resection for most malignant tumors of the anterior cranial fossa. Morbidity includes dry eyes, possible optic nerve damage, and radionecrosis. Newer radiation delivery methods include intensity modulation radiation therapy.

## Chemotherapy

Chemotherapy involves cisplatin and 5-fluorouracil for paranasal sinus cancers and vincristine, cyclophosphamide, doxorubicin, and cisplatin for esthesioneuroblastomas. Cisplatin can also serve as a radiosensitizer, and concomitant intravenous cisplatin and radiation therapy is used in certain patients after tumor resection. Some studies advocate the use of chemotherapy and radiation therapy preoperatively. This approach has been pioneered by investigators at the University of Virginia who report that this strategy could shrink the tumor, decrease local dissemination, and facilitate the resection that follows.<sup>44</sup> It is unclear, however, if it also increases the risk of wound healing complications and makes the margin of the resection less distant. At this time, a recommendation is to consider preoperative radiation therapy and chemotherapy only for exceptionally large tumors where such an approach would shrink the tumor and facilitate further surgery.

## Conclusions

Malignant tumors of the anterior skull base usually arise from nasal or paranasal sinus tissues. Treatment of anterior skull base cancer is complex due to the significant anatomic detail of the region and the variety of cancers that occur in this area. Multimodality therapy through a team approach is the standard management approach for these tumors. Currently, the optimal surgical therapy is the anterior craniofacial approach. Combined with adjuvant radiation therapy, 5-year disease-free survival rates have improved. Potential complications include cerebrospinal fluid leakage, meningitis, abscess formation, and pneumocephalus.

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