# Chapter 194: Complications of Skull Base Surgery

## Victor L. Schramm

There is a tremendous potential for a devastating patient outcome from skull base surgery. The combination of a prolonged and complex anesthetic; a tumor resection involving head and neck; neurosurgical, neurotologic, and vascular surgeons; and the need for a complex reconstruction leads to an almost geometric progression of potential complications. Added to the potential for treatment-related complications is the preexistent psychologic stress, underlying medical disease, and the ravage of prior therapy. The frequency of difficulty experienced by the patient undergoing skull base surgery can be exemplified by the question asked by an excellent neurosurgeon after being involved with three or four combined resections: "Are all skull base cases so complicated?" An outcome analysis of 130 consecutive patients of mine has given credence to this question. In fact, virtually all patients undergoing skull base surgery have some alteration in cosmetic, physiologic, or functional status because of the expected sequelae or untoward complications related to skull base surgery.

Patients considered for skull base surgery bring with them a unique set of factors that predispose them to complications. Their tumors are unusual either in their histology or biologic behavior and because of their primary location or extension, they are frequently beyond an individual surgeon's area of expertise. A true team approach is necessary to plan for a resection dealing with the major vascular, central nervous system, cranial nerve, and pharyngeal components of the tumor management. The patient's physiologic age, particularly regarding cardiovascular and pulmonary status, requires special consideration because of the stress of a prolonged procedure witht he need for large fluid volume replacement and the potential for postoperative aspiration. Although difficulty to quantify, the patient and family's psychosocial status greatly influences their ability and willingness to cope with skull base tumor management. They have most often been on an emotional roller coaster and may be deciding if surgery is an alternative to suicide. Prior therapy also influences the design of the surgical resection and reconstruction. More than 60% of patients have failed previous therapy, and the consequences of surgery and radiation therapy greatly influence the potential for complications. In addition, most patients are experiencing almost intolerable pain, and the combination of narcotic analgesics and various coagulation-influencing medications influences preoperative counseling as well as intraoperative management.

This chapter includes a brief description of the most frequently utilized surgical procedures and the sequelae, as well as potential complications related to these cranial-base procedures. Although there is considerable overlap in the occurrence and consequences of the various complications, they are divided into the areas of preoperative evaluation, anesthesia, central nervous system, medical, wound, and functional status categories. The overall plan for prevention of complications, as well as the actual complication rate observed, is also included.

## Preoperative Evaluation

Because of the anatomically hidden location of most tumors involving the skull base, the preoperative physical examination must be complemented by detailed comuterized tomography (CT) and magnetic reconance imaging (MRI). Equally important in the preoperative assessment is information gained regarding the patient's psychologic and physiologic capability of withstanding this type of surgery. Many hours of discussion spread over several days are required to provide the patient and family members enough information and understanding to allow them to subsequently cope with the sequelae and complications they will encounter.

Those patients whose tumors approximate the petrous carotid artery also undergo preoperative angiography with test balloon occlusion of the involved carotid system. A standard three-vessel angiogram is completed, and then the test balloon occlusion is done with one of the available soft balloon catheters. The occlusion is done in the internal carotid artery if the patient has not previously been irradiated or in the common carotid artery in the event of prior radiation history. Currently, the test occlusion is done initially with the patient awake and normotensive; and subsequently with anesthesia assistance in monitoring, the blood pressure is pharmacologically lowered to a mean of approximately 50 torr or until the patient develops any neurologic change. Some form of blood flow analysis or compressed electroencephalogram (EEG) monitoring is also done to make the test as predictive as possible. Approximately 10% of patients tested have failed to tolerate the balloon occlusion, and an additional 10% have had changes that would put them at increased risk for cerebrovascular complications.

There is potential during the balloon occlusion for clot and embolus distal to the deflated balloon and also for arterial spasm and hypoperfusion, particularly in the middle cerebral distribution. In elderly or previously irradiated patients, inflation of the ballon in a manner that produces an elongation of the balloon within the artery can fracture the intima or even rupture the arterial wall. In our early experience, nearly 10% of patients suffered some balloon occlusion-related carotid injury, demonstrating that training and supervising experience are as important for the radiologist as for the surgeon subsequently performing the patient's tumor resection.

## Intraoperative Management

### Anesthesia

The safe management of an anesthetic may be of 24-hour duration involving massive blood loss requires an especially talented anesthesia team. Virtually all available monitoring techniques are utilized, including arterial line, central venous pressure, oximetric Swan-Ganz catheter, pulse oximetry, end tidal carbon dioxide measurement, temperature probe with automatic heating control, urinary output, and frequent intraoperative hematologic evaluation. A lumbar subarachnoid spinal fluid drain is placed whenever dura is to be exposed. In the event that th drain cannot be placed or is not functional, the risk of intraoperative traction cerebritis increases markedly. An olive tup ureteral catheter used as a lumbar drain is easier to advance into the subarachnoid space but has a greater potential for lumbar nerve root irritation. The ureteral catheter, however, is preferred to the softer Silastic lumbar drain because the Silastic drain is more difficult to remove and in one instance broke, leaving a segment that required secondary surgical removal. Subclavian placement of a Swan-Ganz catheter or central venous line has resulted in a pneumothorax in less than 1% of patients but must be recognized so that a chest tube can be placed.

The positioning and padding of the patient for the extended anesthesia are done with the patient placed on an alternating-pressure air mattress over a heating blanket. Despite this, areas of skin pressure necrosis have been noted in four patients and two instances of ulnar nerve injury have occurred in the past 130 patients treated.

Blood pressure during the majority of the procedure is maintained at a planned hypotensive level except when the petrous carotid is dissected. Although there is a seemingly unending tendency among anesthesiologists for the intravascular volume to be maintained with crystalloid, we have found that if the amount of crystalloid administered exceeds the volume of blood transfused, there is an increased incidence of postoperative wound edema and complications, as well as pulmonary complications. Because of past experience with intraoperative bleeding, we empirically transfuse platelets and fresh frozen plasma beginning after the patient has received four units of blood. Although this practice is contrary to the usual standard for administration, it has been found essential to prevent potentially lethal intracranial bleeding during and subsequent to the operative procedure.

Because of complications observed related to carotid management, a simple protocol has been developed should the carotid be entered during the dissection. Before petrous carotid dissection the patient's blood volume and hematocrit are normalized and the blood pressure maintained at or above the patient's norm. If petrous carotid bleeding does occur, the patient is heparinized, the blood pressure is maintained or increased with transfusion and pharmacologic measures, and the effort of all surgeons is directed toward repairing the artery with no more than intermittent carotid occlusion. The remainder of the surgical procedure even with heparinization has been less troublesome than that observed in patients developing a dilutional or consumption coagulopathy, and the minor subsequent bleeding tendency is preferable to an embolic stroke.

Although the consequences may not be recognized until the operative procedure is over, the greatest potential area of complication is related to hypoperfusion or bleeding within the brain parenchyma. In situations where resection of the petrous or cavernous carotid artery becomes mandatory, the distal ligation is done as close to the ophthalmic artery as possible to try to maintain perfusion through the distal carotid and hopefully to prevent thrombosis and thromboembolism. If the petrous carotid resection is intracavernous, it has been found safest to sacrfice the artery without grafting. Although it would seem intellectually preferable to graft the precavernous segment, long grafts potentially exposed to oropharyngeal contamination have produced more complications than resection without grafting. When the petrous carotid artery is decompressed but not entered, the potential for cerebrovascular accident is less than 5%. There is very little additional risk with carotid sacrifice; however, the potential for stroke increases to 20% if the artery is injured, and in our experience grafting a long segment of cervical and petrous carotid artery increases the risk of vascular rupture or cerebrovascular accident to nearly 50%.

The possibility of interventricular or interparenchymal bleeding caused by intraoperative or postoperative diathesis seems always to be a potential danger (Fig. 194-1). Although unexplained, this has been prevalent in patients who have clivus chordoma. Two of my patients had life-threatening preoperative bleeding into or surrounding the intradural or intraparenchymal extension of the clivus chordoma, and an additional two had fatal postoperative interparenchymal bleeding. Although it is possible to prevent intraoperative coagulopathy by prophylactic factor transfusion, it has proven to be most efficient to discuss this blood product use with the anesthesia staff and hospital transfusion committee so that the intraoperative needs can be understood and met.

Although virtually all sequelae and complications related to skull base surgery have their origins intraoperatively, they are not usually immediately recognized or recognizable, and they are discussed here as postoperative complications.

## Postoperative Management

### Central nervous system

The potential for central nervous system vascular complications continues into the postoperative recovery. If the petrous carotid has been injured, ligated, or grafted, consideration should be given to continuing heparin anticoagulation. Delayed stroke is possible and is related either to hypoperfusion following carotid ligation or to thromboembolism.

The possibility of carotid artery or vertebral artery rupture can be predicted in part based on the area of exposure, extent of carotid injury, and the security of the reconstruction. Massive arterial bleeding is an event that is dreaded by the medical and nursing staff, and disaster drill training is mandatory. The personnel involved in caring for the patient must be aware of the location of potential bleeding and the location and technique of applying pressure for control of hemorrhage. In those patients who have undergone carotid or vertebral decompression, blood is kept available at least through the tenth postoperative day. The operative management of a carotid or vertebral rupture depends on the location and etiology of the carotid or vertebral perforation. If pharyngeal exposure is not present, then repair and grafting can be considered. In two circumstances where the contralateral petrous carotid ruptured, a secondary contralateral infratemporal fossa approach was utilized for control in one patient and permanent balloon and coil occlusion of the artery in another.

The management of postoperative spinal fluid pressure and spinal fluid leakage resolves around incremental removal of spinal fluid via the lumbar subarachnoid drain. In patients where access for watertight dural closure is possible and the dural closure can be reinforced with well-vascularized tissue (either a galeal pericranial flap or a microvascular free flap transfer), the patients are maintained with a low normal spinal fluid pressure. In circumstances where dural closure is adjacent to the cavernous sinus or in the region of the optic chiasm and pituitary, a vascularized, carefully placed reconstruction is completed, and postoperative intermittent spinal fluid removal is done for 2 or more days. Usually the CSF removal is done at a rate of 20 to 30 mL every 4 to 6 hours. For patients with demonstrated CSF leak, a similar amount of spinal drainage is done with the patient being maintained in an inclined or erect position. When a vascularized tissue reconstruction has been incorporated in the patient's management, it has not been necessary to surgically intervene. With other circumstances, should the leak continue through an incision or into the pharynx, a secondary closure should be considered within a few days.

Problems related to an intracranial mass effect can occur from several causes. A tension pneumocephalus can be produced if the patient is able to increase nasopharyngeal pressure. This has occurred infrequently in our experience because we routinely utilize a tracheostomy even for anterior craniofacial patients and maintain a nasopharyngeal airway behind the soft palate for several days. However, in one patient who had a nasopharyngeal airway but not a tracheostomy a tension pneumocephalus did develop (Fig. 194-2). Pneumocephalus can be managed by needle aspiration of the air via the craniotomy bone cut and by temporary intubation as necessary. Cerebral edema either as a consequence of fluid overload or traction-related cerebritis and edema usually does not produce focal signs but does delay the patient's mental status recovery. The restriction of fluids intraoperatively and postoperatively, as well as the use of hyperventilation, diuretics, and steroid therapy, is indicated.

Although epidural or subdural hematoma is a possibility, thus far we have not had sufficient clot formation occur to necessitate evacuation unless the hematoma was produced by a major vascular rupture. The presence of a flap reconstruction, either galeal pericranial or free flap, adjacent to dura can produce a mass effect if it becomes edematous (Fig. 194-3). In addition to the edema inherent in the transfer of a galeal pericranial or microvascular free flap, venous obstruction seems to be the primary reason for progressive or delayed edema. For the galeal pericranial flap in anterior fossa reconstruction, sufficient space must be left between bone segments where the flap is transferred beneath the skull base. Packing can be removed postoperatively from the nasal and nasopharyngeal cavity to decrease pressure in the anterior fossa if necessary. When a microvascular free flap is utilized, any large anterior or lateral bone defect should be reconstructed to keep the flap primarily extracranial. If there is ever any question about the quality of the arterial or venous microvascular anastomosis, wound exploration and vascular revision should be considered.

Cranial nerve deficits may be expected in situations where nerves have been resected or may result from dissection around any of the intracranial or extracranial portions of the nerves. These nerve deficits produce postoperative problems only when multiple lower cranial nerves have been injured. The reslt is prolonged and excessive aspiration. The potential for aspiration pneumonitis is always to be anticipated and managed by intraoperative placement of tracheostomy, prolonged nasogastric feeding, and frequent pharyngeal suctioning along with meticulous oral care. Patients who have experienced a preoperative loss of ninth, tenth, and twelfth cranial nerve function generally tolerate the postoperative recuperation with less difficulty than when these cranial nerve deficits have been produced acutely at surgery (Fig. 194-4). Postoperative vocal cord injection or laryngoplasty and temporary or prolonged gastrostomy feedings make the patient's recuperation more tolerable.

Patients who lose periorbital facial nerve function as well as corneal sensation because of injury or resection of the first division of the trigeminal nerve require special eye protection and often ultimately require permanent tarsorrhaphy. Situations that require resection of the cavernous sinus and its contents provide the dilemma of whether or not to remove orbital contents. Our experience has been that the physiologic loss of vision produced by third nerve paralysis along with the potential for corneal ulceration and enophthalmitis makes resection of orbital contents preferable. To avoid the cosmetic defect of an open orbital cavity, the lids are left in place, the bulbar conjunctiva is reapproximated, and the orbit is fillwed with the reconstruction, allowing a prosthesis to be worn subsequently.

When a facial nerve must be resected, an interposition graft is routinely placed. A fascial sling procedure or temporalis lower face reanimation is done at the time of surgery and eyelid reanimation with an eyelid weight, and lower lid shortening is done subsequently.

Seizure activity and endocrine disorders have been quite infrequent. When seizures occur in the early postoperative recovery, the patients have been successfully managed with intravenous administration of phenytoin (Dilantin). Later seizure activity is controlled with phenytoin (Dilantin) or phenobarbital administered for 6 to 12 months following surgery and then tapered and discontinued if possible. Endocrine disorders have included diabetes insipidus and hypopituitarism, particularly hypothyroidism. The onset of diabetes insipidus has been an ominous sign usually associated with both dissection in the area of the hypophyseal stalk and cerebral infarction. The acute management of diabetes insipidus has been possible with the administration of DDAVP along with volume and electrolyte management. Those patients surviving have not required long-term management. The greatest problem we have had with hypothyroidism is the delayed recognition of the problem, and once the problem is recognized, thyroid replacement has produced a successful, uneventful outcome.

## Wound complications

Wound infections, including cellulitis and abscess, have fortunately been quite infrequent. Patients are managed with prophylactic antibiotic therapy, most generally high-dose intravenous administration of a second-generation cephalosporin. When a wound infection occurs, subsequent antibiotic therapy is based on wound or Hemovac culture. The occurrence of an abscess has necessitated drainage in one instance. Cervical skin flap necrosis is potentially a greater danger in craniofacial surgery when a microvascular anastomosis has been done. In addition to the careful planning of skin flap design, special attention must be extended to avoid folding and compression of the skin flaps during the prolonged surgical procedure.

Temporalis muscle necrosis has occurred because of devascularization of the infratemporal and pterygomaxillary area or because of external carotid resection (Fig. 194-5). For this reason the temporalis muscle is not routinely used in skull base reconstruction, and often when the muscle appears nonviable it is resected and the temporal fossa filled with some other form of reconstruction.

The exposure of bone used in reconstruction to air or nasopharyngeal secretions predisposes to lack of vascularization and osteomyelitis. This has occurred in only one instance when temporalis muscle necrosis and subsequent overlying skin necrosis exposed the temporal craniotomy bone flap. The presumed reason why bone complications have been relatively infrequent in the 130 patietns subsequently discussed is that the bone reconstruction is isolated by a well-vascularized flap and because only the frontal and lateral cranial areas are reconstructed with bone. The skull base that is potentially adjacent to the nasopharynx or resection cavity is managed by soft tissue reconstruction only.

A wound hematoma other than that affecting the central nervous system is treated as it would be for other head and neck procedures. However, if a tracheostomy has not been done, a cervical hematoma may compromise the patient's airway. An additional consideration for evacuation of a hematoma must be given when a microvascular free flap has been used and venous outflow obstruction might be produced by the hematoma.

Complications related to pedicle or free flap reconstruction have been infrequent. Three patients who have had free flaps placed across the nasopharynx for skull base reconstruction have suffered nasopharyngeal obstruction requiring secondary correction (Fig. 194-6). A single instance of distal flap necrosis occurred in a latissimus myocutaneous pedicle flap necessitating prolonged wound care and secondary skin grafting. Overall, the relatively low incidence of wound care complications we believe is due to the liberal use of free flap reconstruction. Although a free flap has not been used routinely for the standard anterior craniofacial resection, 70% of the patients undergoing a lateral skull base resection have been reconstructed with a microvascular free flap.

## Functional Recovery

The long-term outcome of patients undergoing and surviving craniofacial resection has been encouraging. Although those patients who have experienced a stroke have the severe functional deficit related to the location and extent of their infarction, they have not had difficulties different from the patient sustaining a non-surgical-related cerebrovascular accident.

All patients undergoing anterior craniofacial resection have been able to manage cavity care and require decreasing amounts of physician care over time. Also, all patients undergoing anterior craniofacial resection have returned to their preoperative level of activity relatively soon following surgery and radiation therapy.

In some patients it is difficult to separate sequelae from complications in that many of the long-term deficits have involved mastication and deglutition in those patients treated by lateral craniofacial resection. Patients who have undergone mandibular resection or temporomandibular joint mobilization have some degree of trismus and malocclusion. Only if condylar or mandibular resection has been done, however, has this been a factor altering the form of oral intake. These patients must continue to do jaw-stretching exercises indefinitely, particularly if they have undergone planned postoperative radiation therapy.

Those patients with cranial nerve deficits involving the palate, pharynx, and larynx have indeed required prolonged speech and swallowing therapy with the addition of vocal cord injection, a dental speech aid prosthesis, or pharyngeal tightening. Rarely has a patient had to rely on gastrostomy feedings permanently, and no patient has had a permanent tracheostomy.

The free flap reconstruction has most often been obtained from the rectus abdominis muscle and less frequently from the latissimus muscle. Although there is denervation atrophy of the muscle flap in the area of reconstruction, donor site disability has been virtually nonexistent and those patients so inclined have had minimal limitation of shoulder or abdominal function even in vigorous athletic activity.

## Surgical Technique: Prevention of Complications

Surgical technique and to an extent philosophy have been modified over several years because of the sequelae and complications we have observed. In general, our patients receive perioperative antibiotic therapy, lumbar subarachnoid spinal fluid drainage, and a tracheostomy. Preparation for the surgical procedure is done with a circumferential scalp, face, and neck scrub with soap, povidone-iodine (Betadine), and alcohol, and the patient's head is placed on a sterile head holder or in a sterile three-point pin fixation. In this way retrograde contamination is less likely during the prolonged surgical procedure. Meticulous dural reconstruction is done with either temporalis fascia or pericranium. Bone reconstruction is limited to the exposed portion of the cranium, and the bone segments are secured with either titanium wire or titanium minimplates to avoid interfering with subsequent CT or MRI or to prevent electron scatter during planned postoperative radiation therapy.

### Anterior craniofacial resection

The lateral rhinotomy and some form of bifrontal craniotomy are the mainstays of the anterior craniofacial resection. Unless the facial bone or facial skin is involved directly with tumor, continuity of these structures is maintained or reestablished. Routinely resecting the bone at the nasal-maxillary junction is not necessary, and three-point nasal bone facial fixation can be done at the frontonasal, infraorbital, and piriform aperture areas. The craniotomy is conveniently done via a frontal sinus approach or, if the frontal sinus is not sufficiently developed, by doing a beveled bone cut with the oscillating bone saw splitting the frontal bone to obviate the necessity of burr hole placement in the frontal area. This allows the desired low subfrontal intracranial approach, provides the ideal access for placement of the galeal pericranial flap to cover dura and bone, and allows maximal bone-to-bone contact during reconstruction. Orbital contents nearly always are preserved unless there is direct extension into the fat in the orbital apex. The orbital contents are subsequently supported with a slowing of fascia or pericranium and occasionally with a bone reconstruction. As stated, no bone reconstruction has been necessary in the anterior fossa floor since sequelae of pulsatile oscillopsia caused by exposure of pulsatile dura to orbital contents have not occurred, and consequences of minimal inferior dural displacement in the nasal vault have not been a problem. Skin grafting in a cavity that is not accessible via an orbital exenteration or a maxillectomy defect is avoided, and secondary epithelialization is more mucosal-like and helps to prevent collection of inspissated secretions and secondary infection. Packing in the nasal-nasopharyngeal sinus cavity is left in place long enough for the galeal pericranial flap to adhere, approximately 5 days. Pupillary reactions are observed while it is being placed, as they are postoperatively, to be sure that venous compression or possibly ophthalmic artery compression has not occurred.

### Preauricular, Infratemporal, Transtemporal Dissection

This surgical approach is done through an incision made in the upper cervical skin crease extended with a preauricular parotidectomy type of incision and then above the ear extending to the posterior and superior temporal line and across the frontal bone in a position that could be continued as a bicoronal incision. The skin flap is elevated anteriorly past the masseter muscle in the face and to the lateral and superior orbital rim for cranial exposure. Cervical dissection, if not involving a neck dissection, includes dissection and control of the internal and external carotid as well as the upper jugular vein. The facial nerve is managed by a "nontouch" technique, leaving a cuff of soft tissue around the trunk of the facial nerve but mobilizing this soft tissue away from the mandible and then elevating the parotid entirely from the masseter muscle fascia to protect the facial nerve in an envelope of soft tissue. The temporal artery is preserved, if possible, during this dissection to maintain the lateral blood supply to the temporalis muscle. The temporalis muscle is then elevated from the temporal squama but is left attached to the soft tissue adjacent to the upper divisions of the facial nerves so that traction injury to the brow and orbital divisions of the facial nerve is minimized (Fig. 194-7). The periosteum is then elevated beneath the muscle over the lateral orbital rim and zygomatic arch, and a separate tunnel is made parallel to the branches of the facial nerve over the zygomatic process of the maxilla. After the orbital contents have been elevated away from the lateral orbital wall, a reciprocating saw cut is made at the frontozygomatic suture, across the lateral orbital wall, at the junction of the zygoma and maxilla, extending to the inferior orbital fissure, and also across the posterior zygomatic arch parallel to the temporal squama. This bone complex is then removed to facilitate further mobilization of the temporalis muscle and overlying parotid and facial nerve. If the tumor resection does not require mandibular resection, the temporomandibular joint contents are dissected from the glenoid fossa, the anterior attachments, divided, and both the stylomandibular and sphenomandibular ligaments separated so that the mandible can be transposed inferiorly and anteriorly without placing traction on the facial nerve.

The extent of the temporal craniotomy is dictated by the requirements of the tumor dissection. Usually it begins at the superior orbital rim level at the pterion and extends posterior to the glenoid fossa, which is removed along with the temporal craniotomy bone flap. The bone cuts through the posterior and medial glenoid fossa are made with a chisel so that bone loss is minimized and anatomic repositioning is possible. An infratemporal craniectomy is extended to the level of the foramen ovale. If upper cervical and petrous carotid decompression is necessary, the third division of the trigeminal nerve must nearly always be sacrificed. Petrous carotid artery identification is usually possible in an area of bone dehiscence in the floor of the middle fossa. With the mandible transposed, it is also possible to trace the internal carotid to the skull base by removing the styloid process and then drilling the bone in the medial aspect of the glenoid fossa to expose the proximal portion of the petrous carotid. With the artery identified in two locations, the bone can be thinned over the petrous carotid canal with a cutting burr, and after the carotid is mobilized within the carotid canal, which is done incrementally with microdissection, further bone removal is done with small rongeurs. Dissection of the petrous carotid canal and at the turn from the vertical to the horizontal segment and again at the junction of the petrous and cavernous carotid requires great care and patience to avoid penetrating the artery. However, total transposition of the petrous carotid artery is possible, and since the artery is rarely penetrated by tumor, this is now the preferred technique.

The management of the cavernous sinus and its contents varies depending on the extent of tumor invasion and tunmor type. If the entire cavernous sinus is to be resected, it is essentially surrounded in the dissection with control obtained in the area of the superior orbital fissure, and after removing the posterior clinoid, the clinoid segment of the carotid is ligated or clamped with an aneurysm clip preserving, if possible, the ophthalmic artery. For benign tumors compressing the cavernous sinus, it is preferable to identify the neurovascular structures proximal and distal and then dissect tumor away from the third, fourth, and sixth nerves. Although the dissection may produce a temporary weakness of extraocular muscle function, motor function for the most part returns in 3 to 6 months. Bleeding from the cavernous sinus makes dissection tedious but is controlled with Gelfoam packing and gentle pressure moving the dissection intermittently from one location to another.

When the nasopharynx has been exposed to a dissected petrous carotid artery and grafted dura, a rectus abdominis muscle free flap interposition is routinely used for the reconstruction. The free flap is chosed for reconstruction because of the greater incidence of wound complications when the temporalis muscle has been rotated into the infratemporal fossa or when fat grafts have been used.

**Postauricular, transtemporal, infratemporal resection**

A postauricular, transmastoid, transtemporal approach to the skull base is chosen for tumors arising primarily within the temporal bone area or when tumors extent to the temporal bone from anterior or posterior sites. If the external ear is not involved, the incision begins in an upper cervical skin crease and extends behind the mastoid tip at least 3 cm posterior to the auricular concha and then follows the temporal line into the location of a bicoronal skin incision. The cervical exposure, facial nerve and parotid, temporal, zygomatic, and mandibular dissections are similar to that outlined for the preauricular approach. If a temporal bone resection is to be accomplished, the posterior aspect of the temporal craniotomy is made continuous with the temporal bone and surrounding craniectomy. The bone of the glenoid fossa is sacrificed if the mandible and condyle are resected for tumor margin. The petrous carotid artery is routinely totally decompressed and transposed to allow safe resection of the temporal bone or an anterior exposure for dissection of the clivus, foramen magnum, and petrous apex. The use of the anterior infratemporal fossa portion of the dissection has provided great advantage in the preservation of facial nerve and lower cranial nerve function. In appropriate situations it is possible to dissect the jugular foramen, jugular bulb, and hypoglossal canal from an anterior approach after the carotid artery has been transposed. It is now an unusual circumstance where the facial nerve needs to be transposed, and the resulting early and late facial nerve function is much improved. When a total temporal bone resection is required or when a suboccipital approach is necessary, a posterior fossa craniotomy or craniectomy is accomplished and upper control of the sigmoid sinus is obtained by splitting the posterior leaf of the dura and ligating the sigmoid sinus at the sindural angle. If the facial nerve has been resected, a segmental graft is directed from the posterior fossa to the distal resection margin. A technique to minimize the possibility of cerebrospinal fluid (CSF) leak around the area where the facial nerve penetrates the dural reconstruction has been devised. This includes obtaining a small vein to place as a sleeve around the proximal portion of the facial nerve graft and suturing this vein to the perineurium. The vein graft can then be sutured to the dura, securing essentially a watertight closure without constricting the nerve graft. The same technique can be used for dural closure around a dissected or resected carotid at the distal petrous to cavernous sinus segment.

Because of the frequency of tenuous dural closure in the posterior fossa and near the midline, free flap reconstruction is again routinely chosen. I prefer to use the rectus abdominis with a segment of overlying fat and skin. The skin can be deepithelialized except in the area of the ear canal. Although the muscle does atrophy, the overlying fat and dermis remain at approximately the volume that was transferred so that cosmetic contouring of the lateral face and scalp is possible.

## Observed Sequelae and Complications of Skull Base Surgery

The fine line distinction between a sequela and a complication must be discussed with the patient and family preoperatively. There are many consequences of surgery that are unavoidable and indeed are not complications. These, however, may be viewed as complicating factors retrospectively if the patient is not adequately informed. Patient adjustment and satisfaction are greatly enhanced if there is an ongoing preoperative and postoperative discussion explaining the reason for and the possible adjustment to the surgical outcome. The expected sequelae of the various surgical approaches are outlined as follows:

1. Anterior craniofacial sequelae

    a. Altered facial sensation
    b. Loss of smell
    c. Incisional hair loss
    d. Possible change in facial contour

2. Preauricular infratemporal sequelae

    a. Altered facial sensation
    b. Eustachian tube dysfunction
    c. Variable trismus/malocclusion
    d. Atrophy of temporal fossa
    e. Temporary facial or permanent segmental facial paralysis
    f. Diplopia

3. Postauricular transtemporal sequelae

    a. Altered facial sensation
    b. Conductive or sensorineural hearing loss
    c. Vertigo and tinnitus
    d. Mandibular dysfunction
    e. Facial paralysis
    f. Hoarseness and swallowing difficulty.

Each patient may have a different degree of involvement, and this must be included in the preoperative discussion.

For purposes of preoperative discussion, the potential complications of craniofacial surgery are outlined in the box. By anticipating and discussing the potential for complications with the patient and mandatorily with a family member or significant other, the psychologic reaction to a postoperative complication is lessened and the patient and family deal with and compensate for the problem much more readily. We have found that detailed discussion of the potential for complications, as well as written information given to the patient explaining the potential complications, is best done sufficiently before surgery so that further questions can be answered and explanations given preoperatively.

**Box: Potential Complications**

***Anesthesia***

1. Pneumothorax
2. Pressure skin or nerve injury
3. Coagulopathy
4. Fluid volume overload
5. Lumbar drain, nerve root irritation, or retained catheter

***Central nervous system***

1. Vascular
    a. Stroke and death
    b. Carotid rupture
    c. Intracranial or parenchymal bleeding
    d. Cerebral edema

2. Mass effect
    a. Pneumoencephalus
    b. Intracranial flap edema

3. Traction cerebritis

4. Seizure

5. Endocrine
    a. Diabetes insipidus
    b. Hypopituitarism

6. Cerebrospinal fluid
    a. Leak
    b. Meningitis / cerebritis

7. Cranial nerve loss

***Medical***

1. Pulmonary
    a. Atelectasis or respiratory failure

2. Cardiovascular
    a. Hypertension
    b. Air embolus
    c. Myocardial infarction
    d. Deep vein thrombosis / embolus

3. Renal
    a. Urinary tract infection (URI)
    b. Failure

4. Hematologic
    a. Bleeding diathesis
    b. Transfusion reaction
    c. Transfusion-transmitted disease

***Wound***

1. Infection
    a. Cellulitis
    b. Abscess
    c. Bone flap

2. Hematoma / bleeding

3. Muscle or skin flap necrosis

4. Reconstruction
    a. Flap necrosis
    b. Nasal obstruction

***Functional***

1. Visual loss / diplopia

2. Dysphagia / aspiration

3. Hoarseness.

## Observed Complications of Skull Base Surgery

A psychologically painful review has been completed of 130 skull base resections done over the past 5 years. Because of the great disparity in the complication rate and severity, the analysis has been separated into two categories. Thirty patients have undergone anterior craniofacial resection, and the outcome overall has been quite satisfactory (Table 194-1). By contrast, the frequency and severity of complications associated with lateral skull base approaches have been much greater (Table 194-2). In fact, because of the number of vascular-related complications, our skull base team has modified not only technique but also philosophy to decrease mortality and improve the quality of survival. Because of this, we have been able to avoid injury to the carotid artery during the past 18 months. However, despite this and evidence from preoperative balloon occlusion testing that carotid resection should be tolerated, two patients who had the cavernous carotid resected but not grafted suffered fatal cerebral infarction. The facial nerve function outcome has also improved with the modifications explained previously. It is now unusual for a patient not to have normal facial nerve function within 3 to 6 months after surgery. Pneumonia was the presumed cause of sepsis in patients where this occurred. The continuing frequency of pneumonia has been life threatening in only one patient who developed multisystem failure but has been the object of continuing team discussion and vigorous perioperative care. One patient developed *Candida albicans* meningitis and another had *C. albicans* sepsis requiring prolonged administration of amphotericin B. Other patients' meningitis or wound infection responded rapidly to systemic antibiotic therapy.

**Table 194-1.** Observed complications after anterior craniofacial resection (n = 30)

| | |
|---|---|
| Unilateral vision loss | 2 |
| Diplopia | 2 |
| CSF leak * | 1 |
| Pneumoencephalus | 1 |
| UTI | 3 |
| Pneumonia | 1 |

* Combined anterior and infratemporal resection.

The question raised regarding the frequency of complications related to skull base surgery is certainly an appropriate one. Although many patients have multiple complications, overall more than 40% of them experience medical difficulties; greater than 20% have had vascular complications; and 20% developed wound complications. An additional 20% express some bothersome postsurgical sequelae. I sincerely hop that the investigators gaining experience in the increasing number of centers now doing skull base surgery share their experiences and that those wishing to undertake such surgical endeavors strive to learn from others before they repeat our mistakes.

**Table 194-2.** Observed complications with preauricular or postauricular lateral approach (n = 100)

| | |
|---|---|
| **Preoperative** | |
| Carotid tear or rupture of balloon occlusion * | 5 |
| **Intraoperative** | |
| Massive bleeding ** | 10 |
| Stroke | 4 |
| Stroke / postoperative death | 3 |
| Pressure skin / nerve necrosis | 3 |
| Myocardial infarction, arrhythmia, and death | 1 |

**Postoperative**

| | | |
|---|---|---|
| Pneumonia *** | | 35 |
| UTI | | 13 |
| Thrombophlebitis | | 1 |
| Pulmonary embolus / death | 1 | |
| Carotid rupture | | 4 |
| Carotid-related death | 3 | |
| Stroke (delayed contralateral) | 1 | |
| Vertebral rupture **** | | 2 |
| Intracerebral bleeding | | 2 |
| Meningitis | | 3 |
| Wound infection or abscess | 5 | |
| Temporalis muscle necrosis | 2 | |
| Facial paralysis | | |
| Temporary | | 45 |
| Permanent brow | | 32 |
| Sepsis | 3 | |
| Permanent gastrostomy | | 2 |

* 59 evaluations.
** 20 or more units plus platelets and fresh frozen plasma (FFP).
*** 16 required prolonged ventilator assistance.
**** 1 suffered ischemia.

And are the complications worth the effort? The answer overall is yes. Families are grateful for the chance of treatment even if the patient has died. Survival has varied from near 100% for all types of benign tumor treatment to less than 20% for nasal melanoma or undifferentiated carcinoma. The survival rate 3 years or longer has been 70% for patients with malignancy treated primarily by skull base resection and approaches 40% for salvage surgery. The outcome certainly could be better, but when compared to suicide or almost certain death from disease, results seem favorable.