A combined frontotemporal and lateral infratemporal fossa approach to the skull base

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A variety of neoplasms involve both the infratemporal fossa and the base of the middle cranial fossa, in medial proximity to the cavernous sinus and orbital apex. To provide simultaneous access to both the intracranial and extracranial aspects of these tumors, a temporal or frontotemporal craniotomy may be combined with a lateral exposure of the infratemporal fossa. The approach, which is readily achieved by a neurosurgeon and an otolaryngologist acting as a team, involves a unilateral frontotemporal incision extended inferiorly onto the neck, a lateral facial flap reflected anteriorly, and transection of the zygoma followed by its reflection inferolaterally with the temporalis muscle. This exposure provides excellent visualization of both the intradural and extradural aspects of the anterior portion of the cavernous sinus, allowing for an aggressive resection of neoplasms involving this region. Experience with this procedure is reported here in the management of nine patients: three with nasopharyngeal angiofibromas, three with low-grade malignancies of the upper aerodigestive tract, and three with sphenoid ridge meningiomas.

KEY WORDS • skull base neoplasm • nasopharyngeal angiofibroma • brain neoplasm

The resection of neoplasms involving the skull base at the anteromedial aspect of the middle cranial fossa is hindered technically by the limited exposure provided by standard neurosurgical and otolaryngological approaches, and by the medial proximity of the orbital apex and cavernous sinus. Some neoplasms found in this region, such as invasive meningiomas of the sphenoid ridge and nasopharyngeal angiofibromas, are histologically benign, and may be cured if complete excision can be achieved.1,3,5,9,10 Others, such as low-grade malignancies of the upper aerodigestive tract, have been controlled by wide local excision when they are in purely extracranial locations.7 By combining a neurosurgical exposure of the middle cranial fossa with an otolaryngological exposure of the infratemporal fossa, it is possible to provide simultaneous access to the intracranial and extracranial aspects of those tumors that involve the skull base in this region. Such an exposure permits accurate identification of the anterolateral and inferolateral margins of the cavernous sinus and facilitates the aggressive resection of these neoplasms.

Operative Technique

After the induction of endotracheal anesthesia, a temporary tarsorrhaphy is performed to prevent postoperative chemosis, and a lumbar subarachnoid drain is placed to facilitate temporal lobe retraction. With the patient supine, the head is turned 45° toward the nonoperative side, extended slightly, and placed in a three-point fixation device. A frontotemporal incision is carried anterior to the tragus, inferior to the zygoma, and then below the mandible onto the neck (Fig. 1A). The skin flap is elevated superficial to the temporalis fascia superiorly and superficial to the parotid fascia inferiorly. If necessary, the internal and external carotid arteries may be isolated in the neck through the inferior limb of the incision. As the flap is reflected anteriorly, the plane of dissection is kept deep to the outer layer of the temporalis fascia to protect the superior or frontal branch of the facial nerve, and this subfascial plane is developed from the zygomatic process of the frontal bone to the zygomatic arch. The periosteum is then elevated along this line and the flap is further reflected.
Approach to skull base neoplasms

**FIG. 1.** Artist’s drawing depicting the technique for extradural exposure of the anterolateral and inferolateral boundaries of the cavernous sinus. 

A: The inferior limb of the incision is carried 3 cm inferior to the angle of the mandible to permit exposure of carotid bifurcation.  
B: Exposure of the zygoma and zygomatic bone deep to the outer layer of the temporalis fascia and periosteum.  
C: View showing the osteotomy superior to the zygomatico-facial foramen extending superiorly through the lateral wall of the orbit.  
D: Inferolateral displacement of the temporalis muscle and zygomatic complex to expose the periorbita and infratemporal fossa.  
E and F: Frontotemporal craniotomy with extradural elevation of the temporal pole to facilitate medial resection of the greater sphenoid wing and squamous temporal bone and to provide medial access to the infratemporal fossa.

...to expose: 1) the superolateral rim of the orbit; 2) the lateral aspect of the body of the zygoma to the zygomatico-facial foramen; and 3) the inferior aspect of the zygomatic arch (Fig. 1B). The zygoma is then transected at the frontozygomatic suture, across the midpoint of its body, and at the most posterior extent of the arch, and the first two cuts are connected just within the lateral rim of the orbit (Fig. 1C). The temporalis muscle is then dissected free from the temporal fossa and reflected inferiorly and laterally with the zygoma (Fig. 1D).

A free frontotemporal bone flap is created, tailored to provide access to the intracranial portion of the tumor, and the lateral aspect of the sphenoid ridge is removed with rongeurs (Fig. 1E). By opening the spinal drain, or by opening the dura and evacuating the basal cisterns, the temporal lobe may be gently elevated extradurally. The anteromedial portion of the squamous temporal bone and the entire greater wing of the sphenoid bone may then be removed with rongeurs, opening the lateral aspect of the superior orbital fissure, the foramen rotundum, the foramen ovale, and the foramen spinosum (Fig. 1F). The point at which the dura of the most anteromedial portion of the middle cranial fossa becomes continuous with the periorbita of the lateral wall of the orbit is now exposed, as are the second and third divisions of the trigeminal nerve leaving the middle cranial fossa within their dural sleeves. If needed, more medial exposure may be gained by transecting the third division of the trigeminal nerve, removing the medial and lateral pterygoid muscles, and removing the lateral pterygoid plate with a Kerrison rongeur.

At the completion of the tumor resection, the dura (if it has been opened or resected) is closed or grafted in as watertight a fashion as possible. If the pharynx or...
maxillary sinus has been entered, a portion of the temporalis muscle is folded into the infratemporal fossa to help isolate the epidural space. If the periorbita has been resected it is repaired with a graft of pericranium to prevent adhesions involving the extraocular muscles. The zygoma and bone flap are then wired back into place, and the scalp and skin are closed.

Representative Case Reports

This operative approach was utilized in the management of three nasopharyngeal angiofibromas, three low-grade upper aerodigestive tract tumors, and three sphenoid ridge neoplasms. The following cases illustrate the procedure.

Case 1

This 14-year-old boy presented with epistaxis. Computerized tomography (CT) scans (Fig. 2 upper) and arteriograms revealed a large vascular mass filling the nasopharynx, extending laterally through an enlarged pterygomaxillary fissure to involve the right infratemporal fossa. Superiorly, the mass filled the sphenoid sinus and eroded the greater wing of the sphenoid bone to involve the orbital apex and inferior aspect of the cavernous sinus.

After the preoperative embolization of the external carotid vessels feeding the mass, a combined frontotemporal infratemporal fossa exposure was performed. After extradural retraction of the temporal lobe and resection of the greater sphenoid wing, the superior pole of the tumor, which was entirely extradural, was bluntly dissected from the inferior aspect of the cavernous sinus and orbital apex. Brisk venous bleeding was encountered as the superior pole of the tumor was delivered and was controlled with Gelfoam and gentle tamponade. The second and third divisions of the fifth cranial nerve were dissected free from the lateral aspect of the mass and preserved, the medial and lateral pterygoid plates were removed with a Kerrison rongeur, the internal maxillary artery was ligated, and the bulk of the tumor was delivered laterally through the infratemporal fossa. The small portion of the tumor remaining with the sphenoid sinus was removed transnasally. The operative blood loss was 1200 cc.

Histological examination of the permanent pathological sections confirmed the diagnosis of nasopharyngeal angiofibroma. The patient experienced an uneventful postoperative course, and was discharged on the 5th postoperative day with trismus and hypesthesia in the distribution of the second and third divisions of the trigeminal nerve. One year postoperatively, he has mild restriction of mandibular excursion and mild facial hypesthesia, but no clinical or radiographic evidence of recurrent tumor (Fig. 2 lower).

Case 2

This 68-year-old right-handed man presented with a mass filling the right posterior nasal cavity. A CT scan revealed an enhancing mass filling the right infratemporal fossa, extending into the right maxillary, ethmoid, and sphenoid sinuses, and involving the right orbital apex and the medial aspect of the right middle cranial fossa. Transnasal biopsy revealed a moderately well-differentiated adenocarcinoma.

A combined frontotemporal infratemporal fossa exposure was used to approach the tumor laterally. The tumor had invaded the dura of the floor of the middle cranial fossa, and was adherent to the inferior temporal lobe. An anterior temporal lobectomy was performed and the involved dura was resected. The inferolateral...
portion of the cavernous sinus was entered, and the second and third divisions of the trigeminal nerve, which were involved extracranially, were sacrificed. Because the orbital apex was invaded by tumor, a partial maxillectomy and an orbital exenteration were performed through a Weber-Ferguson incision in combination with the lateral approach to achieve a gross total excision of the mass. The operation lasted for 16 hours and the estimated blood loss was 7500 cc.

The patient tolerated the procedure well, and by the following morning, although intubated, was alert and responding appropriately to verbal commands. On the 3rd postoperative day, he became febrile and confused, and a cerebrospinal fluid (CSF) profile was suggestive of meningitis, although he continued to receive perioperative antibiotics. After two operative explorations, a CSF fistula involving the orbital cavity was thought to be sealed, but the patient later developed Gram-negative meningitis and died without regaining consciousness. At autopsy, 7 months after his initial operative procedure, a small amount of residual tumor was present within the cavernous sinus.

Case 3

This 48-year-old right-handed woman underwent a left frontotemporal craniotomy and what was believed to be the complete excision of a 5-cm meningioma involving the lateral sphenoid ridge. She presented again 5 years later with recurrent proptosis. A CT scan revealed evidence of tumor in the lateral orbit, along the sphenoid ridge, in the middle cranial fossa, and in the temporalis muscle and infratemporal fossa (Fig. 3 left). The tumor was approached via a combined frontotemporal infratemporal fossa exposure. The temporalis muscle was found to be involved with tumor and was resected at its attachment on the coronoid process of the mandible. The lateral pterygoid muscle was also involved with tumor and was likewise resected. In order to identify normal periorbita, the lateral portion of the orbital roof was removed, as were the entire greater and lesser sphenoid wings, including the anterior clinoid process. A nodule of tumor entering the superior aspect of the cavernous sinus below the anterior clinoid was withdrawn in a single piece, and bleeding was controlled with gentle tamponade. When the bulk of the tumor had been removed, the involved periorbita was resected as far proximally as the anulus of Zinn and replaced with a patch graft of pericranium. The involved frontal and middle cranial fossa dura was then resected from this point posteriorly, the latter flush with the anterolateral and inferolateral margins of the cavernous sinus. The dural defect was repaired with a patch graft of pericranium. Because both the roof and the lateral wall of the orbit had been resected, they were reconstructed by the plastic surgery service with free rib grafts.

The patient had an uneventful postoperative course; she experienced complete resolution of her proptosis and her visual acuity returned to normal. A methacrylate cranioplasty placed 3 months postoperatively became infected and was later removed. One year postoperatively she is employed at a job. She has no CT evidence of residual meningioma (Fig. 3 right), but there is a left frontalis nerve palsy and a mild restriction of mandibular excursion.

Discussion

The infratemporal fossa is a quadrangular space bounded anteriorly by the maxillary sinus, medially by the pterygoid plate, laterally by the temporalis muscle and ramus of the mandible, and superiorly by the greater sphenoid wing in the floor of the middle cranial fossa. Normally it contains the medial and lateral pterygoid muscles, the mandibular division of the trigeminal nerve, the maxillary artery, and the pterygoid plexus of veins; but it also contains minor salivary gland rests which are considered to be the origin of some of the neoplasms found there, and may secondarily be involved by neoplasms of the upper aerodigestive tract and by some sphenoid ridge meningiomas. A number of lateral approaches to neoplasms found in the infratemporal fossa have been reported; these utilize a transection of the zygomatic arch (either alone or with a partial mandibular resection), a subtotal resection of the petrous temporal bone, or a temporal craniectomy to widely expose the region. While neoplasms confined to the infratemporal fossa and its extracranial environs may be successfully removed with such approaches, tumors that also involve the bone or dura of the floor of the middle cranial fossa medially are more difficult to completely expose. Some authors have regarded these tumors as inoperable or as requiring a subtotal resection, in part due to the proximity of the cavernous sinus.

Fig. 3. Case 3. Left: Preoperative enhanced computerized tomography (CT) scan of a 48-year-old woman with recurrent proptosis 5 years following the resection of a sphenoid ridge meningioma. At surgery, the temporalis and lateral pterygoid muscles, periorbita, and part of the dura over the lateral aspect of the cavernous sinus were found to be invaded by tumor and were resected. Right: Enhanced CT scan 1 year postoperatively revealing resolution of proptosis and no residual tumor. The lateral orbital wall has been reconstructed with a free rib graft.
The surgical procedure described here has evolved from the infratemporal fossa approach popularized by Fisch for the resection of aerodigestive tract neoplasms involving the infratemporal fossa, and the frontotemporal approach developed by Derome and Guiot for the resection of hyperostosing sphenoid ridge meningiomas. In the initial four patients we treated with this disease (who have been reported previously) the exposure was achieved via a retroauricular incision. The preauricular incision described here, first utilized in a patient with a previous frontotemporal craniotomy, has been found to provide the same exposure without transecting the external auditory canal, and is therefore preferable as reconstruction of the canal often leaves it stenotic. Early in our experience the value of transecting the zygoma so as to include the lateral orbital rim was not fully appreciated. The lateral displacement of the posterior and superior portions of the zygomatic bone not only exposes the infratemporal fossa but also opens the lateral wall of the orbit, and with a temporal craniectomy allows for the complete resection of the greater sphenoid wing. The greater wing forms the lateral margin of the superior orbital fissure which transmits the third, fourth, first division of the fifth, and the sixth cranial nerves from the cavernous sinus to the orbital apex, and the lateral margin of the foramen rotundum and the foramen ovale which transmits the second and third divisions of the fifth cranial nerve from the inferior portion of the cavernous sinus. Complete resection of the greater wing therefore defines the anterolateral and inferolateral boundaries of the sinus, and in addition provides direct access to the pterygomaxillary fissure in the medial wall of the infratemporal fossa. The extradural elevation of the temporal lobe permitted by a temporal craniectomy further enhances this medial exposure within the infratemporal fossa.

The most common benign tumor involving the base of the middle cranial fossa from below is the nasopharyngeal angiofibroma. This highly vascular neoplasm of adolescent males has its origin in the roof of the nasal cavity posteriorly, and gains access to the infratemporal fossa by widening the pterygomaxillary fissure. At presentation, 10% to 20% of patients have proptosis, with radiographic evidence of widening of the superior orbital fissure and displacement of the intracavernous carotid artery. Despite eroding bone and displacing intracranial structures, this tumor only rarely actually invades dura. Currently, its best management is thought to be complete excision, which is curative but has proven difficult to achieve in those patients with intracranial involvement. Jafek, et al., reported the management of 15 patients with intracranial extension with a frontotemporal craniotomy followed by a lateral rhinotomy. They advocated incomplete resection of tumors involving the middle cranial fossa medially, and treated 11 of their patients with radiation therapy postoperatively, presumably on this basis. Fisch reported the management of nine patients with intracranial involvement via an infratemporal fossa approach utilizing an inferolateral displacement of the zygomatic arch and a subtotal resection of the petrous temporal bone. An incomplete excision was achieved in four patients with tumor “medial to the cavernous sinus,” two of whom later experienced progression of their disease. The anterior exposure provided by the present approach provides better access to the superior pole of the tumor than either of these prior approaches, with a single operation and without a time-consuming resection of the petrous temporal bone. This approach is technically easier than that proposed by Fisch, and provides greater access to the orbital apex than can be achieved through the temporal bone. With this approach, complete excisions have been achieved in three consecutive patients with angiofibromas extending medial to the cavernous sinus, with no mortality and no morbidity other than facial hypesthesia.

While complete excision of a nasopharyngeal angiofibroma is believed to be curative, the role of surgery in the management of malignant aerodigestive tract neoplasms involving the floor of the middle cranial fossa from below is yet unclear. Fisch and Smith and Sharkey have reported approaches to tumors in the infratemporal fossa based on an inferolateral displacement of the zygoma and a subtotal petrosectomy. In Fisch’s series of 13 patients with nasopharyngeal carcinoma, seven patients with extensive disease died despite radiation therapy and surgery, but six patients with more limited disease involving the infratemporal fossa were alive and disease-free with a follow-up period of 2 to 5 years. In Smith and Sharkey’s series of seven patients with a variety of malignant neoplasms involving the infratemporal fossa and parapharynx in whom an en bloc incision with tumor-free margins was achieved, five were disease-free with a mean follow-up period of 2 years. Both authors consider that tumor traversing the dura is unresectable. Sekhar, et al., have reported a combined infratemporal middle cranial fossa approach, which allows for the resection not only of involved dura but also of the intrapetrous carotid artery; they reported initial success with a limited follow-up period.

The approach reported here is more anterior, not suited for lesions involving the petrous temporal bone, but providing good access to the infratemporal fossa and floor of the middle cranial fossa anteriorly. Retraction of the temporal lobe greatly enhances the inferomedial exposure, permits intradural inspection, and facilitates the wide resection of involved dura. Despite this wide exposure, a true en bloc excision of invaded tissue is difficult or impossible to achieve in this region, and after excision it is difficult to isolate the subarachnoid space from the nasopharynx. In addition to the case described here (Case 2), another patient with a nasopharyngeal carcinoma developed a postoperative wound infection and meningitis. One year postoperatively he is alive and pain-free, but has biopsy-proven evidence of recurrent tumor. A third patient, with a low-grade adenoid cystic carcinoma, remains disease-free 2 years postoperatively.

Hyperostosing meningiomas of the sphenoid ridge,
while histologically benign, are locally invasive and require wide exposure and aggressive resection for their effective management.\textsuperscript{1,4,10} In the large series reported by Pompili, et al.,\textsuperscript{10} bone was involved in 94\% of the cases, periorbita in 30\%, and temporalis muscle in 12\%. Those tumors that recur after incomplete resection often invade the infratemporal fossa as well. By protecting the periorbita through a separate brow incision, Derome and Guiot\textsuperscript{7} have resected the entire greater and lesser sphenoid wings via a frontotemporal approach, achieving what was considered to be a complete excision in 70\% of their cases. They believed that the orbital decompression afforded by this bone resection was beneficial even in those cases in which a complete excision was not possible. The combined approach reported here provides a wider exposure of the interface between normal anatomy and tumor along the lateral wall of the orbit and in the temporal and infratemporal fossae than may be achieved via a frontotemporal approach, and may therefore be preferred in the management of tumors that have recurred after an incomplete resection. In addition to the patient described here (Case 3), the other two patients in this series with hyperostosing sphenoid ridge meningiomas extensively involving the infratemporal fossa experienced improvement of visual acuity and proptosis with orbital decompression despite incomplete tumor excision.

Of the nine patients operated on with this approach to date, the single death and the only serious morbidity associated with this procedure have been in those patients with malignant aerodigestive tract neoplasms, as described above. In all patients, the dissection of the temporalis and lateral pterygoid muscles required to widely expose the infratemporal fossa has at least partially denervated these muscles, restricting mandibular excursion postoperatively, although this has not been functionally significant. Complete removal of the lateral wall of the orbit produces mild enophthalmos, if any, and no functional deficit.

The strength of this operative approach is that in a technically straightforward manner it provides a wide exposure of the interface between normal and neoplastic tissues in the middle cranial fossa, infratemporal fossa, and lateral orbit. Just as benign tumors arising within the cavernous sinus, displacing the carotid artery and nerves within it, may often be removed without injuring these structures,\textsuperscript{12} benign tumors such as nasopharyngeal angiofibromas and some meningiomas which displace these structures from without may be safely removed with adequate exposure. Invasive neoplasms, whether histologically benign or malignant, that traverse the walls of the cavernous sinus are difficult to remove without impairing cranial nerve function, but in cases in which only a margin of the sinus is invaded, the definition of its anterior and inferior boundaries aids in evaluating intraoperatively the resectability of a tumor. A combined exposure of the middle cranial and infratemporal fossae greatly facilitates the complete excision of benign neoplasms involving the skull base medially, and allows for the maximally aggressive resection of carefully selected malignant neoplasms in this region.

References