Temporal Bone Meningiomas

ABSTRACT—Meningiomas involving the temporal bone may originate from arachnoid cell nests present within the temporal bone (intratemporal), but more frequently originate from arachnoid cell nests of the posterior or middle cranial fossa with secondary invasion of the TB (extratemporal). In this study, we retrospectively reviewed the charts of 13 patients with meningiomas involving the temporal bone who underwent surgery. Tumors of the posterior fossa with only temporal bone hyperostosis, but without invasion, were excluded. Patients presented primarily with otologic symptoms and signs. The tumors originated in the temporal bone (5/13), jugular foramen (4/13), petroclival region (2/13), the asterion (1/13) or the internal auditory meatus (1/13). All of the intratemporal meningiomas had the radiological appearance of en-plaque meningiomas. The tumor extended into the middle ear (11/13), eustachian tube (5/13), and/or the labyrinth (3/13). A gross total resection was achieved in 11 patients and a subtotal resection in 2 patients. The lower cranial nerves were infiltrated by tumor in 4 patients, and were sacrificed. At a mean follow-up of approximately 6 years, 12 patients are currently alive and doing well and 1 died from tumor progression. Six patients showed tumor recurrence and were reoperated on (5/6) or followed conservatively (1/6). Surgical treatment of temporal bone meningiomas is associated with high recurrence rate due to indiscreet tumor margins. Combined surgical approaches (temporal craniotomy and mastoidectomy) by neurosurgical and otological teams are recommended for meningiomas originating in the temporal bone.

Harvey Cushing¹ first coined the term meningioma in 1922 to describe the usually benign tumors originating from arachnoid lining cells. He described two distinct varieties, the global type and the en-plaque type. The en-plaque meningioma extended as a superficial carpet of intradural tumor, and was associated with thickened dura and extensive involvement of the adjacent bone; whereas, the global type grew as a spherical tumor expanding the sylvian fissure. He was puzzled by the fact that two distinct types of meningiomas could arise from the same area: the pterion. He postulated that differences in vascularity of the bone or dura may favor one type over the other.¹ In 1947 Proctor and Lindsay² called attention to tumors involving the temporal bone

and first noticed that meningiomas of the temporal bone usually spare the bony labyrinth. They also described how the temporal bone could be involved by tumors originating within the temporal bone, by tumors arising from adjacent structures and by tumors metastasizing from distant primary foci.

In 1964 Nager,³ in his seminal work, cited 30 cases of temporal bone meningiomas and added 7 more, some of which were operated on by Walter Dandy. While the majority of temporal bone meningiomas had large intracranial components with secondary involvement of the temporal bone, Nager postulated a primary temporal bone origin in 6 cases. To explain the unusual origin of these 6 cases, he examined normal temporal bones and

found arachnoid granulations in four sites: (1) in the internal auditory meatus; (2) along the greater superficial petrosal nerve and geniculate ganglion; (3) within the jugular foramen; and (4) in the middle ear through small brain herniations through the tegmen (Fig. 1). In 1983 Rietz et al,⁴ summarized 79 cases of temporal bone meningiomas reported in the world literature and found that approximately 70% of cases were combined intracranial and intratemporal meningiomas with only 25% being only intratemporal.

In this report, we describe 13 cases of meningiomas involving the temporal bone, 5 of which originated within the temporal bone as judged by clinical symptoms, preoperative radiological studies, and intraoperative findings. We draw attention to the similarities of intratemporal meningiomas with the Cushing's en-plaque variety and emphasize their high recurrence rate even after aggressive surgery.

CLINICAL MATERIALS AND METHODS

The charts of 13 patients with meningiomas involving the temporal bone operated on at the Baptist Hospital in Memphis between 1981 and 1996, were reviewed. There were a total of 416 intracranial meningiomas operated on, of which 92 (22%) involved the posterior fossa. Patients with cerebello-pontine angle meningiomas and temporal bone hyperostosis were excluded. There were 10 women and 3 men with a mean age of 50 (range: 31 to 77 years).

The clinical manifestations were: hearing loss in 9 patients (69%); tinnitus in 6 patients (46%); headaches in 5 patients (38%); dysphagia, dizziness and otalgia in 3 patients (23%); unsteady gait, seizures and fullness of the ear in 2 patients (15%); and otorrhea in 1 patient (8%) (Table 1). The duration of the symptoms ranged from 2 months to 8 years with a mean of 28 months. Previous biopsy, usually at referring facilities, through mastoidectomy or tympanotomy was performed in 10 of 13 cases. The preoperative diagnosis prior to biopsy and angiography was meningioma (7 cases), glomus jugulare tumor (4 cases), cholesteatoma (1 case), and intracanalicular vestibular schwannoma (1 case). In 2 of the 4 cases with a preoperative diagnosis of glomus tumor, even the initial biopsy was read as glomus jugulare tumor. This diagnosis was placed in doubt when subsequent cerebral arteriogram showed minimal vascularity.

The physical exam showed decreased hearing in 12 patients, dysmetria in 2 patients and involvement of cranial nerves (CN) 6: 1 patient, (CN) 7: 1 patient, and (CN) 9,10 in 2 patients. One patient had a normal physical exam.

Patients were evaluated preoperatively by computed tomography (CT) (11/13), magnetic resonance imaging (MRI) (9/13) and cerebral angiography (10/13). On MRI, brainstem compression was present in

3 cases, and on CT hyperostosis was present in 6 cases. Most tumors evaluated by angiography were avascular or faintly vascular, but in 3 cases there was moderate tumor blush.

Preoperative audiometry was obtained in 10 cases, with useful hearing (<50 dB hearing loss and over 50% speech discrimination score) present in half of the patients.

RESULTS

Surgery was performed for progressive symptoms or documented tumor growth. Gross total tumor removal was achieved in 11 cases (84%). In the remaining cases, tumor was present in the cavernous sinus or along the brain stem and was left undisturbed (Table 1).

Various surgical approaches were utilized. The approach most often used was the transmastoid (10 cases), either alone (2 cases) or in combination with a middle fossa craniotomy (3 cases) (Fig. 2), with a lateral skull base (infratemporal fossa) approach (4 cases) or with a suboccipital craniectomy (1 case). The different variants of the transmastoid approach included: transcochlear (3 patients), translabyrinthine (3 patients), infralabyrinthine (2 patients), and simple mastoidectomy (2 patients). A middle fossa craniotomy alone was used in 3 cases.

Based on intraoperative findings, there were 5 cases of intratemporal meningiomas (38%) and 8 cases of extratemporal meningiomas with secondary temporal bone invasion (62%). In the latter group, a dural origin of the tumor from the jugular foramen, petroclival region, internal auditory canal (IAC) and the sinodural angle was documented intraoperatively. All cases of intratemporal meningiomas showed hyperostosis of the temporal bone associated with "carpet-like" involvement of the dura along the middle or posterior cranial fossa and a soft-tissue mass in the middle ear; the radiographic appearance of the lesion was that of an en-plaque meningioma. Of the cases where the temporal bone was felt to be involved secondarily, the tumor was felt to be arising from the jugular foramen in 4 patients (30%), the petroclival region in 2 patients (15%), the internal auditory meatus in 1 patient (7%), and the sinodural angle (asterion) in 1 patient (7%). Overall, tumor was found in the middle ear in 11 patients; in the eustachian tube in 5 patients; involving the sigmoid sinus, transverse sinus or jugular vein in 5 patients; involving the middle cranial fossa floor (tegmen) in 4 patients; and involving the external auditory canal or tympanic membrane in 2 patients. The labyrinth and cochlea were invaded by tumor in 3 patients.

CN involvement was frequently seen intraoperatively and necessitated sacrifice of the involved nerve in the majority of cases. The facial nerve was involved in 3

Figure 1. Drawing illustrating the presence of arachnoid cells (black dots) within the internal auditory canal, around the greater superficial petrosal nerve and geniculate ganglion, the jugular bulb, or the tegmen along the origin of the eustachian tube. These arachnoid cells can presumably give origin to meningiomas arising from the temporal bone (intratemporal meningiomas). Adapted from Nager et al.³

cases (at the level of the IAC, geniculate ganglion or tympanic segment) and was sacrificed in 2 patients. In one patient a primary reanastomosis of the facial nerve was performed. The lower CN were involved in 4 patients and could not be spared. Other CN involved were CN 6 (1 case), CN 8 (1 case) and CN12 (1 case).

Permanent postoperative complications included four facial nerve dysfunctions (House–Brackmann grade III in 2 and grade VI in the remaining), 4 lower CN deficits (CN IX and X) and one hypoglossal nerve palsy. Three of four patients with postoperative facial nerve paresis or palsy had been operated on by a transcochlear approach with facial nerve transposition. One of the 2 patients with new postoperative facial nerve palsy had facial weakness preoperatively. Two of

four patients with postoperative lower CN deficits presented initially with dysphagia. One patient underwent tarsorrhaphy, 2 patients underwent tracheostomy, 3 had temporary gastrostomies, and 4 had teflon injection for vocal cord paralysis. At an average follow-up of 6 years (range: 6 months to 11.6 years), 12 of 13 patients were independent in their activities. One elderly patient who underwent a subtotal resection of an extensive petroclival meningioma as life-saving surgery, died 6 months later from tumor progression. There were 6 recurrences, 5 of which were reoperated on. Half of the recurrences occurred at the jugular foramen. Two patients that were reoperated on are known to have residual, stable disease.

CLINICAL EXAMPLES

Meningiomas Arising Within the Temporal Bone

Case No. 1

This 51-year-old man presented with a 2-month history of progressive right hearing loss, pulsatile tinnitus, dizziness, and right retro-orbital headache. Audiometric studies showed normal hearing on the left with a 32-dB conductive hearing loss on the right. A mastoidectomy was performed at a referring facility, a tumor was encountered in the middle ear and a biopsy established the diagnosis of meningioma. A CT scan through the temporal bone showed hyperostotic bone in the tegmen extending to the glenoid fossa, associated with a mass in the middle ear (Figs. 3A, 3C, and 3D). MRI showed dural enhancement in the floor of the middle cranial fossa (Fig. 3B). The tumor was removed through a combined middle cranial fossa craniotomy and mastoidectomy (Fig. 2). During surgery, a vascular, grayish mass was found in the antrum and epitympanum, enveloping the ossicular chain and invading the posterior superior portion of the tympanic membrane. The facial nerve was not involved (the tympanic segment was covered by bone). Similarly, there was no invasion of the otic capsule. The dura of the middle cranial fossa appeared vascular and discolored and was excised. However, no definite tumor was found on histopathological examination. A prosthesis was used to bridge the capitulum of the stapes and the handle of the malleus. A tympanoplasty and meatoplasty was performed. The inner table of the middle fossa bone flap was used to reconstruct the floor of the middle cranial fossa after drilling the hyperostotic bone. A vascularized pericranium and posterior temporalis muscle flap was used to seal the defect and prevent a cerebrospinal fluid (CSF) leak. There were no postoperative complications and the patient has retained some hearing in the operated ear.

Table 1. Clinical Manifestations of 13 Patients with Temporal Bone Meningiomas

Case #	Age/sex	Symptoms	Tumor Location	Approach	Complications			Recurrence	CF/U
					Transient	Permanent	F/U		
1	51/M	2-month H/O mild hearing loss, dizziness, and tinnitus	TB	Combined MCF craniotomy & mastoidectomy	None	None	1 yr.	None	Good
2	37/F	8-yr. H/O fluctuating hearing loss	TB	MCF craniotomy	CN 5 paresis	None	4.5 yrs.	None	Good
3	61/F	1-yr. H/O tinnitus, hearing loss, and otorrhea	TB	MCF craniotomy	None	None	6.7 yrs.	None	Good
4	31/F	6-yr. H/O fullness in the ear, with mass behind the TM	TB	Combined MCF craniotomy, Lateral skull base	None	None	11.6 yrs.	Yes (Sphenoid sinus, optic canal)	Good
5	61/F	6-month H/O hearing loss, with mass behind TM	TB	Infralabyrinthine/suboccipital	CSF leak	None	9.5 yrs.	Yes (JF)	Good
6	49/M	2-yr. H/O pulsatile tinnitus, with dysphagia	JF	Translabyrinthine/lateral skull base	None	CN 9,10 palsies, moderate	5.1 yrs.	Yes (JF)	Good
7	42/F	7-yr. H/O tinnitus, dysphagia, and otalgia	JF	Translabyrinthine/lateral skull base	CN 6 paresis	CN 7 paresis CN 9,10,11 palsies	9.2 yrs.	Yes (JF)	Good

8	50/F	6-month H/O hearing loss, HA, and unsteady gait	JF	Intralabyrinthine/ lateral skull base	CN 7 paresis	CN 9,10,11 palsies	7.5 yrs.	Yes (Petrus apex)	Good
9	53/F	3 month H/O "pressure" feeling of the right neck and mild hearing loss	JF	Transcochlear/ lateral skull base	None	CN 9,10,11,12 palsies, mild CN 5 paresis Moderate CN 7 paresis	11 yrs.	None	Good
10	48/F	1-yr. H/O tinnitus, vertigo, and hearing loss	IAC	Translabyrinthine	CN 7 paresis	None	5 yrs.	None	Good
11	77/F	4-month H/O hearing loss, tinnitus, otalgia, and diplopia	Petroclival	Transcochlear (subtotal resection)	None	CN 7 palsy	6 months	NA	Pt. died 6 mo. after surgery from tumor progression
12	65/F	1-yr. H/O dysphagia, decreased hearing, facial weakness, and unsteady gait	Petroclival	Combined MCF craniotomy/ transcochlear (subtotal resection)	Hemiparesis, CN 3,4 paresis	CN 7 palsy	6 months	NA	Mild disability
13	34/M	Presented with temporal lobe seizures to outside hospital 9 yrs. prior to admission, underwent subtotal removal of tumor, XRT, now with new temporal lobe seizures	Asterion	Combined MCF craniotomy & mastoidectomy	None	None	6 yrs.	Yes (Asterion)	Good

TB = temporal bone; MCF = middle cranial fossa; TM = tympanic membrane; JF = jugular foramen; H/O: History of; F/U: follow-up; H/A: headache; IAC: internal auditory canal; and CF/U: condition on last follow-up.

Figure 2. (A) Drawing illustrating the combined middle fossa craniotomy/mastoidectomy approach for intratemporal meningiomas. Lateral view of the temporal bone. Red interrupted line indicates the skin incision, blue interrupted line shows the area of the temporal craniotomy, and the shaded area represents the mastoidectomy. (B) Drawing illustrating the exposure obtained after anterior reflection of the temporalis muscle and mastoidectomy. Critical structures of the temporal bone (semicircular canals, ossicles, facial nerve, sigmoid sinus) are depicted as seen from a lateral view of the temporal bone. Facial nerve is shown in yellow color, transverse and sigmoid sinuses in blue color, and temporalis muscle in red color. (C) Drawing illustrating temporal bone structures as seen from superiorly (middle fossa view). The facial nerve is shown in yellow color from its entrance to the IAC to its exit at the stylomastoid foramen. The middle meningeal artery and foramen spinosum are seen in red. Two retractors are shown elevating the temporal lobe extradurally. The superior wall of the IAC was drilled showing the facial nerve coursing toward the geniculate ganglion and the cochlear nerve toward the cochlea. A lateral and superior view of temporal bone structures is important for total removal of meningiomas arising in the temporal bone.

Case No. 4

The patient is a 31-year-old woman with 2 year history of tinnitus, hearing loss, "fullness" in the left ear, and a mass seen behind the tympanic membrane. Exploration of the left middle ear showed a grayish mass that proved to be a typical meningioma on histology. At the time, the tumor was confined within the temporal bone without significant intracranial extension

(Fig. 4A). She had useful hearing in the left ear. She was observed for approximately 2 years. She developed a mass in the left temporal area that was removed and was identified as a meningioma involving the temporalis muscle (Fig. 4B). Soon after that follow-up CT scans showed extension of the temporal bone meningioma in the infratemporal fossa and she was referred to us for further treatment (Fig. 4C). On exam she had only a mild conductive hearing loss on the left. A middle fossa

Figure 3. Case No. 1: Meningioma arising within the right temporal bone. (A) axial CT, contrast-enhanced image showing diffuse hyperostosis of the right temporal bone (arrow). (B) coronal T1-weighted, gadolinium-enhanced image showing dural enhancement along the floor of the middle cranial fossa (arrow). (C) hyperostotic bone, floor of the middle cranial fossa (arrow). Note sparing of the labyrinth (arrowhead). (D) soft-tissue density (tumor) filling the epitympanum and surrounding the malleus, incus, and stapes (extending to the oval window) (arrow).

craniotomy was combined with a lateral skull base approach in two stages. During the first stage the entire floor of the middle cranial fossa was drilled out. Extension of the tumor into the middle ear was removed and all hyperostotic bone around the internal carotid artery, facial nerve, and eustachian tube was removed. During the second stage, the infratemporal part of the tumor was removed. The tumor was invading the glenoid fossa, the zygoma, the pterygoid muscles, and the parotid gland. Postoperatively, there were no complications. She described an improvement in tinnitus and no change in hearing. Six years after the last surgery she

was found to have tumor recurrence in the sphenoid sinus, the left optic canal, and infratemporal fossa.

Jugular Foramen Meningiomas with Temporal Bone Involvement

Case No. 6

The patient is a 49-year-old man with 2-year history of pulsatile tinnitus and dysphagia. Physical exam showed left hearing loss [speech reception threshold

Figure 4. Meningioma arising within the temporal bone. Case No. 4: (A) Left temporal bone "en plaque" meningioma (arrow) (coronal CT, contrast-enhanced image). (B) Mass (tumor) involving the left temporalis muscle (□). (C) Tumor extension into the infratemporal fossa (arrow).

(SRT): 20%, 65 dB pure tone average (PTA)]. CT scan showed a mass involving the left jugular foramen (Figs. 5A and 5B). The patient was referred to us for evaluation of a "glomus tumor." An arteriogram showed only a faint tumor blush unlike a glomus tumor. A tympanotomy and biopsy established the diagnosis of meningioma. The tumor was removed by a translabyrinthine/lateral skull base approach. During surgery the tumor was found to arise from the dura of the jugular foramen with involvement of CN 9 and 10. The tumor was also found in the middle ear, in the eustachian tube orifice, and in the jugular vein. Postoperatively, he underwent a temporary gas-

trostomy, tarsorrhaphy, and Teflon injection for vocal cord paralysis. He recovered well and was able to return to his previous occupation. He developed a recurrence at the jugular foramen and underwent a subtotal resection (small amount of tumor adherent to the internal carotid artery was left behind). Follow-up scans have showed no change in size in 2 years.

Case No. 9

Patient is a 53-year-old woman with decreased hearing, "fullness" of the right ear and "pressure" feel-

Figure 5. Jugular foramen meningiomas with temporal bone extension. (A, B): Case No. 6: (A) Enhancing lesion extending through an enlarged left jugular foramen (arrow, axial MRI, T1-weighted, gadolinium-enhanced image). (B) note erosion of the bone at the jugular foramen (arrow). (C, D): Case No. 9: (C) Enhancing mass in the infratemporal fossa and parapharyngeal region, extending medial to the ramus of the mandible and posterior to the pterygoid plates (arrow). (D) Cerebral arteriogram, showing vague enhancement, not consistent with glomus jugulare tumor.

ing in the neck for 3 months. A CT scan showed a right jugular foramen tumor extending to the infratemporal fossa (Fig. 5C). A biopsy at a referring facility was read as glomus jugulare tumor. Cerebral arteriogram showed encasement and stenosis of the cervical ICA and moderate vascularity, not consistent with a diagnosis of a glomus tumor (Fig. 5D). She was operated on via a transcochlear/lateral skull base approach. The tumor was peeled off the adventitia of the cervical ICA and was also removed from the parapharyngeal space, infratemporal fossa, and jugular foramen. The tumor extended to the middle ear, eustachian tube, and invaded the cochlea. The lower CN were infiltrated by tumor

and were sacrificed. Postoperatively she underwent a tracheostomy and Teflon injection. She has showed no evidence of tumor recurrence over 11 years. Her swallowing has improved. She has resumed her occupation.

Meningioma of the Petroclival Region with Temporal Bone Involvement

Case No. 12

A 65-year-old woman had a petroclival meningioma subtotally removed 15 years before she was

referred to us. She underwent external radiation therapy. She presented to us with 1-year history of facial weakness, dysphagia, decreased hearing, and unsteady gait. She had no measurable hearing on the right. In addition, she had CN 5, 7, and 9 paresis on the right side. MRI showed tumor recurrence involving the right temporal bone, petrous apex, cavernous sinus, and cerebello-pontine angle (Figs. 6A and 6B). During surgery the tumor was found to invade the facial nerve at the level of the IAC and the geniculate ganglion and was sacrificed. Tumor was also invading the cochlea, the eustachian tube, and the middle ear. The tumor in the cavernous sinus was not removed. She had a tracheostomy and a gastros-

tomy. She is currently recovering well, but she requires assistance in her daily activities.

DISCUSSION

Meningiomas arising from the temporal bone are rare lesions.^{3,5-12} Their origin is likely related to the presence of arachnoid cells within the IAC, around the greater superficial petrosal nerve (GSPN), the geniculate ganglion, the jugular bulb, or from arachnoid granulations that infrequently herniate through the tegmen into the middle ear.^{3,13,14} Dissections of normal temporal bones by both Nager and Guzowski^{3,14} support this theory. Although spontaneous brain herniations into the middle ear are certainly rare, tegmen defects are not (incidence of 6 to 15% in one cadaver study).^{15,16} However, pure intratympanic meningiomas confined to the middle ear have not been associated with any form of dural prolapse through the tegmen and in some cases there is no association of the tumor with the tympanic segment of the facial nerve.^{6,7,9,11,12,17} Furthermore, there is no normal meningeal investment of the tympanic and mastoid segments of the facial nerve. These findings have prompted a number of authors to propose that ectopic arachnoid cells, which are trapped within the skull bones or along the extracranial portion of cranial nerves (CN) are responsible for the formation of extracranial meningiomas.^{4,18-20} Furthermore, given that ectopic, extraneuraxial meningiomas have even been described in places such as the parotid gland, parapharyngeal space, deltoid muscle and fingers, led Shuangshotti et al,¹⁸⁻²⁸ to propose that these tumors may arise from multipotential mesenchymal cells along meningocytic, fibroblastic and Schwann cell lineages. Although most meningiomas arise from arachnoid cells, the embryological origin of those cells, whether neural crest or mesenchymal, is still controversial.²⁹ Harvey Cushing¹ considered meningiomas to be neuroectodermal, originating from a "primitive leptomeningeal cell" (the "meningocyte"), that has the ability to differentiate along various histological lines. Others, such as Kepes,²⁹ favored a mesodermal origin. The fact that meningiomas histopathologically seem to follow mesenchymal lines (such as fibroblastic, xanthomatous, chondroblastic, etc.), that they do not show differentiation along glial or neuronal lines and that they lack electron microscopic findings characteristic of neural crest derivation, favors a mesenchymal (mesodermal) origin of meningiomas.²⁹

In this report, we describe 13 cases of temporal bone meningiomas and postulate a primary intratemporal origin in 5 of these cases. The remaining cases involved the temporal bone by extension through the jugular foramen, the IAC, the sinodural angle (asterion), and the petroclival area. All five intratemporal meningiomas had radiographic similarities with the en plaque type of meningioma, (significant hyperostosis and os-

Figure 6. Petroclival meningioma with temporal bone involvement. Case No. 12: Axial and coronal MRI T1-weighted, gadolinium-enhanced images showing enhancing mass occupying the anterior temporal bone and the petroclival region (arrows).

seous involvement associated with minimal intradural component), as described by Cushing.¹ Although speculative, it is possible that an osseous origin of a meningioma from ectopic arachnoid cells leads to an en-plaque variety, whereas an intradural arachnoid origin leads to the more common globoid type with significant overlap between both types. The clinical significance of the en-plaque variety lies more in its tendency to invade along preformed passages, such as the Haversian canals or in the submucosal plane of air cells that makes recurrence after surgery more likely.^{3,10} It does not, however, imply a more rapid growth or an unfavorable prognosis, as most patients with pterional en-plaque meningiomas have a slow growth and favorable prognosis.¹

In our study, the majority of patients presented with hearing loss and tinnitus, as in most other studies.^{4,17,30} Approximately half of the patients were initially thought to have a different diagnosis, most commonly a glomus jugulare tumor. This misdiagnosis occurred at both the clinical and the histopathological level. One patient suffered from fluctuating hearing loss for 8 years and was treated with numerous myringotomy tubes before the diagnosis was made. Two patients were misdiagnosed as having glomus tumors even after a biopsy, before an arteriogram showed a hypovascular mass and raised doubts about the diagnosis. The difficulty lies in that glomus tumors and meningiomas have nests of cells that tend to be uniform; however, an epithelioid appearance of the cells in a highly vascularized fibrous stroma suggests the diagnosis of a glomus tumor rather than a meningioma.^{4,31} In contrast, a tightly whorled appearance, presence of psammoma bodies and, epithelial membrane antigen and vimentin positivity are characteristics of meningiomas.³² In uncertain cases, electron microscopic examination may show desmosomes, cytoskeletal filaments or interdigitating cytoplasmic processes in meningiomas and intracytoplasmic dense core granules in glomus tumors.⁴ Other useful radiographic features to distinguish meningiomas from glomus tumors include: (1) a typical "vascular blush" is seen in glomus tumors, although occasional meningiomas can be also vascular^{33,34}; the vascularity of glomus tumors seen in arteriograms has, according to some authors, replaced the need for a biopsy of these tumors³⁵; (2) CT scans often show hyperostosis of the temporal bone with little bone erosion in meningiomas, in contrast to glomus tumors where bone erosion is more common^{33,36}; (3) MRI scans usually show a "salt and pepper" heterogeneous appearance or serpentine flow voids in vascular glomus tumors; in contrast, meningiomas tend to be homogeneously enhancing; (4) adjacent dural thickening and enhancement of the middle fossa floor is usually seen with en-plaque temporal bone meningiomas, but not with glomus tumors.

Another diagnostic dilemma is the rare meningioma of the IAC.³⁷ These tumors may arise from arachnoid cells within the IAC, displace CN 7 and 8 in vari-

ous, atypical directions (in contrast to vestibular schwannomas, where an anterior-superior course of the facial nerve in relationship to the tumor is commonly observed) and occasionally penetrate along nerve fibers into the cochlea, vestibule, and semicircular canals, as seen in one of our cases.

Preoperative diagnosis of meningioma affecting the temporal bone is important from a hearing preservation standpoint.³⁸ Previous studies have shown that attempted hearing preservation after meningioma removal is more often successful than after removal of vestibular schwannomas.³⁸ This difference may be due to the diverse and multifactorial causes of hearing loss in temporal bone meningiomas (most commonly due to involvement of the ossicles and less commonly due to involvement of the cochlear nerve or the labyrinth) in contrast to vestibular schwannomas that so frequently show an intimate relationship with the cochlear nerve and its blood supply. Although postoperative audiometric follow-up was not adequate in all of our patients, at least two patients experienced improved hearing postoperatively.

It should be noted that despite gross total resection of the tumor in the majority of our patients, there was a recurrence rate of approximately 54% at 6 years of follow-up. Recurrences were predominantly in the jugular foramen. Nager et al³⁹ emphasized that once a meningioma has involved the temporal bone, its tendency to extend outside the skull greatly increases (to 43%). He found that the most common pathway of extension was through the jugular and lacerate foramina into the parapharyngeal space, where it may present as a nasopharyngeal, oropharyngeal, retromaxillary, retromandibular, or cervical neck mass.³⁹ Resection of recurrent tumor is associated with higher complication rates and is seldom curative. Furthermore, adjunct treatments such as external radiation therapy or chemotherapy are of limited use and at times controversial.⁴⁰ Focused radiation (gamma knife, LINAC), has changed the philosophy of skull base surgery over the last 10 years, from "total" to "near total" resections with preservation of infiltrated, but still functioning, CN.⁴¹ In this respect, local recurrence amenable to repeat resection may be associated with less morbidity than "cure" by radical resection resulting in significant postoperative deficits. Although we practice this philosophy in older patients, we are still lacking long-term results in patients with skull base meningiomas treated with radiosurgery.

We recommend an aggressive removal of the tumor during the first surgery only for young patients. We believe that the risks of CN dysfunction are justified when the patient is young and wishes a total tumor removal. The problem of indiscreet tumor margins can be overcome by the use of image-guided systems that provide continuous topographic orientation and define the extent of the lesion.^{42,43} Because the incidence of postoperative lower CN palsies was high, especially for tu-

mors originating in the jugular foramen, we recommend surgery only for patients who have progressive tumor growth or clinical symptoms. Watchful waiting is an option, especially for older patients.

A variety of surgical approaches are available for removing meningiomas of the temporal bone, depending on the exact location of the tumor, need for hearing preservation, and the overall aggressiveness of the surgery.^{38,44-48} Tumors involving the jugular foramen are treated by an infralabyrinthine/lateral skull base approach, whereas tumors involving the petroclival region can be treated by a petrosal or a transcochlear approach.^{34,45,46,48} For lesions of the cerebello-pontine angle and IAC, the retrosigmoid, translabyrinthine or transotic approaches should be considered.⁴⁹ We recommend that meningiomas arising from the temporal bone itself to be treated by a combined middle fossa craniotomy/mastoidectomy approach (Fig. 2). This approach gives a view of the temporal bone from superiorly and laterally, allows removal of all hyperostotic bone and involved dura and allows wound reconstruction with vascularized temporalis muscle graft to prevent CSF leak. The approach can be modified depending on hearing preservation to include the labyrinth. We believe that this approach offers the best chance for aggressive tumor removal and, thus, minimizes the risk of recurrence. It also emphasizes the value of combining neurosurgical and neuro-otological expertise in treating these rare but intriguing lesions of the temporal bone.

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