Meningiomas of the posterior petrous bone: functional outcome after microsurgery

HISCHAM BASSIOUNI, M.D., ANJA HUNOLD, M.D., SIAMAK ASGARI, M.D., AND DIETMAR STOLKE, M.D.

Department of Neurosurgery, University Hospital Essen, Germany

Object. The aim of this study was to analyze a subgroup of patients harboring cerebellopontine angle meningiomas originating from the posterior petrous bone in regard to clinical presentation, surgical anatomy, complications, and long-term functional postoperative results.

Methods. Data in a series of 51 patients with meningiomas of the posterior petrous bone who had undergone microsurgical treatment at the authors’ institution between 1989 and 2002 were retrospectively reviewed. The patient population consisted of 46 women and five men with a mean age of 53 years (range 22–70 years). The main symptom on first admission was impaired hearing in 41%, dizziness in 20%, and tinnitus in 18% of the patients. Results of physical examination and audiological testing revealed hypacusis in 65% of patients, cerebellar ataxia in 31%, and impairment of the fifth cranial nerve in 26%. All patients underwent surgical treatment via a lateral suboccipital approach. Intraoperatively, the tumor was found to be attached to the postmeatal dura in 37%, the premeatal dura in 27.5%, the suprameatal dura in 19.6%, the inframeatal dura in 7.8%, and centered on the porus acusticus in 5.9% of cases. Tumor extension into the internal acoustic meatus was present in seven patients. Tumor resection was categorized as Grade I in 14 patients, Grade II in 29, Grade III in six, and Grade IV in two patients, according to the Simpson classification system. The site of displacement of the cranial nerves was predictable in up to 84% of patients, depending on the dural origin of the tumor as depicted on preoperative magnetic resonance (MR) imaging studies. Postoperatively, a new and permanent facial paresis was observed in five patients (9.8%). In 38 patients in whom both pre- and postoperative audiological data were available, hearing function deteriorated after surgery in 18.4% and improved in 7.9%. Clinical and MR imaging postsurgical data from a mean period of 5.8 years (range 13 months–13 years) were available in all patients. Forty-four patients (86%) resumed normal daily activity. Tumor recurrence was observed in two patients (3.9%), and both underwent a second surgery.

Conclusions. Preoperative detailed analysis of MR imaging data gives the surgeon a clue about the dislocation of critical neurovascular structures, particularly the cranial nerves. Nonetheless, the exact relationship of the cranial nerves to the tumor (dislocation, adherence, infiltration, and splaying of nerves) can only be fully appreciated during surgery.

Key Words • cerebellopontine angle • hearing preservation • meningioma • microsurgery • suboccipital approach

Clinical Material and Methods

Patient Population

We retrospectively reviewed the clinical records and neuroradiological images obtained in 51 patients who had been treated microsurgically for a meningioma of the posterior petrous bone at our institution between January 1989 and June 2002. The diagnosis of meningioma had been confirmed on histological examination in each case. Only tumors originating from the dura of the posterior petrous pyramid, verified on preoperative MR imaging, and on the surgical record were the focus of this study. Meningiomas extending into the CPA from other sites of dural origin (for example, lateral infratentorial, petroclival, and jugular foramen) were not included in our analysis.

Neuroradiological Studies

Magnetic resonance images including contrast-enhanced studies had been obtained in all but one patient. This patient had a cardiac pacemaker and thus posterior fossa cisternog-
raphy was performed instead. High-resolution CT scanning of the petrous bone had been performed in 12 cases. To assess the patency of dural venous sinuses and to evaluate the possibility of preoperative tumor embolization, cerebral angiography had been performed in 16 patients early in this series. In recent years, MR angiography replaced conventional angiography, and preoperative embolization was no longer performed.

Classification of Tumors

Tumors were classified according to their site of dural attachment in relation to the PA as demonstrated on preoperative MR images and as revealed in the surgical record. Five tumor groups were created: retromeatal, premeatal, suprameatal, inframeatal, and centered on the IAM (Fig. 1). Tumors with a significant intrameatal portion were assessed separately.

Surgical Procedure

All cases were surgically treated using a standard lateral suboccipital (retrosigmoid) craniotomy while the patient remained in the semisitting position. As is done in performing surgery for acoustic neuroma, the patient’s head is rotated to the tumor side so that the petrous ridge is in a straight line with the surgeon’s view. The head is flexed and care is taken not to impede venous return; generally, three fingers can still be placed between the chin and the sternum. Standard anesthesia monitoring is used to detect and treat air embolism.

In two cases in which the lateral cerebellomedullary cistern was occluded by tumor, the cisterna magna was opened instead by enlarging the craniotomy to the foramen magnum. A nerve stimulator was used in 18 patients to help identify the facial nerve. After tumor resection is completed the dural attachment area on the posterior surface of the petrous bone is either excised (Simpson Grade I resection) or coagulated (Simpson Grade II resection). In seven patients, gross tumor extension into the IAM necessitated drilling of the posterior meatal wall for complete lesion removal. No resection of the petrous bone was performed in three patients in whom tumor invasion of the petrous pyramid had been apparent on preoperative MR imaging studies.

Patient Follow Up

All patients underwent follow up with clinical examination and MR imaging studies 6 months and 1 year after surgery. Thereafter, patients were examined at 1- or 2-year intervals based on each follow-up result. Assessment of facial nerve function preoperatively and at each postoperative follow up was based on the House–Brackmann grading system. An otological examination was routinely conducted in the Department of Otolaryngology by performing pure tone audiometry and speech discrimination testing before discharging the patient from the hospital. Both pre- and postoperative audiological data were rated according to the scale proposed by Gardner and Robertson and were available for analysis in 38 patients.

Results

Clinical Data

Our series consisted of 46 women and five men with a mean age of 53 years (range 22–70 years). Otological symptoms were the main presenting complaints in 40 patients (78%), with impaired hearing in 21 (41%), dizziness in 10 (20%), and tinnitus in nine (18%). Hearing loss was characterized as having a sudden onset in seven patients (13.7%). Seven patients (13.7%) presented with trigeminal neuralgia, and atypical facial pain occurred in two additional patients. The mean duration of symptoms before hospital admission was 21 months (range 2 weeks–12 years). Results of physical and audiological assessment revealed impairment of the eighth cranial nerve in 33 patients (64.7%). Gait ataxia was present in 16 patients (31.4%). Facial numbness or a decreased corneal reflex, indicating fifth cranial nerve impairment, was present in 13 patients (25.5%). Gait ataxia occurred predominantly in patients with a retromeatal tumor location, whereas trigeminal nerve abnormality predominated in those with premeatal lesions (Table 1).

Neuroradiological Investigation

Gross brainstem compression occurred in 12 patients;
however, hydrocephalus was present in only three patients preoperatively. High-resolution CT scanning revealed a hyperostosis of the petrous bone immediately behind the PA in three patients. In three patients with gross intrameatal tumor growth, dilation of the IAM was noted on the lesion side when compared with the contralateral IAM. In three additional patients with gross tumor infiltration of the petrous bone, high-resolution CT scanning results demonstrated reduced aeration of mastoid air cells, osteolysis, and sclerosis of the petrous bone on the affected side (Fig. 2). The mean diameter of the tumors on MR images was 3.6 cm (range 1–6 cm). According to angiography studies, the main arterial blood supply was delivered by the meningeal branch of the meningohypophysial trunk (10 patients). Preoperative superselective embolization of the tumor was possible in only two cases. In one of these the posterior branch of the middle meningeal artery was occluded preoperatively; in the other, the occipital artery.

**Location and Classification of Meningiomas**

Three meningiomas were centered on the PA (Fig. 3). Nineteen tumors were attached to the dura mater posterior to the PA (retromeatal; Fig. 4), 14 originated from the dura mater anterior to the PA (premeatal; Fig. 5), 10 were in a suprameatal position, and four were attached to the dura mater inferior to the PA (inframeatal). Seven tumors demonstrated a significant intrameatal extension. One tumor could not be classified because it was evenly attached behind, above, and in front of the PA. En plaque growth of the meningioma with multiple attachment sites, mainly around the rim of the PA, was observed in three patients during surgery (one unclassified and two premeatal tumors). Two meningiomas in the premeatal group invaded the Meckel cave, and one tumor in the inframeatal group encroached into the jugular foramen.

**Surgical Considerations**

The direction of displacement of the trigeminal, facial, vestibulocochlear, and lower cranial nerves was rather predictable, depending on the dural origin of the tumor as demonstrated on preoperative MR imaging studies (Table 2).

The facial and vestibulocochlear nerves were present as solid nerve bundles and were separated from the tumor by an arachnoid sheath in 41 patients (80%). In these cases the nerves could be clearly identified and protected. In six patients the facial nerve was incorporated into the capsule of the tumor and could be identified with the aid of a nerve-stimulating electrode; the nerve was anatomically preserved in four of these cases. In two patients with tumors of hard consistency, however, preservation of the facial nerve was not anatomically possible.

The extent of tumor resection according to the Simpson classification was Grade I in 14 patients (27.4%), Grade II in 29 (56.9%), Grade III in six (11.8%), and Grade IV in two (3.9%) with premeatal meningiomas and tumor extension into the Meckel cave. A tumor remnant (Simpson Grade III) was left in three patients with frank infiltration of the petrous bone and in three patients with infiltration of cranial nerves (one case each involving the fifth cranial nerve, seventh–eighth nerve complex, and lower cranial nerves). Given that all three patients had normal or useful residual function of infiltrated nerves preoperatively, a trace of tumor was left in these patients to preserve cranial nerve function.

Extensive bleeding from a prominent hyperostosis at the site of tumor dural origin was noted in nine patients. This was treated by removing the exostosis with the aid of a diamond drill and waxing.

**Meningiomas With Intrameatal Extension**

Seven patients in this series had a major intrameatal tu-
moral portion. Only one of these patients presented with mild facial paresis, and all but one had profound preoperative hearing impairment (sudden onset in two). Three patients complained of tinnitus. Gait ataxia was present in one patient with retromeatal tumors, and one patient with a premeatal tumor suffered from atypical facial pain.

The tumor involved the IAM in six of these seven patients, according to MR imaging studies. It was presumed to be involved in one patient, based on preoperative posterior fossa cisternography, and its actual involvement was later confirmed intraoperatively (Fig. 3). High-resolution bone window CT scanning was performed in four patients. Results demonstrated expansion of the IAM in three patients and no abnormality in the diameter or bone structure of the IAM in one patient. The tumor was centered on the PA in two patients, and the diagnosis of meningioma was made intraoperatively in both cases.

During surgery, the seventh–eighth nerve complex was displaced posteriorly in three patients (one with a tumor centered on the PA and two with premeatal lesions) and inferiorly in one and anteriorly in two patients with retromeatal tumors.

All tumors could be completely resected after drilling the posterior wall of the internal auditory canal. A new facial paresis occurred after surgery in four patients, but fully resolved in all on follow up. Hearing was preserved at the preoperative level in only one patient who had had serviceable hearing before surgery. All other patients were deaf postoperatively. None of the petrous meningiomas with intrameatal extension recurred after a mean follow up of 5.2 years, and all patients in this subgroup returned to their previous level of activity.

Postoperative Complications

The main complications in this series were related to facial and auditory nerve functions (discussed later). A new or an aggravated postoperative gait ataxia was observed in seven patients, although it has completely resolved in four of them. A CSF leak at the wound site in three patients was treated using lumbar puncture in two and VP shunt placement in the other. A rhinorrhea observed in two other patients resolved in both after insertion of a lumbar CSF drain for several days. One of three patients with preoperative hydrocephalus required VP shunt insertion 3 weeks after...
surgery. Decreased function of the ninth and 10th cranial nerves occurred temporarily in three patients, but full nerve function returned clinically within 2 months. No aspiration pneumonia was observed and no tracheotomy was needed in any case. There was no death related to surgery in this series.

Permanent postoperative morbidity, other than seventh and eighth cranial nerve lesions, was 16% (Table 3).

**Postoperative Facial Nerve Function**

Only three patients in this series had mild facial nerve paresis preoperatively (House–Brackmann Grade II). The facial nerve was infiltrated by an intrameatal tumor extension in one of these patients. During surgery a trace of tumor was left on this nerve, thus preserving function at the preoperative level. In the second patient facial nerve function worsened (House–Brackmann Grade IV), although the nerve itself was anatomically preserved during surgery. In the third patient facial nerve dysfunction ameliorated immediately after surgery, and no facial weakness was visible at the 1-year follow up. Permanent worsening of facial nerve function was noted in four other patients postoperatively. A temporary facial nerve paresis resolved completely within 9 months postsurgery in seven patients (Table 4).

In two patients in whom the facial nerve could not be preserved intraoperatively, a gold weight was inserted into the upper eyelid early after surgery. Another patient with a House–Brackmann Grade IV facial nerve paresis was treated using a protective eye shield at night, artificial tears, and ophthalmic ointments.

**Postoperative Hearing**

Detailed pre- and postoperative otological data were available in 38 patients (Table 5). In 10 of these patients with no preoperative auditory impairment, hearing was fully preserved. In eight patients hearing was preserved at the preoperative serviceable level (Gardner Class II). Postoperative improvement in hearing occurred in two patients with a postmeatal lesion and in one patient with a premeatal tumor (7.9%). Although preservation of the eighth cranial nerve was attempted in every patient, hearing irreversibly deteriorated immediately after surgery in seven patients (18.4%) who had had normal or serviceable preoperative hearing. This involved two postmeatal, four premeatal, and...
one infratemporal tumor. In 10 patients the preoperative deafness persisted.

The tumor diameter in the three patients with postoperative hearing improvement did not differ significantly from those in whom hearing was lost after surgery (mean diameter on preoperative MR images 3.4 cm compared with 3.6 cm, respectively).

Patient Follow Up

All patients had a follow up of at least 1 year postsurgery including clinical examination and MR imaging assessment. The mean follow-up time was 5.8 years (range 13 months–13 years). Forty-four patients (86.3%) had resumed normal premorbid activity (Karnofsky score 90–100). Six patients (11.8%) were independent, but had major neurological deficits, mainly residual gait ataxia and facial nerve paralysis (Karnofsky Score 70–80). One patient required permanent assistance (Karnofsky Score 50). Tinnitus, which had been the presenting symptom in nine patients, resolved completely in seven and to an acceptable degree in two patients.

Two recurrences were observed in this series, occurring between 2 and 4 years after the first resection, and both patients underwent a second surgery because of radiological and clinical progression. Both recurrences (one retromeatal and one infratemporal tumor) happened in patients who had undergone an apparent complete resection during the first surgery (Simpson Grade II). One of the recurrent tumors displayed atypical features on histological examination. No clinical or radiological progression of residual tumor was observed in three patients with gross infiltration of the petrous bone, in two patients with tumor invasion of the Meckel cave, and in patients with infiltration of cranial nerves after a mean postoperative observation period of 5.4 years. No adjuvant therapy has been used in patients with known residual tumors after surgery.

Histological Investigation

The meningioma was the meningotheliomatous subtype in 24 patients, fibroblastic in 18, transitional in six, and psammomatous and secretory in one patient each. The meningioma was classified as atypical in one patient.

Discussion

Five to eight percent of all intracranial meningiomas occur in the CPA. Of these CPA tumors, acoustic neuromas comprise 70 to 80%, meningiomas 10 to 15%, and epidermoid tumors 4 to 5%. The remainder are composed of diverse other lesions. One thousand fifty-three intracranial meningiomas have been treated surgically at our institution between January 1989 and June 2002. Meningiomas originating from the posterior petrous pyramid constituted 4.8% (51 patients) of all surgically treated intracranial meningiomas during this period. During the same time period we have surgically treated 36 patients with a lateral infratentorial, 33 patients with a petroclival, and six patients with a jugular foramen meningioma, which were not considered in this report.

Classification and Surgical Considerations

Castellano and Ruggiero, in reviewing Olivecrona’s series, classified meningiomas of the posterior fossa into five groups according to the site of dural attachment: cerebellar convexity, tentorium, posterior surface of the petrous bone, clivus, and foramen magnum. Among these groups, tumors of the posterior surface of the petrous bone was the largest and constituted 42% of all posterior fossa meningiomas. This classification system, based on the dural origin of the tumor, was also adopted by Yaşargil of his review on 53 meningiomas of the basal posterior cranial fossa, including 30 CPA meningiomas. Samii and Ammirati preferred the term “posterior pyramid meningioma” to denote tumors having their main bulk in contact with the posterior petrosal pyramid, regardless of the site of dural attachment.

Most published series about meningiomas of the CPA have focused on tumors originating from the dura mater of the petrous bone, the tentorium, the clivus, and the jugular
foramen. It has been shown that petroclival meningiomas constitute a separate entity. These lesions are less frequently excised totally and are associated with higher surgical morbidity and mortality rates than tumors solely attached to the posterior petrous dura. In the microsurgical era, surgical morbidity and mortality rates in patients with petroclival meningiomas have ranged between 31 and 50% and between 0 and 17%, respectively. Partial resections are common with meningiomas in this location, whereas the rate of total removal ranges from 25 to 85%.

Total removal, defined as Simpson Grades I and II resection and no visible tumor remnant on follow-up MR imaging, was achieved in 84.3% of patients harboring meningiomas whose dural attachment was restricted to the posterior surface of the petrous bone. The reasons for performing a subtotal resection in this series included invasion of petrous bone, infiltration of functioning cranial nerves, and tumor extension into the Meckel cave. When present, a hyperostosis of the petrous bone underlying the tumor origin was removed by drilling because the hyperostotic bone may...
Meningiomas of the posterior petrous bone

TABLE 2

<table>
<thead>
<tr>
<th>Tumor Location</th>
<th>CN V</th>
<th>CN VII &amp; VIII</th>
<th>CN IX, X, &amp; XI</th>
</tr>
</thead>
<tbody>
<tr>
<td>retromental</td>
<td>ant-sup, 11; unrelated, 8</td>
<td>ant, 16; inf, 3</td>
<td>inf, 10; unrelated, 9</td>
</tr>
<tr>
<td>premeatal</td>
<td>ant, 13; infiltrated, 1</td>
<td>pst, 7; inf, 6; unrelated, 1</td>
<td>inf, 2; unrelated, 12</td>
</tr>
<tr>
<td>suprameatal</td>
<td>ant, 6; unrelated, 4</td>
<td>inf, 7; pst, 1; unrelated, 2</td>
<td>inf, 2; unrelated, 8</td>
</tr>
<tr>
<td>inframeatal</td>
<td>sup, 1; unrelated, 3</td>
<td>pst, 2; sup, 2; inf, 3</td>
<td>inf, 1; unrelated, 3</td>
</tr>
<tr>
<td>centered on PA</td>
<td>ant, 1; unrelated, 2</td>
<td>pst, 1; ant, 1; infiltrated, 1</td>
<td>inf, 1; unrelated, 3</td>
</tr>
</tbody>
</table>

* Ant = anterior; inf = inferior; pst = posterior; sup = superior.

Headache was the main symptom and gait ataxia the predominant neurological sign in 36 patients with lateral infratentorial meningioma (unpublished data). In patients with meningiomas of the jugular fossa, neuropathies of the lower cranial nerves are common preoperatively and, in fact, occurred in 50% in a recent series. In contrast, hearing impairment was the main presenting complaint and neurological sign in our patients (54 and 65%, respectively). Hearing loss has been reported to be present in 60 to 75% of patients with meningiomas of the CPA.3,9,24,33,37,39 Except for trigeminal nerve abnormalities, other cranial nerve deficits are rare in these patients preoperatively. Facial pain resulting from trigeminal nerve compression was a major presenting symptom in nine patients in this series and mainly affected those with a premeatal meningioma (Table 1). Postoperative resolution of this symptom was observed in all but one patient. Sekhar and Jannetta reported resolution of trigeminal neuralgia after surgery in all eight patients in their series. Hence, it seems useful to differentiate among meningiomas originating from the posterior petrous surface, tentorial, clivus, or jugular foramen. Although the bulk of these tumors often occupy the CPA, each subtype shows different clinical and surgical characteristics.

Neuroradiological Workup

Magnetic resonance imaging is the diagnostic tool of choice to delineate the dural origin of the tumor preoperatively and to detect tumor extending into the IAM, the jugular foramen, or the Meckel cave. Note, however, that bone window high-resolution CT scanning is more sensitive than MR imaging in demonstrating bone changes, such as expansion and erosion of the IAM, in cases with gross intrameatal tumor extension. Patency of the venous sinuses can be depicted accurately on preoperative MR imaging or MR angiography. Because these tumors usually receive their major arterial blood supply from branches of the meningo-hypophyseal trunk, preoperative embolization of the tumor usually was not possible, nor was it believed to be an important adjunct to surgery.

In most patients, preoperative MR imaging study results allow for accurate classification of a tumor in relation to the PA. Nonetheless, there are several limitations. The exact dural origin of the tumor or en plaque extensions may become visible only during surgery in some cases. Even on MR imaging studies it is usually not possible to demonstrate intimately involved neurovascular structures directly or to determine their position in relation to the tumor preoperatively. Tumor consistency and the relationship between arachnoid membranes and tumor surface are important determinants for functional preservation of neurovascular structures and are recognized only during surgery. With these limitations in mind, preoperative classification of these tumors according to their dural attachment in relation to the IAM gives the surgeon valuable information about the most probable dislocation of the fifth through 11th cranial nerves. The facial–vestibulocochlear nerve complex was consistently found on the ventral aspect of retromental tumors. Schaller, et al., found the seventh–eighth nerve complex on the lateral (posterior) aspect of 57% of premeatal tumors. These nerves were separated from the tumor in 59% of retromental meningiomas and were never found on the medial (anterior) aspect of the tumor.

Surgical Approaches

Different surgical approaches have been used for resection of CPA meningiomas including the lateral suboccipital (retrosigmoid), transpetrosal, translabyrinthine, transcoclear, and middle fossa approaches.4,11,16,19,24,27,30,32,33,37,39,40 In clival and petroclival meningiomas the petrosal approach has certain advantages because it shortens the surgical distance to the tumor and allows for superior visualization and...
In meningiomas of the posterior petrosal surface a lateral suboccipital approach suffices even when the tumor is located ventral to the seventh–eighth nerve complex. All tumors in this series were successfully removed using this approach. Early drainage of the lateral cerebellomedullary cistern allowed gentle retraction of the cerebellum and direct visualization of the tumor. This approach has been used successfully by other investigators of CPA meningiomas. In contrast to the translabyrinthine approach, the lateral suboccipital approach has been used successfully by other investigators of CPA meningiomas. In contrast to the translabyrinthine approach, the lateral suboccipital approach has been used successfully by other investigators of CPA meningiomas. In contrast to the translabyrinthine approach, the lateral suboccipital approach has been used successfully by other investigators of CPA meningiomas.

Facial Nerve Preservation

Preoperative facial nerve paresis is a rare sign (6% in our study) even in patients with large tumors or lesions with gross intrameatal extension. Intraoperatively, the facial nerve can usually be preserved because it is separated from the tumor surface by the arachnoid membrane. Once the nerve is identified, the arachnoid is stripped away by using it as a protective sheath for the nerve during further resection. This scenario was observed in the majority of our patients, and facial nerve function was preserved in these cases (80%). When the arachnoid membrane has undergone regressive changes and is firmly adherent to the tumor or when the facial nerve courses through the tumor, the lesion can be detected using a stimulating electrode. Usually, anatomical preservation using a meticulous microsurgical preparation technique is possible in these cases provided that the nerve is identified as a single strand. In two patients (3.9%) harboring large tumors of hard consistency, the nerve was splayed over the tumor surface and thus could not be preserved; it had been identified on the brainstem site in one case. Permanent deterioration of facial nerve function has been reported to be between 7 and 30% in the literature and was observed in five patients in the present series (10%).

Postoperative Hearing

Yaşargil reported an improvement in hearing function in 12 patients and deterioration in only one case in a series of 30 CPA meningiomas, which had been microsurgically resected via the retrosigmoid approach. Matthies, et al., reported on a series of 134 meningiomas involving the CPA. The lateral suboccipital approach (retrosigmoid) had been used in the majority of their patients, and hearing was preserved in 82% and improved in 6%. These figures compare favorably with a hearing preservation rate of 40% in a previous series of 1800 vestibular schwannomas treated at the same institution. Some investigators have reported a dramatic improvement in auditory function after microsurgical removal of a lesion, even in patients with large posterior petrosal meningiomas and in those with profound hearing impairment preoperatively. The preoperative hearing level in the patients in the present study was preserved in 38 (69%) in whom detailed pre- and postoperative audiological data were available. The rate of hearing preservation was highest in patients in the suprameatal and retromeatal subgroups (100 and 73%, respectively) and lowest in those in the premeatal subgroup (43%). Postoperative hearing improvement occurred in 8% of our patients. None of the seven patients whose hearing loss was sudden demonstrated postoperative improvement. There was no relationship between tumor size and hearing preservation in our patients, a finding supporting previous clinical studies. Tinnitus was a major complaint in 18% of our patients preoperatively and was ameliorated in all of them postoperatively.

An analysis of the data in this study allowed no prediction in regard to postoperative hearing function to be made in an individual case. Every effort should thus be made to preserve normal anatomical structures subserving auditory function and hearing. Ablative approaches (translabyrinthine and transcochlear) are not recommended.

Intrameatal Meningioma

The incidence of involvement of the IAM by meningioma is reported to range from 10 to 20%. Seven patients (13.7%) in this series had a significant intrameatal tumor portion that necessitated drilling of the posterior meatal wall for complete removal. Note that purely intrameatal meningiomas have only rarely been described in the literature and were not observed in our patients. These tumors are believed to arise from intrameatal arachnoid cell clusters. Two tumors in our series were symmetrically centered on the PA and had a small extrameatal portion, thus making an

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Preoperative and postoperative facial nerve function after 1 year of follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor Location</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No Deficit</td>
</tr>
<tr>
<td>retromenatal</td>
<td>18</td>
</tr>
<tr>
<td>premenatal</td>
<td>13</td>
</tr>
<tr>
<td>suprameatal</td>
<td>10</td>
</tr>
<tr>
<td>inframeatal</td>
<td>4</td>
</tr>
<tr>
<td>centered on PA</td>
<td>2</td>
</tr>
<tr>
<td>intrameatal growth</td>
<td>6</td>
</tr>
</tbody>
</table>

* Grades are based on the House–Brackmann facial nerve grading system.
† Indicates same patient with facial nerve infiltration by tumor.
intrameatal origin most probable. Note that the facial nerve was displaced posteriorly in one of these cases. The facial nerve was anatomically preserved in all patients. Although temporary postoperative facial paresis was common, full recovery of the seventh cranial nerve was the rule.

Only one patient in this group had serviceable preoperative hearing that could be preserved following surgery. All other patients were functionally deaf preoperatively and their hearing did not improve postoperatively. Grey and co-workers reported that 45% of their patients with gross intrameatal tumor extensions were deaf preoperatively, compared with 5% of patients in whom the IAM was not involved. An ischemic lesion of the cochlear nerve and inner ear structures was an issue among these cases, and microscopic invasion of the cochlea by tumor was demonstrated on histological sections. Atrophic changes of the cochlear nerve, ganglion cells, or hair cells in the organ of Corti may be the cause in some irreversible cases of hearing loss despite meticulous surgical preparation technique and anatomical preservation of the vestibulocochlear nerve.

Tumor Recurrences

Two tumors in this series recurred (recurrence rate 3.9%) and necessitated a second surgery after a mean follow-up period of 3 years. Tumor resection in both cases had been complete on initial surgery, and one tumor had shown atypical features on histological examination. In general, the recurrence rate varies between 3.2 and 23% among the different series, but is usually less than 10%. Analysis of these study data, however, also show that the effectiveness of radiosurgery depends on the biological nature of the tumor, and patients with atypical or malignant meningiomas still experience a high recurrence and progression rate.

Conclusions

Analysis of preoperative MR images in regard to the exact dural origin of a meningioma in relation to the PA gives the surgeon valuable information about the most probable site of dislocated cranial nerves. Nonetheless, the exact relationship of critical neurovascular structures in relation to the tumor can only be fully appreciated intraoperatively. Hence, a meticulous microsurgical preparation technique augmented by electrophysiological monitoring is a prerequisite to obtain an optimal functional result. Analysis of the study data shows that hearing preservation and amelioration can be achieved even in patients with large tumors by using the lateral suboccipital approach. Hearing-ablative approaches are thus not recommended. We recommend leaving a trace of tumor on infiltrated but functioning cranial nerves because no recurrence has been observed from these tumor remnants in this or any previously reported series.

Acknowledgment

We thank Dr. Siamak Asgari for the intraoperative photographs in Fig. 3.

References

2. Al-Mefty O, Smith RR: Clival and petroclival meningiomas, in

<table>
<thead>
<tr>
<th>Table 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preoperative and postoperative auditory function in 38 patients in whom audiological data were available</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tumor Location</th>
<th>Preop Hearing</th>
<th>Postop Hearing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Deficit</td>
<td>Serviceable*</td>
</tr>
<tr>
<td>intrameatal growth</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>inframeatal</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>suprameatal</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>premeatal</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>retromeatal</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

* Serviceable hearing refers to Gardner and Robertson Class II.
† Not serviceable hearing refers to Gardner and Robertson Classes III through V.
35. Spetzler RF, Daspit CP, Pappas CT: The combined supra- and infratentorial approach for lesions of the petrous and clival regions: experience with 46 cases. J Neurosurg 76:588–599, 1992

H. Bassiouni, et al.