Meningiomas represent the second most common tumor in the CPA, with a prevalence of 10 to 15% of all CPA lesions.\textsuperscript{11,12} Posterior petrous meningiomas refer to those meningiomas originating from the posterior surface of the petrous bone and excluding the other original tumor of the CPA. The clinical manifestations, surgical difficulty, and outcomes for the various posterior petrous meningiomas are clearly different because of their various locations. It is necessary to classify and analyze them so that better clinical applications can be determined.

**Clinical Material and Methods**

**Patient Population**

We retrospectively reviewed a series of 82 cases of posterior petrous meningiomas treated at our hospitals from February 1996 to December 2002. The patients consisted of 13 men and 69 women with ages ranging from 19 to 74 years (median age 47 years). Disease courses in these cases ranged from 10 days to 20 years. The various clinical manifestations were described in Table 1. The most common presenting symptoms were headache (52%) and gait disturbance (46%), whereas cranial nerve palsies represented the most common presenting signs (fifth, sixth, seventh, eighth, and ninth to 11th cranial nerve impairments).

**Neuroradiological Evaluation**

The largest tumor diameter on CT scans and/or MR images defined the tumor size, which was categorized as small (< 3 cm, 13 [16%] of 82 lesions), medium (3–4 cm, 14 [17%] of 82 lesions), and large (> 4 cm, 55 [67%] of 82 lesions). All patients had undergone CT scanning and/or MR imaging studies, and a comparison of tumor size based on imaging results is featured in Table 2. The largest tumor was 8 × 7 × 7 cm and 55 cases involved large tumors. According to the anatomical relationship with the posterior surface of the petrous bone and with special reference to the IAC, posterior petrous meningiomas were classified into three types: Type I, located laterally to the IAC (28 cases); Type II, located medially to the IAC, which might extend to the cavernous sinus and clivus (32 cases); and Type III, extensively attached to the posterior surface of the petrous bone, which might envelop the seventh and eighth cranial nerves (22 cases).

**Pathological Type**

Histopathological tumor classification was performed:
Posterior petrous meningiomas

**TABLE 1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type I (no. of cases)</th>
<th>Type II (no. of cases)</th>
<th>Type III (no. of cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN paralysis</td>
<td>2</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>VII</td>
<td>2</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>VIII</td>
<td>7</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>IX–XI</td>
<td>5</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Gait ataxia</td>
<td>19</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Headache or ICP</td>
<td>18</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

* CN = cranial nerve; ICP = intracranial pressure.

39 were fibroblastic, 27 meningothehial, 10 mixed, three transitional, two anaplastic, and one psammomatosus. Type I lesions had a mainly fibroblastic constitution, Type II meningothelial and mixed, and Type III fibroblastic and meningothelial.

**Surgical Procedure**

Sixty-four patients were treated via the suboccipital retrosigmoid approach (28 patients with Type I lesions, 14 with Type II, and 22 with Type III). Among the remaining 18 patients with Type II meningiomas, eight underwent surgery via the temporal–occipital craniotomy subtemporal transpetrous transtentorial approach; the other 10 patients were treated via the supra- and infratentorial craniotomy presigmoid approach. During surgery, monitoring of fifth and seventh cranial nerve integrity was performed in 37 cases (20 patients with Type II lesions and 17 patients with Type III lesions).

**Evaluation of Treatment**

The extent of tumor removal was evaluated based on intraoperative observation and postoperative enhanced CT scanning or MR imaging obtained within 3 months of surgery. Gross-total removal was achieved if there was intraoperative evidence of no residual tumor and if results of postoperative radiographic evaluation demonstrated no evidence of enhancing tumor. Otherwise, the effect was considered a subtotal resection.

**Results**

**Surgical Outcome and Short-Term Treatment Effect**

Sixty-eight (83%) of 82 cases were subject to total resection and 14 to subtotal resection (Table 3). All Type I tumors were completely resected (28 cases) via the suboccipital retrosigmoid approach. Among these cases, two had slight seventh nerve paralysis and seven had a decrease in audition. Regarding those patients with Type II meningiomas, 14 underwent resection via the suboccipital retrosigmoid approach, eight via the subtemporal transtentorial approach, and 10 via the presigmoid approach. Patients in 24 cases underwent total resection, and in eight subtotal resection. Eight patients experienced seventh nerve paralysis or some aggravation, whereas 11 patients suffered hearing decrease. In patients with Type III lesions, all operations were performed via the suboccipital retrosigmoid approach. Sixteen of 22 cases involved total resection, and six subtotal resection. Six patients suffered seventh nerve paralysis or some aggravation. Nine patients had decreased audition. The number of subtotal resections was 14 and six of these cases had residual tumor in the cavernous sinus.

According to the House and Brackmann classification, postoperative compared with preoperative facial-nerve paralysis among the three meningioma types is featured in Table 4. The rate of functional preservation of the facial nerve was 81%. Posterior cranial nerve deficits occurred in seven patients. Cerebrospinal fluid leakage was found in one case, whereas subcutaneous fluid accumulated in seven cases. Bacterial meningitis was detected in five cases. Two patients suffered postoperative intracranial hematomas, which required surgical removal and resulted in temporary neurological deficits. Six patients had different degrees of paralysis on opposite extremities, although their symptoms improved after dehydration, glucocorticoid, and physical treatment. No deaths occurred among this group.

**Postoperative Follow Up**

Fourteen patients did not undergo follow up. The duration of follow up in the other 68 patients ranged from 0.5 to 8 years, with a mean follow up of 4.5 years. Among the treated cases, 57 patients recovered well, eight gained self-dependence, and three lost self-dependence because of posterior cranial nerve dysfunction or hemiplegia.

Fourteen patients who had undergone subtotal resection received adjuvant fractionated radiation therapy or gamma knife treatment. Clinical or radiographic evidence of recurrence appeared in five cases; in all five, a residual portion of the tumor had been left to preserve vital structures such as the cavernous sinus (three cases), the brainstem (one case), and the posterior inferior cerebellar artery (one case). Three of these patients underwent a second surgery to have the tumor completely removed and experienced no sequela. The other two patients refused repeated operation and remained in the follow up. During the follow-up period, we found no long-term side effects of radiation therapy.

**Discussion**

**Definition and Classification of Posterior Petrous Meningiomas**

The most common site of posterior cranial fossa meningiomas is the petrous bone, where 45% are found to have dural attachment. The posterior petrous surface of the temporal bone is relatively unique in its relationship to the venous sinuses because the sigmoid, superior petrosal, and inferior petrosal sinuses because the sigmoid, superior petrosal, infe-
rior petrosal, and cavernous sinuses form a ring surround-
ing the posterior face of the petrous bone. The meningio-
mas located in this region have a very close relationship
with the four aforementioned sinuses. In the past, menin-
giomas that extended to the CPA, regardless of the location
of the base—including those originating from the tentori-
um, transverse sinus, and lateral clivus—were considered to
be CPA meningiomas. Posterior petrous meningiomas are
defined as such because they are located at the posterior sur-
face of the petrous bone, excluding meningiomas arising
from the tentorium, transverse sinus, lateral clivus, and so
forth.

Based on the anatomical relationship with the IAC, Samii9
classified posterior petrous meningiomas into two
types: those anterior to the IAC and those posterior to the
IAC. The clinical manifestations and surgical methods or
effects were different between these two types of menin-
giomas. Most investigators hold the same view.2113,Ya-
şargil, et al.,16 asserted that meningiomas in this region should
be classified into anterior petroclival meningiomas and pos-
terior CPA meningiomas. Schaller, et al.,12 reported on 31
CPA meningiomas and divided them into premeatal and
retromeatal meningiomas. They considered premeatal me-
ningsiomas to be associated with a significantly worse post-
operative functional outcome compared with retromeatal
meningiomas, although premeatal meningiomas became
symptomatic earlier and had smaller sizes. Desgeorges and
colleagues13 classified the posterior surface of the petrous
bone into three equal zones according to imaging manifes-
tation: zones A, M, and P. A tumor was called an AM, MP,
or AMP meningioma if the base of the meningioma extend-
soh forth.

| Table 4 |

| Comparison of facial nerve paralysis for three types of posterior petrous meningiomas |

<table>
<thead>
<tr>
<th>House–Brackmann Grade</th>
<th>Preop Paralysis: Meningioma Type</th>
<th>Postop Paralysis: Meningioma Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>III</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

* Subtotal resection refers to remain slice residual tumors of close conglutination to the vital structures such as brain stem, nerves, and vessels in order to protect those structures. This equals to grade IV a of Kabayashi resection classification.

TABLE 3
Comparison of surgical treatment for three types of posterior petrous meningiomas

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Facial Nerve Paralysis or Aggravation</th>
<th>Postop Compared w/ Preop Audition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Improvement</td>
<td>Consistent</td>
</tr>
<tr>
<td>I</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>III</td>
<td>16</td>
<td>6</td>
</tr>
</tbody>
</table>

Note, however, that the arachnoid layer might be main-
trocoagulated or resected and infiltrating bone was ground.

Seventy-five percent of patients experienced hearing im-
provement or maintained their preoperative level. We pro-
ected the peripheral vessels and nerves carefully during the
dissection (generally the tumor compressed the facial nerve
forward and the lower cranial nerves downward). To reduce
the potential for tumor recurrence, invading dura was elec-
trocoagulated or resected and infiltrating bone was ground.

Note, however, that the arachnoid layer might be main-
tained, allowing a plane of dissection away from neurovas-
cular structures.

Type II posterior petrous meningiomas are located med-
dial to the IAC, which might extend to the cavernous sis-
us and clivus (excluding meningiomas from the clivus,
32 cases; Figs. 2 and 3). Tumors of this type occasionally
compressed the seventh and eighth nerves outward, pressed
the brainstem inward, pushed the fifth nerve upward, and
time of detection. In our series, 69 (84%) of 82 cases were
larger than 3 cm and it was very difficult to define their
A, M, and P zones clinically. Recently, Bassiouni, et al.,3 re-
ported on a series of 51 patients with meningiomas of the
posterior petrous bone. According to the site of dural attach-
ment in relation to the porus acusticus, he divided these le-
sions into five groups: retromeatal, premeatal, suprameatal,
inframeatal, and centered on the internal acoustic meatus.
Interestingly, three tumors with en plaque growth had mul-
tiple attachment sites, and one of the tumors could not be
classified because it was evenly attached behind the poste-
rior petrous bone. In our series, there were 22 cases of the
kind of tumor that was extensively attached to the posterior
surface of the petrous bone (incidence 27%). This phenom-
enon has never been included in other authors’ classifica-
tions.9,12 Thus we advocated a new classification system for
posterior petrous meningiomas. According to imaging mani-
festations and intraoperative observations (anatomical rela-
tionship between the tumor and the IAC, shift direction
of the seventh–eighth complex, and so forth), we classified
posterior petrous meningiomas into three types.

Type I posterior petrous meningiomas were located later-
Al to the IAC (28 cases; Fig. 1). Signs of cerebellar compres-
sion, such as gait ataxia, represent the main clinical char-
acteristics. All tumors in these cases were totally resected
via the suboccipital retrosigmoid approach. Generally, the
size of the tumors was large and compressed the cerebel-
ulum, therefore excessive retraction of the cerebellum was
not required during the operation and the surgical field was
exposed fully well. Surgery for this meningioma was the
easiest among the three lesion types and its total resection
rate was the highest. All Type I tumors were completely
resected and the rate of anatomical preservation of facial
nerve was 100%; the functional preservation rate was 93%.
Seventy-five percent of patients experienced hearing im-
provement or maintained their preoperative level. We pro-
ected the peripheral vessels and nerves carefully during the
dissection (generally the tumor compressed the facial nerve
forward and the lower cranial nerves downward). To reduce
the potential for tumor recurrence, invading dura was elec-
trocoagulated or resected and infiltrating bone was ground.

Note, however, that the arachnoid layer might be main-
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cular structures.

Type II posterior petrous meningiomas are located med-
dial to the IAC, which might extend to the cavernous sis-
us and clivus (excluding meningiomas from the clivus,
32 cases; Figs. 2 and 3). Tumors of this type occasionally
compressed the seventh and eighth nerves outward, pressed
the brainstem inward, pushed the fifth nerve upward, and

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crushed the ninth to 11th nerves downward. Therefore the main symptoms of these tumors were cranial nerve dysfunction (such as hearing loss, trigeminal neuralgia, or hypoesthesia) and facial or abducens nerve palsy. This result was consistent with past reports. Because of the close relationship between the tumor and the posterior cerebral artery, superior cerebellar artery, anterior inferior cerebellar artery, brainstem, and cranial nerves, surgery for the lesion was the most difficult among the three meningioma types and cranial nerve dysfunction was relatively evident. The mostly posteriorly displaced seventh–eighth complex represented a continuous obstacle during tumor removal and might explain why this type of tumor had an increased risk of the seventh–eighth palsy. We resected these tumors via three different approaches: suboccipital retrosigmoid (14 cases), temporooccipital craniotomy subtemporal transtentorial (8 cases), and presigmoid approach (10 cases). In 20 cases we performed intraoperative monitoring of the fifth and seventh nerves. Total resection was performed in 24 cases, whereas subtotal resection was performed in eight. The rate of total resection was 75%. The rate of anatomical preservation of facial nerve was 97%, whereas the functional preservation rate was 75%. Sixty-six percent of patients experienced hearing improvement or maintained their preoperative level of hearing. Five cases demonstrated various grades of opposite-extremity hemiplegia, which was primarily due to the removal of the tumor adhesion to brainstem compulsorily. One should carefully separate the arachnoid mater interface between tumor and brainstem, nerves, or vessels, especially when inward tumor compression is evident. The surgeons should analyze T2-weighted MR images carefully before operation to observe whether there is edema in the brainstem and arachnoid mater interface between the tumor and brainstem.

Type III posterior petrous meningiomas extensively attach to the posterior surface of the petrous bone and might envelop the seventh or eighth cranial nerves or extend into the IAC or develop into the cavernous sinus and clivus (22 cases; Fig. 4). All of these meningiomas were more than 4 cm in size and compressed the cerebellum or brainstem and involved the adjacent nerves; thus both of the above symptoms were observed clinically. There were two types of tumor morphologies: an expansive type (8 cases) and en plaque type (14 cases). Meningiomas with an en plaque growth pattern were more infiltrative and could invade neighboring structures or encircle them. It was more difficult to dissect this tumor completely from the neurovascular bundle. All cases were resected via the retrosigmoid approach. Intraoperative fifth–seventh nerves monitoring was performed in 17 cases. Total resection was performed in 16 cases and subtotal resection in six. The rate of total resection was 73%. The rate of anatomical preservation of facial nerve was 95%, whereas the functional preservation rate was 73%. Fifty-nine percent of patients had hearing improvement or hearing similar to the preoperative level. Tumor bases extensively attached to the posterior surface of the petrous bone and accepted blood supply from both the brain and meninges so that blood sources were very abundant. The primary objective was to remove the tumor base to stop the blood supplement. Occasionally, with the large tumors, it was not easy to separate the base until internal decompression had been accomplished. The base was then
removed and separated from the tumor capsule. Internal decompression was performed repeatedly and the tumor resected little by little. Regarding separation of vessels adherent to the capsule, the vessels could not be amputated by electrocoagulation until one had verified that the vessels supplied blood to the tumor alone. Because a majority of these lesions (64%) demonstrated infiltrative growth, one must distinguish the vessels and nerves carefully during surgery and determine whether there is an arachnoid layer between the tumor and vessels or nerves. The arachnoid layer might be absent in some cases. If the tumor is densely adherent to the vital vessels or nerves, it might be optimal to leave a small margin of tumor on them.

**Tumor Resection and Treatment Effect**

The following factors may determine the effect of the surgery: patient age; tumor size, location, and texture; extent to which the tumor envelops vessels and nerves; and the degree of invasion to the pia mater of the brainstem. As shown in Table 3, the rate of total resection was compared between Types I and III, and between Types I and II. There was a significant difference at a probability value less than 0.05. The rate of total resection among the different lesion types was also compared and the statistical difference was significant (p < 0.01). Compared with Type I meningiomas, total resection was more difficult in Types II and III, although the difference in the total resection rate between these types was not significant. It is easy to conclude that compared with Type I meningiomas, postoperative nerve-function impairment was relatively more evident in lesion Types II and III.

Statistical comparisons were performed with regard to tumor size. A comparison of the incidence of a large tumor has statistical significance between Types I and II, or between Types II and III (both p < 0.01). Type II meningiomas were smaller than Type I or III lesions and the symptoms occurred earlier accordingly. To preserve vital vascular and central nervous system structures, we did not perform total resection in 14 cases. Among these, six cases had residual tumor in the cavernous sinus and the other eight cases had residual tumor with close adherence to the brainstem, vessels, or nerves. These patients underwent gamma knife therapy after surgery. Schaller, et al.,12 analyzed meningiomas in the CPA and determined that dysfunction of facial nerve was more evident for premeatal meningiomas than for retromeatal meningiomas either pre- or postoperatively.13 Subtotal resection was performed in 30% of those cases, as was postoperative radiotherapy. Many authors believe that subtotal resection combined with postoperative gamma knife therapy was effective for control of tumor relapse.5,9,14
Posterior petrous meningiomas

Conclusions

Among this series of 82 patients with posterior petrous meningiomas, large tumors accounted for 67% of the lesions. As summarized previously, it seems useful to bring forward a new classification of posterior petrous meningiomas given that the clinical presentations, surgical difficulties, surgical effects, and prognoses vary greatly among the three lesion types. It is more difficult radically to resect Types II and III tumors than Type I lesions, and the postoperative functional outcomes are significantly worse. Preoperative detailed analysis of MR images and clinical data will give surgeons valuable clues about surgical prognoses. Thus we should treat cases with different methods accordingly. Furthermore, we should preserve nervous function and then totally resect the tumor as much as possible. We do not recommend total resection blindly. In this study, the rate of total resection was 83% and two cases failed to maintain facial-nerve preservation. Anatomical preservation of facial nerve was 97.5%, whereas functional preservation was 81%. Hearing function deteriorated after surgery in 33% of patients and improved in 18%. Careful preoperative evaluation, familiarity with the anatomy, effective intraoperative nerve monitoring, and skillful microsurgery techniques are the most important factors for success in the operation for posterior petrous meningiomas.

References


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