Petroclival meningiomas continue to present a significant technical challenge, and resection continues to carry a relatively high risk of neurological morbidity in patients with these lesions because of the tumors’ proximity to cranial nerves, vascular structures, and the brainstem. A combined transpetrosal approach, which includes various degrees of petrosal resection to minimize brain retraction and increase exposure to the petroclival region, has been described for radical resection of these tumors.\(^1\)\(^-\)\(^7\),\(^12\),\(^30\),\(^32\) Despite the development of a variety of surgical techniques, however, this approach has not become widespread because of the high rates of morbidity and mortality during the early years of its use.\(^1\),\(^4\),\(^21\),\(^23\),\(^29\),\(^32\) Complete resection is sometimes not possible, and stereotactic radiosurgery (SRS) for newly diagnosed, incompletely resected, or recurrent tumor has gained increasing attention.

**Petroclival meningiomas resected via a combined transpetrosal approach: surgical outcomes in 60 cases and a new scoring system for clinical evaluation**

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Department of Neurosurgery, Osaka City University Graduate School of Medicine, Osaka, Japan

**OBJECT** Petroclival meningiomas are among the most challenging intracranial tumors to treat surgically. Many skull base approaches have been described to improve resection and decrease patient morbidity. The authors undertook this study to evaluate the results of their treatment of petroclival meningiomas using objective measurements of tumor volume and a new impairment scoring system to assess neurological symptoms that severely affect the patient’s quality of life, such as impairment of swallowing and speaking, motor function, and consciousness and communication.

**METHODS** Between January 1990 and December 2009, the authors used a combined transpetrosal approach to treat 60 patients with benign (WHO Grade I) petroclival meningiomas. In this retrospective study, all 60 cases were analyzed in detail with regard to tumor volume, extent of resection (EOR), long-term tumor control, neurological outcome, and the patient condition. In addition, patients were divided into 2 groups according to the period during which the surgery was performed: the early group, from 1990 to 1999, and the late group, from 2000 to 2009. A new scoring system, the petroclival meningioma impairment scale (PCMIS), was created for quantitative assessment of 8 categories of neurological functions, with scores assigned in each category according to the level of disability and its impact on the patient. The PCMIS was used preoperatively, at 3 months after surgery, and at the time of the last follow-up examination, and the results for the 2 groups were compared.

**RESULTS** There were 24 cases in the early group (1990–1999), and the mean duration of follow-up was 149.3 months. The mean EOR was 96.1%, and good long-term tumor control was obtained in 22 patients (91.7%). One of the patients died because of a postoperative complication in the perioperative period. The PCMIS improved in 3 patients (12.5%), remained stable in 1 (4.2%), and worsened in 20 (83.3%). There were 36 cases in the late group (2000–2009), and the mean duration of follow-up was 77.9 months. The mean EOR was 92.7%, and good long-term tumor control was obtained in 34 patients (94.4%). The PCMIS score improved in 23 patients (63.9%), remained stable in 5 (13.9%), and worsened in 8 (22.2%).

**CONCLUSIONS** The combined transpetrosal approach has provided satisfactory functional improvements and excellent tumor control for patients with petroclival meningiomas. The PCMIS provides a specific tool for quantitative assessment of the patient’s state.

http://thejns.org/doi/abs/10.3171/2014.8.JNS132406

**KEY WORDS** petroclival meningioma; combined transpetrosal approach; surgical management; outcome; new scoring system; skull base
acceptance over the past decade. Because these lesions often grow slowly and may produce symptoms only late in their course, the optimal treatment protocol remains controversial.

During the last 20 years, we have treated patients with medium- or large-sized petroclival meningiomas with surgery (maximum feasible resection) via a combined transpetrosal approach followed by SRS if necessary. In this paper we present the results of our analysis of our consecutive series of cases of petroclival meningioma. The results are quantitatively evaluated with objective measurement of the tumor volume and a new impairment scoring system to assess the patient’s condition, the petroclival meningioma impairment scale (PCMIS).

Methods

Between January 1990 and December 2009, 60 consecutive patients with benign (WHO Grade I) petroclival meningiomas underwent microsurgical resection via a combined transpetrosal approach at Osaka City University. All cases were retrospectively analyzed for tumor volume, extent of resection (EOR), long-term tumor control, neurological outcomes, and patient condition. A new scoring system, the PCMIS, was created for quantitative assessment of the patient’s state.

Patient Population

The median age of the patients at the time of surgery was 54.4 years (range 33–72 years), and there were 51 women and 9 men. For all cases, the mean follow-up period was 8 years and 10 months (range 0–231 months). Excluding 1 patient who died during the perioperative period, the mean follow-up was 13 years (range 98–231 months). All patients underwent neuroimaging and neuroradiological follow-up at intervals of 6–12 months. Patients were divided into 2 groups for comparisons based on the timing of surgery: the early group, which included all patients treated between 1990 and 1999 (n = 24), and the late group, which included all patients treated between 2000 and 2009 (n = 36).

Operative Details

In all patients, maximum possible resection via the combined transpetrosal approach performed as the initial therapy by an experienced senior neurosurgeon. In the early group, retrosellar and petrosectomy was performed in 7 cases and the labyrinth was drilled out in the other 17 patients. In the late group, retrosellar and petrosectomy was performed in 30 cases and the labyrinth was drilled out to widen the surgical corridor in 6 patients with extremely large tumors. The internal auditory canals were opened in all 60 cases. All surgical procedures related to petrosectomy were accomplished by members of our neurosurgical staff. In the early group, gross-total resection was intentionally performed in an attempt at surgical cure of the disease despite the risk of neurological deficits, which occurred in some cases. In the late group, the degree of tumor resection was determined according to inoperative findings with the goal of obtaining good functional results. Consequently, small areas of tumor were left untouched if they were seen to invade the cavernous sinus or adhere severely to critical neurovascular structures (maximum possible resection with minimum neurological disability).

Postoperative Radiotherapy

In most cases, the patients were followed up without additional treatment. SRS was performed in cases of recurrent tumor or regrowth of residual tumor detected on MRI; 17 patients were treated with SRS.

Neuroradiological Evaluation

Preoperative and postoperative neuroimaging studies included 3D contrast-enhanced MRI to measure tumor volume. Postoperative MRI was performed within 3 months after surgery. In each axial MR image, tumor was demarcated by 2 radiologists and volumetric analysis was performed by 2 neurosurgeons. Volumetric analysis should ideally be calculated with computer-based methods, but the MR images obtained in our early group of cases were saved as printed files, so tumor volume was calculated based on the sum of the values obtained through manual measurement on each individual slice.

Extent of resection (EOR) was calculated as follows: EOR(%) = (preoperative tumor volume – postoperative tumor volume)/preoperative tumor volume × 100.

Disabilities and Performance

To define functional outcomes, clinical follow-up was conducted by the operating or referring surgeon. When a follow-up examination was not possible, a telephone interview was conducted with the patient or a close family member. (These interviews were conducted by the authors.) A new scoring system, the PCMIS (Table 1), was created for quantitative assessment of patient status and used preoperatively, at 3 months after surgery, and at the time of the last follow-up examination. The PCMIS addresses 8 categories of neurological functions and conditions associated with adverse effects of petroclival meningiomas and their surgical treatment. Scores are assigned in each category according to the level of disability and its impact on the patient’s quality of life as determined on the basis of patient responses to questionnaires and the opinions of the neurosurgeons who provided treatment, with a maximum score indicating the most severe impairment in all functions. The House-Brackmann grading system is used to assess facial palsy and the Gardner-Robertson scale is used to assess hearing.

Local Control

Recurrence or regrowth of the tumor was diagnosed if progression was observed on neuroimaging. When the tumor remained smaller than before surgery but caused symptoms or when the tumor became larger than preoperative size, it was defined as not controlled. The results of tumor control were thus classified into 2 categories: controlled and not controlled.

Statistical Analysis

Data were analyzed using the Mann-Whitney U-test for unpaired samples or Wilcoxon t-test for paired samples.
Differences correlating to an error probability of less than 0.05 were considered statistically significant. Recurrence-free survival time and the cumulative risk of tumor recurrence were calculated according to the Kaplan-Meier method using JMP 9.0 software (SAS Institute Inc.).

**Results**

**Tumor Characteristics**

In the 24 cases in the early group (1990–1999), the mean preoperative tumor volume was 31.3 cm³ (range 1.7–99.0 cm³). The mean postoperative tumor volume was 2.3 cm³ (range 0.0–32.3 cm³). The mean EOR was 96.1% (range 61.6%–100%) (Table 2).

In the 36 cases in the late group (2000–2009), the mean preoperative tumor volume was 32.1 cm³ (range 3.0–102.6 cm³). The mean postoperative tumor volume was 3.6 cm³ (range 0.0–53.4 cm³). The mean EOR was 92.7% (range 48.0%–100%) (Table 2).

**Follow-Up and Survival**

In the early group (1990–1999), the mean follow-up period was 12 years and 5 months (range 0–231 months). One of patients died because of postoperative intracranial hemorrhage due to severe venous infarction in the perioperative period; excluding that patient, the mean duration of follow-up was 13 years (range 98–231 months). In the late group (2000–2009), the mean follow-up period was 6 years and 6 months (range 7–157 months). There was no death associated with the operation in the late group.

There was no significant difference in recurrence-free survival (calculated using the Kaplan-Meier method) between the early and late groups (Fig. 1).

**Local Control**

In 3 cases, local control was not achieved with maximum feasible resection alone or in combination with SRS. In these 3 cases, the mean preoperative tumor volume was 75.2 ± 32.8 cm³, the mean postoperative tumor volume was 31.5 ± 22.3 cm³, the mean EOR was 62.3% ± 14.7%, and the mean MIB-1 labeling index was 2.3 ± 2.5. In 56 cases, good local tumor control was achieved. In this latter group, the mean preoperative tumor volume was 30.0 ± 20.0 cm³, the mean postoperative tumor volume was 1.6 ± 2.5 cm³, the mean EOR was 95.7% ± 5.1%, and the mean MIB-1 labeling index was 2.6 ± 3.5. In the group without

**TABLE 1. Petroclival meningioma impairment scale (PCMIS)***

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Diplopia</td>
<td>Visible malposition of eye</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Consistent diplopia</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Diplopia when looking in a single direction</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>No impairment</td>
<td>0</td>
</tr>
<tr>
<td>B. Facial sensation</td>
<td>Severe pain, refractory to medication</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pain controllable w/ medication</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Numbness</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>No impairment</td>
<td>0</td>
</tr>
<tr>
<td>C. Facial palsy</td>
<td>House-Brackmann Grade IV–VI</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>House-Brackmann Grade III</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>House-Brackmann Grade II</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>House-Brackmann Grade I</td>
<td>0</td>
</tr>
<tr>
<td>D. Hearing</td>
<td>Gardner-Robertson Grade III–V</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Gardner-Robertson Grade I or II</td>
<td>0</td>
</tr>
<tr>
<td>E. Swallowing &amp; speaking</td>
<td>Complete swallowing impairment treated w/ a feeding tube</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Effortful swallowing &amp; presence of hoarseness</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Effortful swallowing or presence of hoarseness</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>No impairment</td>
<td>0</td>
</tr>
<tr>
<td>F. Motor disturbance</td>
<td>Restricted to bed &amp; requires complete assistance</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Restricted to wheelchair w/ some assistance</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Gait disturbance requiring supportive devices such as cane &amp; brace</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Gait disturbance w/o supportive devices</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No impairment</td>
<td>0</td>
</tr>
<tr>
<td>G. Sensory disturbance</td>
<td>Severe pain, refractory to medication</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pain controllable w/ medication</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Numbness</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>No impairment</td>
<td>0</td>
</tr>
<tr>
<td>H. Consciousness &amp; communication</td>
<td>Complete loss of communication ability</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Some support in basic communication</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Independent in basic communication but dependent in social communication</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Independent in daily &amp; social communication but unable to function in previous employment</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Suitable for previous level of employment</td>
<td>0</td>
</tr>
</tbody>
</table>

* The maximum score, indicating the most severe impairment in all measures, is 38.

**TABLE 2. Tumor characteristics and surgical results in the early (1990–1999) and late (2000–2009) groups**

<table>
<thead>
<tr>
<th>Characteristic or Results</th>
<th>Early Group</th>
<th>Late Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>24</td>
<td>36</td>
</tr>
<tr>
<td>Mean age of patients (yrs)</td>
<td>53.7</td>
<td>54.9</td>
</tr>
<tr>
<td>Mean preop tumor vol (cm³)</td>
<td>31.3</td>
<td>32.1</td>
</tr>
<tr>
<td>Mean postop tumor vol (cm³)</td>
<td>2.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Mean EOR (%)</td>
<td>96.1</td>
<td>92.7</td>
</tr>
<tr>
<td>Mean MIB-1 labeling index</td>
<td>2.88</td>
<td>2.51</td>
</tr>
<tr>
<td>Mean duration of follow-up (mos)</td>
<td>149.3</td>
<td>77.9</td>
</tr>
<tr>
<td>SRS (no. of cases)</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Local control (% of cases)</td>
<td>91.7</td>
<td>94.4</td>
</tr>
</tbody>
</table>
local control, the pre- and postoperative tumor volumes were larger and the EOR was lower than in the group in which local control was achieved. A significant relationship was seen between pre- and postoperative tumor volume and EOR (p < 0.05, Mann-Whitney U-test), but there was no significant relationship between failure to achieve local control and the MIB-1 labeling index (p < 0.05, Mann-Whitney U-test) (Table 3). There was a marked significant difference in recurrence-free survival (calculated using the Kaplan-Meier method) between patients with less than 85% EOR and patients in whom at least 85% tumor resection was achieved (Fig. 2).

Long-Term Disabilities and Performance

The PCMIS score was measured for all of the patients preoperatively, at 3 months after surgery, and at the time of the last follow-up examination. The most common PCMIS disability categories for which scores worsened postoperatively were facial nerve palsy (Category C), diplopia caused by CN III, IV, and/or VI palsy (Category A), and hearing loss (Category D). All of these categories were scored on a scale of 0–3, with 3 indicating maximum impairment.

In the early group, the postoperative total PCMIS score improved in 3 patients (12.5%), remained stable in 1 (4.2%), and worsened in 20 (83.3%), and the mean total preoperative, postoperative, and last follow-up scores were 3.8, 8.0, and 7.1, respectively. The total PCMIS scores after surgery tended to be higher than the preoperative values, indicating increased disability, with the scores not returning to preoperative levels at the time of long-term follow-up. For facial nerve palsy, present in 16 patients (67%), the mean preoperative, postoperative, and last follow-up PCMIS scores were 0.2, 2.0, and 1.5, respectively. For diplopia, present in 14 patients (58%), the scores were 0.7, 1.9, and 1.0, respectively, and for hearing loss, present in 10 patients (42%), the mean preoperative, postoperative, and last follow-up scores were 0.3, 0.7 and 0.7, respectively (Fig. 3).

In the late group, the total PCMIS score improved postoperatively in 23 patients (63.9%), remained stable in 5 (13.9%), and worsened in 8 (22.2%), and the mean preoperative, postoperative, and last follow-up scores were 4.8, 4.1, and 2.8, respectively. The total PCMIS score showed an improvement postoperatively with respect to the preoperative level score, and the score at the time of the most recent long-term follow-up evaluation tended to be significantly better than the postoperative score (p < 0.05, Wilcoxon t-test). As in the early group, the most common disability postoperatively was diplopia, which was present in 16 patients (44.4%), but in the late group the mean score for the most recent long-term follow-up evaluation was very close to the preoperative score. The mean preoperative, postoperative, and last follow-up scores for diplopia were 0.5, 1.2, and 0.6, respectively. The second most common disability postoperatively was facial nerve palsy, which was present in 11 patients (30.6%), but the PCMIS scores for this group recovered to preoperative levels at the time of the most recent long-term follow-up evaluation (mean preoperative, postoperative, and last follow-up scores of 0.4, 0.8, and 0.4, respectively). The next most common disability was hearing loss, which was present in 9 patients postoperatively (25%), and the mean preoperative, postoperative, and last follow-up scores were 0.2, 0.4, and 0.4, respectively. In 1 of these patients, the labyrinth was drilled out to widen the surgical corridor.

In 2 other PCMIS categories, facial sensation (Category B) and motor disturbance (Category F), the scores for the late group showed significant improvement, with the mean postoperative scores in the late group being 0.3 and 0.6 compared with the mean preoperative scores of 0.8 and 1.5 (with scores of 3 and 10 indicating maximum disability) for facial sensation and motor disturbance, respectively (p < 0.05, Wilcoxon t-test) (Fig. 3). In both groups, there was a tendency for the PCMIS scores for diplopia and facial palsy to be worse immediately after surgery than preoperatively and recover at the final follow-up evaluation. On the other hand, there was a tendency for the PCMIS score for hearing to be worse after surgery than preoperatively and not recover. In the late group, the total PCMIS score tended to be better than in the early group at the time of postoperative and recent follow-up evaluation (Fig. 3).

Discussion

Petroclival meningiomas are among the most difficult tumors of the skull base, with respect to surgical treat-
Quantitative Evaluation and Petroclival Meningioma

In patients with petroclival meningioma, assessment of treatment based on the number of new postoperative neurological deficits may be misleading. For example, some neurological symptoms that severely affect patients’ performance status, such as hemiparesis or ataxia, may be dramatically improved after surgery, but other symptoms, such as diplopia, facial nerve palsy, and hearing ability, are sometimes worsened. Therefore, a comprehensive method of measure patients’ status is needed. The Karnofsky Performance Status (KPS) has been the gold standard over the years for comprehensive assessment of a patient’s condition. However, it is not readily applicable to patients with petroclival meningiomas due to the rough classification of each score. A patient suffering hearing disturbance before surgery may have a KPS score of 80, and if he or she additionally suffers facial palsy after surgery, the KPS score will still be 80 postoperatively. In fact, almost all the patients in our case series had a KPS score of 70 or more before and after surgery; 58 (96.7%) of 60 patients had a preoperative KPS score of 70 or more, and 56 (94.9%) of 59 patients had a KPS score of 70 or more postoperatively. Moreover, in 42 (70%) of 60 cases, the difference in KPS scores before and after surgery was within 10 points. Comparison of PCMIS and KPS scores in our early group showed that the PCMIS improved in 3 patients (12.5%), remained stable in 1 (4.2%), and worsened in 20 (83.3%), whereas the KPS score improved in 7 patients (29.2%), remained stable in 7 (29.2%), and worsened in 10 (41.6%). In the late group, the PCMIS improved in 23 patients (63.9%), remained stable in 5 (13.9%), and worsened in 8 (22.2%), whereas the KPS score improved in 21 patients (58.3%), remained stable in 10 (27.8%), and worsened in 5 (13.9%). Evaluation on the basis of KPS scores tends to underestimate postoperative complications in patients with petroclival meningioma. In these patients, disability
To evaluate resection of petroclival meningiomas, the degree of surgical removal has been classified into gross-total, subtotal, or partial in many previous reports. Assessment using the KPS may not be precisely quantifiable. Moreover, the KPS is not comprehensive enough to indicate subtle neurological changes during the course of illness. For these reasons, we formulated a new scoring system, the petroclival meningioma impairment scale (PCMIS), based on a comprehensive neurological examination specific to petroclival lesions. In this scoring system, higher points are assigned to neurological symptoms that severely affect the patient’s quality of life, such as impairment of swallowing and speaking, motor function, or consciousness and communication. The weight of each score was decided based on the questionnaire regarding neurological deficits that severely affect the daily activity. Today, maximum possible resection with functional preservation is regarded as the optimal surgery for petroclival meningiomas, and we believe the PCMIS is more appropriate than the KPS for assessing results for these patients.

To evaluate resection of petroclival meningiomas, the degree of surgical removal has been classified into gross-total, subtotal, or partial in many previous reports. However, considering the recent trend of maximum possible resection with functional preservation, most petroclival meningiomas were subtotally resected, leaving behind some tumor residue around critical neurovascular structures. Therefore, the extent of tumor excision cannot be estimated by this classification (gross-total, subtotal, or partial resection). Thus, we calculated tumor volume and quantitative extent of resection (EOR) to evaluate the extent of tumor removal.

These evaluations in this study should be particularly useful in comparison of treatments such as primary SRS or partial resection followed by SRS.

Comparison of Surgical Results from 2000–2009 versus 1990–1999

To evaluate improvements in techniques with the accrual of cases, patients were classified into 2 groups according to the operative period. In the early group (1990–1999), a high EOR (96.1%) led to a high tumor control rate (91.7%), but the patients’ PCMIS scores worsened after surgery. On the other hand, in the late group (2000–2009), a high EOR (92.7%) led to a high tumor control rate (94.4%), and the PCMIS scores improved after surgery. No significant difference in EOR was identified between these 2 groups, but the mean postoperative PCMIS score was markedly and significantly more satisfactory in the late group than in the early group (p < 0.05, Mann-Whitney U-test). This means that our results from the late group were clearly not attributable to a low resection rate.

The reasons for good results in the late group should be considered as follows: intentional tumor residue in critical regions such as the cavernous sinus or where tumor is severely adherent to critical neurovascular structure (maximal possible resection), in consideration of the effectiveness of SRS; prevention of venous infarction by preservation of basal venous drainage routes; and technical advances in intraoperative monitoring of intracranial nerves or neuronavigation systems. Although improvements in such techniques cannot be evaluated by statistical analysis, our results suggest that the cumulative minor changes in surgical technique and the increase in experience have markedly improved the safety of skull base surgery. So, we suggest that modern skull base surgery is not as dangerous as described in past reports.

Effects of Using a Combined Transpetrosal Approach for Petroclival Meningiomas

The indications for a transpetrosal approach for petroclival meningiomas are sometimes controversial. Transpetrosal approaches are usually advantageous for minimizing temporal lobe retraction, thereby allowing access to the anterior brainstem and clivus and permitting removal of clival tumors. These approaches are, however, laborious, and they entail intricate dissection of intra- and extradural parts of the auditory and nerve complexes.

There was no mortality in this series of 36 consecutive patients who were operated on via combined transpetrosal approach in late group (2000–2009). Serious surgical complication (PCMIS score increase ≥ 15 points) occurred in 1 (2.8%) of 36 patients; this patient had a refractory seizure (status epilepticus) in the perioperative period and required institutional or hospital care. Two patients with aggressive tumors experienced progressive tumor growth.

Al-Mefty et al. reported a retrospective analysis of 64 cases of petroclival meningiomas involving patients who were surgically treated between 1988 and 2012 with the goal of total tumor resection. On follow-up, the average KPS score was 88.28 (median 90). Resection resulted in improved KPS scores in 30 patients (47%), while 23 patients (36%) had equivalent pre- and postoperative KPS scores. In 11 cases (17%), the KPS scores decreased after surgery. We also reanalyzed functional outcome by KPS and found that, in the late group, the KPS score improved on follow-up in 21 patients (58.3%), remained stable in 10 (27.8%), and worsened in 5 (13.9%). Useful hearing was preserved in 23 (73.9%) of 29 patients who were treated surgically with an attempt at hearing preservation, and good facial nerve function (House-Brackmann Grade I or II) was obtained in 32 (86.1%) of 36 patients at the time of the long-term follow-up. The morbidity of the patients in the late group was similar to or slightly more favorable than in other recent series that used hearing-preserving approaches for petroclival meningiomas; in other series, the rates of serious morbidity and mortality have ranged from 6% to 40%, 4,7,10,17,18,21,22,27 Outcomes related to CN VII and VIII were clearly better in this series than those reported from series with non–hearing-preserving approaches, in which hearing was always lost and only 55% of the patients had House-Brackmann Grade I or II facial nerve function at follow-up examination.11,14,28

Optimal Treatment for Petroclival Meningiomas

The surgical management of medium-sized or large petroclival meningiomas has frustrated neurosurgeons for many years. In this study, we evaluated tumor volume quantitatively and showed the relationship between EOR and local tumor control. In the cases in which local control was not achieved, postoperative tumor volume was larger and EOR was lower than with the cases in which local control was achieved. These results draw attention to the favorable effect of maximizing the resection rate on long-term tumor control.
Of course, a high EOR leads to a high tumor control rate. However, the high morbidity rate in our early group (1990–1999) indicates the high surgical risks associated with total excision of lesions, as previous authors of reports have mentioned.4,5,11,31 Observation, SRS, and a combination of partial resection and SRS are also alternatives to radical resection.

Regarding the natural history of these tumors, a study by Van Havenbergh et al.33 presented a retrospective series of 21 cases involving patients with untreated petroclival meningioma who underwent regular clinical and radiological follow-up evaluations. During the follow-up monitoring, tumor growth was observed on imaging studies in 76% of the cases, and in 63% of these cases, the patients’ function deteriorated. These data demonstrate that petroclival meningiomas grow slowly, but that in cases in which they do grow, the long-term outcomes tend to be poor. In our study, patients with large petroclival meningiomas had a greater increase in PCMIS score (reflecting a greater decline in function) than patients with medium-sized tumors.

Radiosurgery has shown promise for control of small petroclival meningiomas.16,26,33 However, radiosurgery is suitable only for small lesions in this location. Unfortunately, most tumors are diagnosed when they are already too large for radiosurgery, and the risk of delayed adverse effects on the brainstem, including transient cranial neuropathies, must be taken into account.33 Flannery et al.8 reported that a significant risk factor for tumor progression was a tumor volume ≥ 8 cm³ in their study on the long-term control of petroclival meningiomas through radiosurgery. Many neurosurgeons have preferred treatments such as the combination of partial resection and additional SRS.13,24 Such treatments have shown acceptable outcomes for fairly long follow-up periods, but the degree of tumor reduction at initial surgery has not been mentioned. In this study, patients with less tumor removal (EOR < 85%) had significantly shorter recurrence-free survival (calculated using the Kaplan-Meier method) than those who had radical tumor excision (EOR ≥ 85%). Safe radical resection for preserving high quality of life is optimal for patients. Our results in the late group (2000–2009) demonstrate the degree of safety with which radical resection of medium-sized or large petroclival meningiomas can be achieved. The mean EOR in this group was 92.7%, and this was achieved with a mortality rate of 0% and a severe morbidity rate of 2.2%. The local control rate was 94.4%, and the percentages of patients with an improved or unchanged PCMIS score were 63.9% and 13.9%, respectively, supporting the relative safety of our treatments. The modern combined transpetrosal approach has provided satisfactory functional improvements for patients with medium-sized or large petroclival meningiomas. Although we have resected tumors via a combined transpetrosal approach, if the same EOR and the improvement of PCMIS score are achieved, other surgical procedures combined with SRS will result in similar outcomes.

We believe maximal resection via a combined transpetrosal approach is the best treatment for medium-sized or large petroclival meningiomas. Adjuvant treatment, especially SRS, can be considered after resection when recurrent tumor or growth of residual tumor is detected on MRI. SRS may also be the preferred primary treatment for asymptomatic patients with small tumors. However, more aggressive treatment is recommended for young patients or patients with short symptom duration.

Conclusions

The present study showed the role of quantitative evaluations for petroclival meningiomas and investigated the surgical results of petroclival meningiomas resected via combined transpetrosal approach. Maximal resection followed by SRS when necessary can provide effective control of these tumors. The PCMIS is a useful scoring scale to comprehensively measure patient’s status with petroclival meningiomas.

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Conception and design: Morisako, Goto. Acquisition of data: Morisako, Goto. Analysis and interpretation of data: Morisako, Goto. Drafting the article: Morisako, Goto. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Morisako. Statistical analysis: Morisako. Administrative/technical/material support: all authors. Study supervision: Goto, Ohata.

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