Surgical outcomes of the minimum anterior and posterior combined transpetrosal approach for resection of retrochiasmatic craniopharyngiomas with complicated conditions

Clinical article

**Noritsugu Kunihiro, M.D., Takeo Goto, M.D., Kenichi Ishibashi, M.D., and Kenji Ohata, M.D.**

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

*Object.* Retrochiasmatic craniopharyngiomas are surgically challenging tumors. Retrochiasmatic craniopharyngiomas with complicated conditions such as large diameter, major calcification, or significant extension to the third ventricle or posterior fossa present surgical challenges; moreover, recurrent retrochiasmatic craniopharyngiomas are particularly formidable challenges. Although the transpetrosal approach to retrochiasmatic craniopharyngiomas published by Hakuba in 1985 can provide unique advantageous exposure of the retrochiasmatic area to allow safe neurovascular dissection and facilitate radical tumor removal, the procedure is viewed as complicated and time consuming and has a high risk of damaging hearing functions. The authors have modified Hakuba’s technique to minimize petrosectomy and reduce surgical complications and have applied this modified approach to retrochiasmatic craniopharyngiomas with complicated conditions. In this study, the authors describe their technique and surgical outcomes to elucidate the role of this modified transpetrosal approach for retrochiasmatic craniopharyngiomas with complicated conditions. This is the first study to report surgical outcomes of the transpetrosal approach for retrochiasmatic craniopharyngiomas.

*Methods.* Between 1999 and 2011, the minimum anterior and posterior combined (MAPC) transpetrosal approach, which is a modification of Hakuba’s transpetrosal approach, was applied in 16 cases of retrochiasmatic craniopharyngiomas with complicated conditions. Eight cases were recurrent tumors, 4 had previously received radiotherapy, 11 had a large diameter, 10 had large calcification, 15 had superior extension of the tumor into the third ventricle, and 10 had a posterior extension of the tumor that compressed the midbrain and pons. In all 16 patients, more than 2 of these complicated conditions were present. The follow-up duration ranged from 0.8 to 12.5 years (mean 5.3 years). Surgical outcomes assessed were the extent of resection, surgical complications, visual function, endocrinological status, and neuropsychological function. Five-year and 10-year recurrence-free survival rates were also calculated.

*Results.* Gross-total or near-total resection was achieved in 15 cases (93.8%). Facial nerve function was completely maintained in all 16 patients. Serviceable hearing was preserved in 15 cases (93.8%). Visual function improved in 13 out of 14 cases (92.9%) that had visual disturbance before surgery. None of the patients experienced deterioration of their visual function. Twelve cases had endocrinological deficit and received hormonal replacement before surgery. New endocrinological deficit occurred in 2 cases (12.5%). Neuropsychological function was maintained in 14 cases (87.5%) and improved in 1 case (6.3%). One case that had received previous conventional radiotherapy treatment showed a gradual decline in neuropsychological function. The 5-year and 10-year recurrence-free survival rates were both 86.5%.

*Conclusions.* The authors obtained good results by using the MAPC transpetrosal approach for the removal of retrochiasmatic craniopharyngiomas with complicated conditions. The MAPC transpetrosal approach should be considered as a therapeutic option for selected cases of retrochiasmatic craniopharyngiomas with complicated conditions.

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**Key Words** • retrochiasmatic craniopharyngioma • skull base • surgical approach • transpetrosal approach • oncology
chiasmatic craniopharyngioma.

In 1985, Hakuba reported the usefulness of the transpetrosal approach for the removal of retrochiasmatic craniopharyngiomas, emphasizing that this approach offers wide exposure of retrochiasmatic lesions and unique posterior-to-anterior and inferior-to-superior projection to the inferior and posterior surfaces of the chiasm, the floor of third ventricle, and the hypothalamic tuber cinereum area. However, in his approach, Hakuba sacrificed 3 semicircular canals with 33% hearing preservation. Al-Mefty et al. used Hakuba’s techniques and reported the effectiveness of the transpetrosal approach for giant retrochiasmatic craniopharyngiomas but have not yet reported outcomes and complication rates in their surgical series. In addition, the complicated surgical procedures involved in the petrosal approach have discouraged neurosurgeons from assessing the most effective approach for removal of retrochiasmatic craniopharyngiomas.

We have modified Hakuba’s techniques to minimize petrosectomy and reduce surgical complications and have applied this approach to 16 patients with retrochiasmatic craniopharyngiomas with complicated conditions such as a history of excision or radiotherapy, tumors with large calcification, large diameter (> 30 mm), superior extension into the third ventricle, or severe posterior extension compressing the midbrain and pons. This study retrospectively analyzed surgical outcomes, including the extent of tumor resection, recurrence rate, surgical complications, visual function, endocrinological status, neuropsychological function, and functional performance status, to elucidate the role of our modified transpetrosal approach for the removal of retrochiasmatic craniopharyngioma with complicated conditions. This is the first study to report surgical outcomes of the transpetrosal approach for retrochiasmatic craniopharyngioma.

Methods

Indications for MAPC Transpetrosal Approach

Minimum anterior and posterior combined (MAPC) transpetrosal approaches were applied to retrochiasmatic craniopharyngiomas with complicated conditions such as a history of excisions or radiotherapy, tumors with large calcification, large diameter (> 30 mm), superior extension into the third ventricle, or severe posterior extension compressing the midbrain and pons. If a retrochiasmatic craniopharyngioma possessed not less than 2 of these complicated conditions and no well-developed middle fossa venous sinus (such as the sphenobasal or sphenopetrosal sinus) blocking the surgical route to the tumor, the MAPC transpetrosal approach was applied.

Patient Population

Between 1999 and 2011, a total of 44 consecutive patients underwent resection of craniopharyngiomas in the Department of Neurosurgery at Osaka City University in Osaka, Japan. Medical records from all 44 patients were retrospectively examined. Tumors showing the following conditions on imaging were defined as retrochiasmatic craniopharyngiomas: 1) the tumor extending toward the posterior fossa and upward toward the third ventricle, displacing the midbrain posteriorly and the optic chiasm anteriorly; and 2) no upward displacement of the anterior cerebral arteries as would be seen in patients with a prechiasmatic craniopharyngioma. Thirty-six of the 44 tumors were classified as retrochiasmatic craniopharyngioma and 16 of these 36 tumors were resected using our modified MAPC transpetrosal approach. These 16 cases formed the sample for this study. All clinical data of the 16 patients were reviewed retrospectively.

Six patients were male and 10 patients were female, and their mean age at the time of surgery was 47.9 years (range 27–71 years; Table 1). Eight patients (50.0%) had undergone previous surgical procedures at other institutions (Table 1). Prior surgical approaches were interhemispheric in 3 patients, pterional in 2, extended transsphenoidal in 2, and orbitozygomatic in 2. Ommaya reservoirs had been placed in 2 patients. Four patients had received repeated or combined operations. The mean interval between first surgery and our surgery was 10.0 years (range 0.7–32.0 years). Four patients had already received radiotherapy prior to referral to our institution. Stereotactic radiosurgery was added in 2 cases, conventional radiotherapy to 1, and conventional radiotherapy and 3 sessions of stereotactic radiosurgery in 1. The mean maximum diameter of the tumor, as estimated from preoperative MR images, was 32.1 mm (range 25–40 mm). A large tumor diameter (maximum tumor diameter > 30 mm) was present in 11 patients (68.8%). A large calcification (intratumoral calcification > 10% of tumor volume on preoperative CT images) was present in 10 patients (62.5%). Superior extension into the third ventricle was documented in 15 patients (93.8%). Posterior extension in which the tumor appeared to be compressing the midbrain and pons was present in 10 patients (62.5%). All 16 patients had no fewer than 2 of these complicated conditions (Table 1).

Nine tumors were removed in a single step via the MAPC transpetrosal approach and 7 tumors were excised in 2 steps via a combination of the MAPC transpetrosal approach and other approaches (for example, orbitozygomatic, interhemispheric lamina terminalis, and transsphenoidal). The mean follow-up duration was 5.3 years (range 0.8–12.5 years). The median survival duration was 5.6 years (range 1.4–12.5 years). Three patients died during the follow-up period: 1 patient of radiation necrosis 3.6 years after surgery; 1 of chronic heart failure 6.1 years after surgery; and 1 of old age 1.7 years after surgery. Another patient was followed up for 0.8 years before being lost to follow-up after being transferred to another hospital for an unrelated disease 1.4 years after surgery. Clinical and ophthalmological examinations, imaging studies, endocrinological studies, neuropsychological function, and surgical complications were reviewed retrospectively based on the medical records at our institution.

Neuroradiological Evaluation

Before surgery, all patients underwent MRI, CT, and angiography. Tumor size was estimated from MR images by measuring the maximum anteroposterior, vertical, and horizontal diameters. The extent of intratumoral calcification-
Transpetrosal approach for challenging craniopharyngiomas

TABLE 1: Characteristics of 16 patients with tumors resected via the MAPC transpetrosal approach

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Previous Op</th>
<th>Interval Btw Ops (yrs)†</th>
<th>Previous Radiation</th>
<th>Max Tumor Diameter (mm)</th>
<th>Calcification (%)</th>
<th>Superior Extension into 3rd Ventricle</th>
<th>Posterior Extension Compressing Brainstem</th>
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<tr>
<td>1</td>
<td>31, F</td>
<td></td>
<td></td>
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* IH = interhemispheric approach; OZ = orbitozygomatic approach; PT = pterional approach; RT = radiation therapy; SRS = stereotactic radiosurgery; TSS = transsphenoidal surgery.
† Interval between first surgery and surgery at our institution.

Extent of Tumor Resection

Neuroradiologists independently reviewed the results of preoperative and postoperative MR and CT images to assess the extent of tumor resection. The extent of resection was determined from MR and CT images obtained within 1 week after surgery and from follow-up radiological studies. All tumors were evaluated using enhanced MRI. However, small calcifications can only be detected on CT, which is why this modality was used for radiological evaluation. If small calcifications were identified, a small residual tumor was considered to be present. Small enhanced lesions that diminished in the late period were judged as representing postoperative reactive changes rather than as residual tumor.

Resection was classified as gross-total resection when there was no residual enhanced lesion or residual calcification, near-total resection when residual enhanced lesion or calcification was limited to less than 0.5 cm³, and subtotal resection when there was residual enhanced lesion or calcification was equal to or less than 0.5 cm³. The volume of the residual enhanced lesion or calcification was calculated as the volume of an ellipsoid: volume = 4πabc/3 × 2³, where a, b, and c represent the orthogonal diameters on the MR image.

Tumor Recurrence

Follow-up MRI was performed within 1 week after surgery, within 3 months after surgery, and then at regular intervals of 6–12 months. Three patients underwent the second MRI session at 4 months after surgery rather than within 3 months. All other patients underwent MRI in accordance with the schedule. Recurrence of the tumor during follow-up was defined as the appearance of new pathological tissue on MR images or the growth of tumor remnants.

Visual Function

Ophthalmological evaluation, including visual acuity and field examination in accordance with the guidelines of the German Ophthalmological Society, was performed by an ophthalmologist before and after surgery and when clinically appropriate. The timing of subsequent assess-
ments was decided on an individual basis. Visual function was quantified using the visual impairment scale (VIS), which is based on visual acuity and visual field defects in both eyes (Fig. 1). Available ophthalmological examinations including visual acuity and visual field testing for reviews were performed in 15 cases. One patient who was transferred to another hospital for an unrelated disease during the follow-up period did not undergo full ophthalmological evaluation.

Endocrinological Status

In addition to clinical symptoms, we evaluated basic levels of luteinizing hormone, follicle-stimulating hormone, free triiodothyronine, free thyroxine, thyroid-stimulating hormone, growth hormone, cortisol, adrenocorticotropic hormone, and prolactin before and after surgery. Anterior pituitary hormone dysfunction was defined as the use of hormone supplementation; deficits in basic levels of luteinizing hormone, follicle-stimulating hormone, free triiodothyronine, free thyroxine, thyroid-stimulating hormone, growth hormone, cortisol, or adrenocorticotropic hormone; or high levels of prolactin without use of dopamine agonists. Diabetes insipidus was diagnosed before and after surgery based on sodium level and the presence of hypotonic polyuria. All patients underwent available endocrinological assessment for review.

Neuropsychological Function

Neuropsychological function was evaluated preoperatively and postoperatively by face-to-face examinations. Patients were classified as showing neuropsychological dysfunction if any of the following conditions were met: 1) score < 70 on the full scale of the Wechsler adult intelligence scale (3rd edition);28 2) score < 20 on the Mini-Mental Status Examination;9 or 3) the patient found it impossible to continue in a previous occupation. These data were available for review from all patients.

Functional Performance Status

Functional performance status was evaluated using the Karnofsky Performance Scale (KPS).

Statistical Analysis

The cumulative risk of tumor recurrence was calculated according to the Kaplan-Meier method; JMP 9.0 software (SAS Institute Inc.) was used.

The MAPC Transpetrosal Approach

Positioning. Patients were placed in a semiprone park bench position. The head was fixed using 3-point fixation with the head rotated and vertex down to keep the temporal side of the head in the horizontal plane.

Skin Incision. The skin incision started at the upper margin of the zygomatic arch anterior to the tragus, turned 2–3 cm above the ear, and then descended behind the posterior margin of the mastoid process. After reflecting the skin flap, a temporal fascia-pericranial flap with a pedicle of the sternocleidomastoid muscle was harvested to prevent leakage of CSF.

Craniotomy. Temporo-occipito-suboccipital craniotomy was performed prior to mastoidectomy. Key bur holes were placed at 4 anatomical landmarks to avoid injuring the sigmoid sinus. The first bur hole was made at the asterion, the second at the intersection of the supramastoid crest with the squamous suture, the third at the mastoid emissary foramen, and the fourth just at the inion-asterion line. The first bur hole was usually just above the lateral end of the transverse sinus, the second just anterior to the transverse-sigmoid sinus junction, the third a few millimeters medial to the posterior edge of the sigmoid sinus, and the fourth just on the transverse sinus.

Preparation for MAPC Petrosectomy. After temporo-occipito-suboccipital craniotomy, the outer cortical bone of the mastoid portion of the temporal bone was removed as a thin triangular plate for cosmetic mastoidectomy. This procedure was not essential and was skipped in cases in which the groove of the sigmoid sinus was too large. At this point, the transverse sinus and transverse sinus–sigmoid sinus junction had been safely exposed (Fig. 2A). Dural dissection from the petrous and mastoid portions of the temporal bone was then started for safe and swift petrosectomy. At the middle fossa, the presigmoid dura was carefully dissected from the posterior surface of the petrous portion of the temporal bone and the entrance of the internal auditory canal was epidurally exposed by cutting the endolymphatic sac (Fig. 2B). After completion of this dural dissection, bone work for petrosectomy was performed (Fig. 2C). This full dural retraction is a unique characteristic of the MAPC transpetrosal approach. The membranous labyrinths of the semicircular canals were kept intact to preserve hearing. A small amount of bone at the petrous ridge was drilled out to obtain a surgical corridor along the axis of the petrous ridge (Fig. 2D and E). The amount of petrous portion of the temporal bone required for petrosectomy is quite limited and this allows a quick surgical procedure.

Dural Opening. The presigmoid dura was opened along the drilled petrosal portion of the temporal bone as far anteriorly as possible while the insertion of the petrosal vein at the superior petrosal sinus was inspected. The subttemporal dura was opened anteriorly and the superior petrosal sinus was divided by Weck clips (Teleflex) at a point anterior to the insertion of the petrosal vein at the superior petrosal sinus to preserve venous reflux from the petrosal vein. The tentorium was cut behind the dural entrance of the trochlear nerve, and the trochlear nerve into the tentorium was exposed.

Intradural Procedure. After superior retraction of the temporal lobe and medial mobilization of the sigmoid sinus, the arachnoid membrane was dissected to obtain a surgical corridor to the retrochiasmatic space (Fig. 3A). The trochlear nerve, oculomotor nerve, C1 and C2 portions of the internal carotid artery, PCoA and its perforating branches, posterior cerebral artery, and superior cerebellar artery were identified step by step; the tumor was widely
Transpetrosal approach for challenging craniopharyngiomas

**Fig. 1.** Tables of visual acuity and visual field defects used to calculate the VIS score. The black boxes with numbers provide an example of the calculation made in a patient with a visual acuity of 0.4 in the left eye and 0.2 in the right eye, together with a bitemporal visual field defect. The VIS score is the sum of these 2 numbers (that is, 35 + 22 = 57). Reprinted with permission from Fahlbusch R, Schott W: J Neurosurg 96:235–243, 2002.

**Fig. 2.** Illustrations of petrosectomy used in the MAPC transpetrosal approach. A: The transverse sinus and transverse sinus–sigmoid sinus junction are safely exposed after temporo-occipito-suboccipital craniotomy and cosmetic mastoidectomy. B: Dural dissection from the petrous and mastoid portions of the temporal bone is completely performed at the middle fossa and the posterior fossa. C: Complete exposed petrous portion of temporal bone is safely and quickly removed in the wide surgical field. D: A small amount of bone at the petrous ridge is drilled out to create a unique surgical corridor. E: The wide exposure and unique posterior-to-anterior and inferior-to-superior projection for retrochiasmatic craniopharyngiomas are offered by the MAPC transpetrosal approach (red arrow). IC = internal carotid artery; PCA = posterior cerebral artery; PCom = PCoA; T = tumor; III = third cranial nerve. Copyright Noritsugu Kunihiro. Published with permission.
exposed behind the optic chiasm, under the hypothalamus, and in front of the midbrain (Fig. 3B). In this approach, the space between the oculomotor nerve and PCoA, as well as below the oculomotor nerve, provided useful surgical fields for tumor resection. After the initial internal decompression of the tumor (Fig. 3C), the pituitary stalk was visualized (Fig. 3D) but not often preserved. The inferior portion of the tumor on the contralateral side was dissected from the contralateral oculomotor nerve, PCoA, and internal carotid artery (Fig. 3E and F). The main corridor between the oculomotor nerve and PCoA allowed safe dissection from the surrounding structures, such as the surface behind the chiasm or hypothalamus on direct visualization. The hypoplastic PCoA was often divided at the intersection point with the posterior cerebral artery, and upward mobilization of the PCoA enlarged the operative space (Fig. 3G and H). By obtaining more upward projection through this wider operative space, the tumor was safely dissected off the inferior surface of the hypothalamus (Fig. 3I). As dissection progressed anteriorly, the inferior and posterior surfaces of the chiasm (C) is well visualized via posterior-to-anterior and inferior upward projection. K: The medial wall of the third ventricle (3rd) is well visualized after more upward projection. IV = fourth cranial nerve; M = midbrain; PCA = posterior cerebral artery; SCA = superior cerebellar artery. TL = temporal lobe; V = fifth cranial nerve.
Transpetrosal approach for challenging craniopharyngiomas

Closure. All opened mastoid air cells were sealed with abdominal fat-soaked fibrin glue; then the mastoid and petrous portions of the temporal bone and dural defect were entirely covered with the harvested fascia-pericranial flap. The lumbar drain was left open for approximately 3 days to allow CSF pressure to reduce and prevent leakage of CSF.

Results

Extent of Tumor Resection

The extent of tumor resection is shown in Table 2. Gross-total resection was achieved in 9 patients (56.3%) and near-total resection was achieved in 6 patients (37.5%). Subtotal resection was found in only 1 patient (Case 2). This patient had particularly complicated conditions, including 4 previous surgeries and a history of conventional radiation therapy.

Tumor Recurrence

During the follow-up period, no tumor recurrence occurred in any of the 9 patients with gross-total resection (Table 2). Regrowth was detected in 1 of the 6 patients with near-total resection but was successfully controlled for 108 months after an additional resection and stereotactic radiosurgery. Regrowth began 8 months after surgery in the patient with subtotal resection. This was controlled by additional resection and stereotactic radiosurgery treatment, but the patient died due to radiation necrosis.

Morbidity and Mortality

No surgery-related deaths occurred. Transient oculomotor nerve palsy was confirmed in 7 patients and was fully resolved within the follow-up period. Facial nerve function was completely maintained in all 16 patients. Serviceable hearing was preserved in 15 of the 16 patients. No other cranial nerve palsies were seen. Venous infarction or contusion-related temporal retraction was not detected. Leakage of CSF and surgical-site infection did not occur in any patients (Table 2).

Visual Function

Results of the VIS are presented in Table 2. Fifteen patients (93.8%) showed visual disturbance before surgery. One patient who was lost to follow-up after admission to another hospital with an unrelated disease did not undergo a full ophthalmological evaluation and thus was not included in this analysis. One patient with normal visual function preoperatively retained normal function postoperatively. Visual function improved after surgery in 13 (92.9%) of the 14 patients who had visual disturbance before surgery. One patient (Case 2) did not show improvement in visual function after surgery. This patient was blind in both eyes (VIS score of 100) before surgery. No patients experienced any deterioration in visual function. The mean VIS score improved from 37.2 ± 33.7 preoperatively to 17.3 ± 31.3 postoperatively.

Endocrinological Status

Twelve patients (75.0%) had an endocrinological deficit or had received hormonal replacement before our surgery. Preoperatively, 4 patients had received replacement of anterior pituitary hormone, 6 patients showed a deficit in anterior pituitary hormone, and 9 patients had diabetes insipidus. Three patients showed deficit of anterior pituitary hormone without diabetes insipidus and 2 patients showed only diabetes insipidus. Postoperatively, 14 patients (87.5%) received endocrine replacement (Table 2). Of these patients, 2 received replacement of anterior pituitary hormone without diabetes insipidus and 1 had diabetes insipidus only. Pituitary stalks were anatomically preserved in 6 patients but preservation of function was only achieved in 2 patients.

Neuropsychological Function

Five patients (31.3%) showed neuropsychological deficit before surgery, and the neuropsychological function in the remaining 11 patients (68.8%) was normal. During follow-up, neuropsychological function was preserved in 14 patients (87.5%), improved in 1 patient (6.3%), and deteriorated in 1 patient (6.3%) (Table 2). The patient who had deteriorated neuropsychological function had received previous conventional radiotherapy and showed a gradual decline in neuropsychological function.

Functional Performance Status

Postoperative KPS scores at final follow-up were compared with preoperative KPS scores in 13 patients. Two patients died of unrelated diseases, and 1 patient was lost to follow-up after admission to another hospital with an unrelated disease and thus was not included in this analysis (Table 2). The mean preoperative KPS score was 80.0 (range 60.0–90.0) and the mean postoperative KPS score was 88.3 (range 70.0–90.0). The KPS scores improved in all but 1 patient (Case 2), who died due to radiation necrosis. All patients (except the one who died due to radiation necrosis) returned to their normal daily life and social activities after surgery.

Long-Term Outcome

The recurrence-free survival rate is shown in Fig. 4. The 5-year recurrence-free survival rate in the 16 patients was 86.5% (Fig. 4). The 10-year recurrence-free survival rate was also 86.5% (Fig. 4). The 5-year recurrence-free survival rates were 100.0% after gross-total resection and 68.5% after near-total and subtotal resection (Fig. 5).

Discussion

Craniopharyngiomas located in the retrochiasmatic region are regarded as challenging tumors to remove safely and totally because of their anatomical location and proximity to critical neurovascular structures. Because of the hidden position of retrochiasmatic craniopharyngiomas behind the optic chiasm, their upward extension into the third ventricle, and their downward extension in front of the brainstem, the surgical exposure of these tumors is usually unsatisfactory.2,20,26,29 Resection of this type of craniopharyngioma has thus been associated with a high rate of surgical mortality, surgical complications, and in-
### TABLE 2: Surgical outcomes in 16 patients with tumors resected via the MAPC transpetrosal approach*

| Case No. | Approach | Resection | Complication       | Recurrence | VA Preop | VF Preop | Total Preop | VA Postop | VF Postop | Total Postop | APH Preop | DI Preop | APH Postop | DI Postop | VIS Score | Endocrinological Dysfunction Preop | Endocrinological Dysfunction Postop | Neuropsychological Deficit Preop | Neuropsychological Deficit Postop | KPS Score Preop | KPS Score Postop |
|----------|----------|-----------|--------------------|------------|----------|----------|-------------|----------|----------|-------------|-----------|----------|-----------|----------|-----------|-------------------------------|-------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 1        | OZ→TP   | GTR       | none               | no         | 0        | 0        | 0           | 0        | 0        | 0           | 0         | no       | 0         | no       | 0         | no                           | no                           | no                  | no            | no            | no            | 90                | 90                |
| 2        | TP      | STR       | none               | yes        | 100      | 25       | 100         | 0        | 100      | 0           | 0         | yes      | no        | yes      | no        | yes                          | no                           | yes                 | no            | yes           | yes           | 60                | dead†             |
| 3        | TP      | GTR       | none               | no         | 28       | 31       | 59          | 2        | 10       | 12          | 0         | yes      | yes       | yes      | yes       | yes                          | no                           | yes                 | yes           | no            | yes           | 70                | dead‡             |
| 4        | TP→OZ   | NTR       | none               | yes        | 15       | 22       | 37          | 0        | 0        | 0           | 0         | yes      | yes       | yes      | yes       | yes                          | no                           | no                  | no            | 80            | 90            | 60                | 90                |
| 5        | TP→TSS  | GTR       | hearing disturbance| no         | 10       | 0        | 10          | 0        | 0        | 0           | 0         | yes      | yes       | yes      | yes       | yes                          | no                           | yes                 | yes           | no            | yes           | 60                | dead‡             |
| 6        | TP      | GTR       | none               | no         | 10       | 10       | 20          | 0        | 0        | 0           | 0         | no       | yes       | yes      | no       | yes                          | no                           | no                  | no            | 80            | 90            | 80                | 90                |
| 7        | TP      | NTR       | none               | no         | 8        | 22       | 30          | 0        | 0        | 0           | 0         | yes      | yes       | yes      | yes       | yes                          | no                           | no                  | no            | 80            | 90            | 80                | 90                |
| 8        | TP      | GTR       | none               | no         | 22       | 6        | 28          | 17       | 6        | 23          | 0         | yes      | yes       | yes      | yes       | yes                          | no                           | no                  | no            | 80            | 90            | 80                | 90                |
| 9        | TP      | NTR       | none               | no         | 4        | 14       | 18          | 0        | 4        | 4           | 0         | yes      | no        | no       | no       | no                           | no                           | no                  | no            | 80            | 90            | 80                | 90                |
| 10       | TP→OZ   | GTR       | none               | no         | 20       | 14       | 34          | 0        | 0        | 0           | 0         | yes      | yes       | yes      | yes       | yes                          | yes                           | yes                 | yes           | yes           | yes           | yes                | 90                |
| 11       | TP      | NTR       | none               | no         | 2        | 0        | 2           | 0        | 0        | 0           | 0         | no       | no        | no       | no       | no                           | no                           | no                  | no            | no            | no            | 80                | 90                |
| 12       | TP      | GTR       | none               | no         | 2        | 22       | 24          | 0        | 22       | 22          | 0         | yes      | yes       | yes      | yes       | yes                          | no                           | no                  | no            | 90            | 90            | 90                | 90                |
| 13       | TP      | NTR       | none               | no         | 75       | 22       | 97          | —        | —        | —           | —         | yes      | no        | yes      | yes       | yes                          | yes                           | yes                 | yes           | 70            | unknown§       | unknown§          |
| 14       | TP→OZ   | NTR       | none               | no         | 100      | 25       | 100         | 60       | 22       | 82          | 8         | yes      | yes       | yes      | yes       | yes                          | yes                           | yes                 | yes           | 60            | 70            | 60                | 70                |
| 15       | TP→IH   | GTR       | none               | no         | 0        | 18       | 18          | 0        | 0        | 0           | 0         | yes      | yes       | yes      | yes       | yes                          | no                           | no                  | no            | no            | yes           | 90                | 90                |
| 16       | TP→OZ   | GTR       | none               | no         | 4        | 14       | 18          | 0        | 16       | 16          | 0         | yes      | yes       | yes      | yes       | yes                          | yes                           | yes                 | yes           | 90            | 90            | 90                | 90                |

* APH = anterior pituitary hormone; DI = diabetes insipidus; GTR = gross-total resection; NTR = near-total resection; STR = subtotal resection; TP = transpetrosal approach; VA = visual acuity; VF = visual field.

† Patient died of radiation necrosis related to the treatment.
‡ Patient died of an unrelated disease.
§ Patient was lost to follow-up.
Transpetrosal approach for challenging craniopharyngiomas

Fig. 4. Recurrence-free survival time (calculated using the Kaplan-Meier method) in patients who underwent surgery for retrochiasmatic craniopharyngiomas via the MAPC transpetrosal approach.

Fig. 5. Recurrence-free survival times (calculated using the Kaplan-Meier method) in relation to the extent of resection in patients who underwent surgery for retrochiasmatic craniopharyngiomas.

complete resection resulting in higher recurrence rates. In addition, previous large series of craniopharyngiomas have reported that retrochiasmatic location, larger size, greater than 10% calcification, extension into the third ventricle, and recurrence are significant prognostic factors that negatively affect the extent of resection. Fahlbusch et al. achieved complete resection in only 21.4% of tumors with greater than 10% intratumoral calcification. Several studies have reported that the rate of total resection in repeat surgery is markedly lower than in primary surgery; moreover, perioperative morbidity and mortality are also increased in cases of repeat surgery. In tumors with posterior extension where the tumor appears to compress the midbrain and pons, most surgeons might recognize that preservation of the membrane of Lilliquist prevents the tumor from adhering to vessels and the brainstem in this area. However, this is less true for recurrent cases. We therefore regarded posterior extension as one of the complicating conditions.

The 16 cases of retrochiasmatic craniopharyngiomas with complicated conditions reported in this series all possessed at least 2 of these risk factors and thus can be regarded as the most challenging subgroup of craniopharyngiomas. Even under such difficult conditions, the results of our MAPC transpetrosal approach were satisfactory in terms of the extent of tumor removal, tumor control, and complication rate. The unique posterior-to-anterior and inferior-to-superior surgical corridor to the retrochiasmatic area afforded by the MAPC transpetrosal approach provides a relatively wide space for surgical procedures in the retrochiasmatic space and offers direct visualization of the posterior and inferior surfaces of the chiasm, the floor of the third ventricle, and the hypothalamic tuberculum cinereum area. In addition, this posterior-anterior corridor to the chiasm and the third ventricle has the advantage of preserving small perforating vessels from the internal carotid arteries that provide the primary blood supply to the optic chiasm and hypothalamus. These characteristics are distinct from other conventional surgical approaches, such as pterional, orbitozygomatic, and interhemispheric lamina terminalis approaches, and are the primary reason for our good results regarding the extent of tumor removal and preservation of visual function in retrochiasmatic craniopharyngiomas with complicated conditions. The endonasal endoscopic approach can also offer a direct view of the posterior and inferior surfaces of the chiasm, but it is not effective in cases of recurrent tumors, tumors with large calcification, and large tumors because the maneuverability of surgical instruments is not as good as it is when using a microscope, particularly when bipolar forceps are needed for dissection of perforating vessels. The endonasal endoscopic approach would thus be unsuitable for the complicated cases reported here.

Despite the effectiveness of the MAPC transpetrosal approach, some considered it to be a time-consuming and difficult procedure that carries a risk of damaging cranial nerves, such as the facial and acoustic nerves, and causing leakage of CSF and surgical-site infection. At our institute, we modified the original transpetrosal approach of Hakuba et al. to overcome these problems and developed the MAPC transpetrosal approach in 1999. In our procedure, the dura mater at the middle and posterior fossa is completely peeled off the superior and posterior surfaces of the petrous portion of the temporal bone before the petrosectomy is initiated. This differs from other petrosal approaches and effectively shortens the surgical time for petrosectomy and reduces the extent of bone removal required. For epidural retraction of the temporal and pre-sigmoid dura, a small amount of petrous drilling along the petrous ridge is sufficient to obtain the surgical corridor to the retrochiasmatic space and is also effective in preserving facial and cochlear functions. In fact, hearing was preserved in 15 of the 16 cases and facial function was preserved in all 16 cases. In addition, no surgical-site infection and no leakage of CSF were seen in any of the 16 cases.

A disadvantage of our MAPC transpetrosal approach was an occasional occurrence of transient oculomotor nerve palsy just after the surgical procedure, but we consider this an acceptable complication considering the surgical difficulty of the cases. Seven patients underwent 2-staged operations involving the transpetrosal approach and another approach. One of the reasons for a second operation was that in cases with adhesions between the tu-
mor and the perforator of the opposite internal carotid artery, these parts of the tumor are more difficult to remove safely via the transpetrosal approach. However, these parts could be removed safely using an orbitozygomatic approach from the contralateral side. Another reason is that the part of the sella turcica or the superoposterior part of the third ventricle is more difficult to access directly because the transpetrosal approach provides inferior-to-superior and posterior-to-anterior projections. However, the residual tumors in the sella turcica could be removed safely via transsphenoidal surgery and residual tumors in the superoposterior part of the third ventricle could be removed using an interhemispheric approach.

There is a school of thought that retrochiasmatic craniopharyngiomas with complicated conditions should be treated conservatively with a combination of safe partial resection and stereotactic radiosurgery to reduce the risks of surgery. This conservative treatment has provided acceptable results for some types of craniopharyngiomas.24,25,27 However, of the cases presented in this report, radiotherapies or radiosurgeries had already been applied in 4 cases; radiotherapies or stereotactic radiosurgeries were not applicable in the other 12 cases because of the proximity of the tumors to the optic chiasm and hypothalamus. In general, radiosurgery is contraindicated if the distance between the tumor and optic apparatus is less than 3 mm because the visual pathways would typically receive more than 10 GY in these situations.24 The 16 cases of retrochiasmatic craniopharyngiomas presented in this report could be considered the most difficult cases to control, and radical resection of the tumor should be regarded as the last treatment. Our results regarding extent of tumor removal, tumor control, complication rate, and visual function were satisfactory compared with the other reports of craniopharyngiomas.3,8,12,19,21,26,29

Conclusions

Although this represents the first report on surgical outcomes of the transpetrosal approach for retrochiasmatic craniopharyngiomas, we achieved satisfactory results using the MAPC transpetrosal approach for the removal of retrochiasmatic craniopharyngiomas under complicated conditions. The MAPC transpetrosal approach can provide an alternative procedure for resection of retrochiasmatic craniopharyngiomas with complicated conditions such as recurrence, history of radiation, large calcification, large tumor diameter, and extreme superior and posterior extension.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Kunihiro, Goto, Ohata. Acquisition of data: Kunihiro, Goto, Ishibashi. Analysis and interpretation of data: Kunihiro. Drafting the article: Kunihiro. Critically revising the article: Goto.

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N. Kunihiro et al.
Transpetrosal approach for challenging craniopharyngiomas


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