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Technical Note

Radical resection of a craniopharyngioma via the extradural anterior temporal approach with zygomatic arch osteotomy

Nakao Ota, Rokuya Tanikawa, Masataka Miyama, Takanori Miyazaki, Yu Kinoshita, Hidetoshi Matsukawa, Takeshi Yanagisawa, Fumihiro Sakakibara, Norihiro Saito, Shiro Miyata, Kosumo Noda, Toshiyuki Tsuboi, Rihei Takeda, Hiroyasu Kamiyana, Sadahisa Tokuda

Department of Neurosurgery, Stroke Center, Sapporo Teishinkai Hospital, Hokkaido, Japan

E-mail: Nakao Ota - nakao1980@gmail.com; *Rokuya Tanikawa - taniroku@gmail.com; Masataka Miyama - volleyboymasataka@gmail.com; Takanori Miyazaki - t.miyazaki0911@gmail.com; Yu Kinoshita - yu19811129@gmail.com; Hidetoshi Matsukawa - nowornever1982@gmail.com; Takeshi Yanagisawa - ty.Takeshi@gmail.com; Fumihiro Sakakibara - gabaru3032@gmail.com; Norihiro Saito - kan.saito424@gmail.com; Shiro Miyata - itaro46@gmail.com; Kosumo Noda - kosumo119@gmail.com; Toshiyuki Tsuboi - buckeyttt@gmail.com; Rihei Takeda - r_takeda@teishinkai.jp; Hiroyasu Kamiyana - h.kamiyama1007@nifty.com; Sadahisa Tokuda - s_tokuda@teishinkai.jp
*Corresponding author

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Abstract

Background: Though the extradural anterior temporal approach (EDATA) with zygomatic osteotomy is useful, there are only few reports of this approach being used for craniopharyngioma resection. Herein, we report our surgical case series and the technical importance of EDATA for the radical removal of a craniopharyngioma.

Methods: We report 7 cases of craniopharyngiomas treated surgically between April 1999 and October 2015. The surgical approaches, clinical presentation, pre and postoperative radiographic examination results, surgical outcomes, and morbidity were analyzed.

Results: The mean follow-up period was 89.1 months. The surgical approach was EDATA with zygomatic osteotomy in 4, combined interhemispheric translamina terminalis approach (IHTLA) and trans-sylvian anterior temporal approach (ATA) in 2, and IHTLA in 1 patient. Complete tumor resection was achieved in all cases, without any recurrence during the follow-up period. Transient morbidities were oculomotor nerve palsy in 2, and meningitis and hydrocephalus in 1 patient. There was 1 case of permanent morbidity due to hydrocephalus that needed a ventriculoperitoneal shunt, and 1 case of blindness on the operative side. Visual acuity and visual field improved in 4 cases, showed no change in 2 cases, and deteriorated in 1 case. Though the pituitary stalk was preserved in 2 cases, all 7 cases needed total hormone replacement therapy.

Conclusion: EDATA with zygomatic osteotomy ensures sufficient mobility of the internal carotid artery, and provides a good lateral and "look up" operative view.

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Hence, it can be used effectively for radical resection of craniopharyngiomas through the opticocarotid space and retrocarotid space.

Key Words: Anterior clinoidectomy, craniopharyngioma, extradural anterior temporal approach, transzygomatic approach

INTRODUCTION

Craniopharynigomas are usually benign tumors. However, their treatment is not easy because they invade vital structures such as the pituitary stalk, hypothalamus, optic nerve and optic tract, and vessels of circles of Willis. Radical resection in the first operation is important because the recurrence rate increases dramatically in case of incomplete tumor resection, and resection becomes more difficult upon successive operations than in the first operation.[10,24,34,35]

Several surgical approaches have been reported for this tumor, including the trans-sphenoidal,[2,4,10,13,17,18,21,22,26] transcortical-transventricular,[20,25] translamina terminalis,[5,27] pterional,[35] or orbitozygomatic approaches.[11,23,37] The extradural anterior temporal approach (EDATA) which reported as the extradural temporopolar approach is a useful approach for aneurysms of paraclinoid lesions, pituitary adenomas, and tuberculum sellae meningiomas.[6,7,36] Though this approach has been reported to be effective for para and suprasellar tumors, there are only few reports of its use for craniopharyngiomas.[32,36] In this paper, we emphasize the effectiveness of EDATA with zygomatic arch osteotomy for craniopharyngioma surgery.

MATERIALS AND METHODS

This retrospective study was approved by our institutional review and ethical board. Patients' demographic data were obtained from their history and medical records. Supplemental information from charts, operative notes, and radiographic reports was also obtained.

Between April 1999 and Oct 2015, 7 patients diagnosed with craniopharyngioma were treated surgically at our institution. These included 1 male and 6 female patients (age, 10–70 years, median age, 32 years).

Radiological evaluation was performed by computed tomography (CT), CT angiography (CTA), and magnetic resonance imaging (MRI) before operation. The tumor was characterized by type (predominantly cystic, solid, or mixed) and location, according to the classification by Yasargil *et al*.[35] The categories by type were A to F (A: Purely intrasellar-infradiaphragmatic; B: Intra and suprasellar, infra and supradiaphragmatic; C: Supradiaphragmatic, parachiasmatic, extraventricular; D: Intra and extraventricular; E: Paraventricular with respect to the third ventricle; and F: Purely intraventricular).

Out of the 7 operations, 4 used EDATA with zygomatic osteotomy, 2 were performed using combined interhemispheric translamina terminalis and trans-sylvian anterior temporal approach (ATA), and 1 was performed using the interhemispheric translamina terminalis approach.

Total resection was defined not only by intraoperative findings but also by postoperative radiographic evaluation using CT and MRI, performed immediately after the operation, and MRI performed before discharge, 3 to 6 months after the operation and then, annually. The outpatient clinic also followed the patients for 1 to 3 months.

Surgical intervention

Illustrative case: Case 7, a 70-year-old woman with a solid-type craniopharyngioma [Figure 1].

Zygomatic osteotomy [Video 1]

Our technique of zygomatic arch osteotomy and anterior clinoidectomy is a modified version of the skull base technique by Dr. Fukushima.[6,7] The patient was placed in

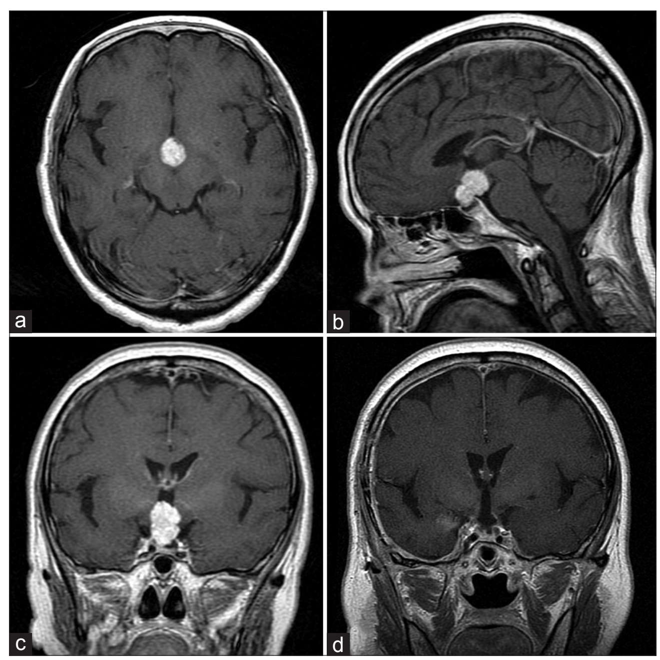

Figure 1: The pre and postoperative magnetic resonance images (MRI) of case 7. (a) Axial image of gadolinium (Gd)-enhanced T1-weighted MRI. Solid well-enhanced tumors exist in the interpeduncular cistern. (b) Saggital image of Gd-enhanced T1-weighted MRI. The tumor exists in the supradiaphragmatic space. (c) Coronal image of Gd-enhanced T1-weighted MRI. (d) Postoperative coronal image of Gd-enhanced T1-weighted MRI. The tumor has been removed completely

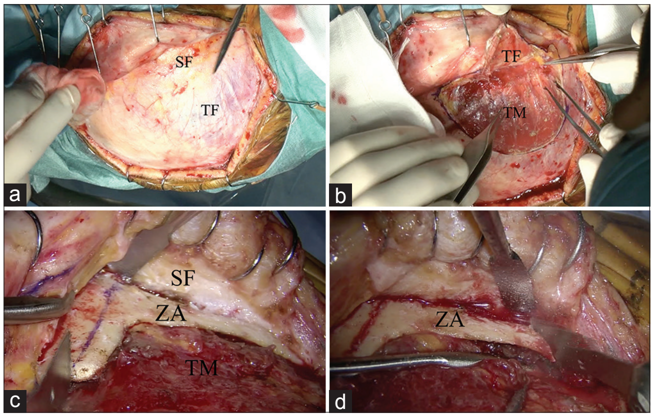

Figure 2: Surgical procedure of zygomatic arch osteotomy. (a) Two-layer skin flap elevation is performed. (b) The superficial fat pad is elevated with the temporal fascia. (c) The temporal muscle is freed from the temporal squama. The zygomatic arch is fully exposed and cut with a sagittal saw. (d) The posterior base of the zygomatic arch is cut with a sagittal saw. "T bone shape" zygomatic arch osteotomy is achieved. SF: superficial fad pad, TF: Temporal fascia, TM: Temporal muscle, ZA: Zygomatic arch

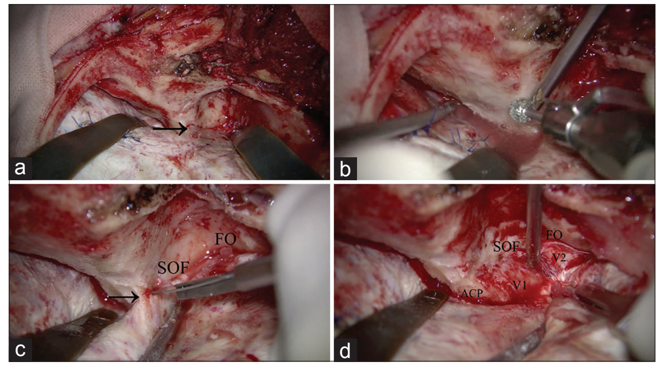

Figure 3: Surgical procedure of anterior clinoidectomy. (a) After zygomatic arch osteotomy, front-temporal craniotomy is performed. The temporal muscle is retracted inferoposteriorly. The lesser wing of the sphenoid bone is partially drilled, and the meningo-orbital band is identified (arrow). (b) Orbital unroofing is performed. (c) The superior orbital fissure and foramen ovale are identified. The meningo-orbital band is cut (arrow). (d) The temporal tip dura is peeled away from the anterior aspect of the cavernous sinus. SOF: Superior orbital fissure, FO: Foramen ovale, ACP: Anterior clinoid process, V1: Ophthalmic nerve, V2: Maxillary nerve

the supine position, with the head rotated 30–40° toward the contralateral side, and slightly vertex down for making "look up" operative field. The skin incision was almost the same as that in the standard pterional approach, however, extended slightly more inferiorly to expose the entire zygomatic root. Two-layer skin flap elevation was performed [Figure 2a]. As the superior temporal line was reached, the areolar connective tissue that is continuous with the pericranial layer was elevated with the galea, leaving the true temporal fascia. The superficial fat pad was elevated with the temporal fascia [Figure 2b]. The temporal muscle was freed from the temporal squama and from its attachment to the inner surface of the zygoma. The zygoma was then cut with a sagittal saw in a "T bone shape" [Figure 2c and 2d]. After removal of the zygomatic arch, the temporal muscle was elevated inferiorly. Standard front-temporal craniotomy was performed. After the craniotomy, all further procedures were performed under microscopic guidance, and hemostasis of the dura mater and bone was ensured.

Orbital skeletonization and extradural anterior clinoidectomy [Video 2]

The dura was elevated extradurally and retracted with extradural steel tapered retractors. The orbital roof and the lesser wing of the sphenoid bone were drilled and shaved flat using a 5-mm extra-coarse diamond burr to remove the bony protrusions. To make a "look up" operative field, orbital flattening is essential [Figure 3a and b]. To avoid heat injury, constant irrigation with cooled saline was performed using the irrigation system attached to the diamond burr, till the drilling procedures were completed. Damage to the periorbital and intraorbital soft tissue should be avoided to prevent postoperative orbital edema. At this point, the bone must be gradually thinned down to a thin shell of cortical bone, which can be easily elevated with skull base dissectors. The temporal dura was also elevated from the anterior to the mid-subtemporal base. The floor of the subtemporal fossa was further flattened with the diamond drill. Complete removal of the lesser wing of the sphenoid bone and partial removal of the greater wing were performed. Then, the superior orbital fissure was identified and unroofed. The meningo-orbital band together with its vessels was then coagulated and divided over a distance of 3 to 5 mm, and a cleavage plane was established by sharp dissection between the dura propria of the temporal tip and the inner cavernous membrane [Figure 3c and d]. The temporal tip dura was then peeled away from the anterior aspect of the cavernous sinus and orbital apex. The optic canal was unroofed in the lateral-to-medial direction. The inside of the anterior clinoid process was drilled until it was hollowed out. The anterior clinoid process was then carefully stripped from the surrounding fibrous adhesions using a small dissector, after which the remaining process was removed [Figure 4a]. In case there are some anatomical variations of the anterior clinoid process and the paranasal sinus within the sphenoid bone, the drilling should be carefully performed.[31] The residual optic strut was then removed carefully by using microalligator forceps or drilling [Figure 4b].

The frontotemporal dura was curvilinearly incised along the orbital ridge. The optic sheath was opened to decompress the optic nerve [Figure 4c]. Then, the distal dural ring was excised circumferentially to achieve movability of the internal carotid artery (ICA). The proximal sylvian fissure was opened [Figure 4d], and the anterior temporal artery was detached from the temporal lobe [Figure 5a]. Then the arachnoid trabeculae between

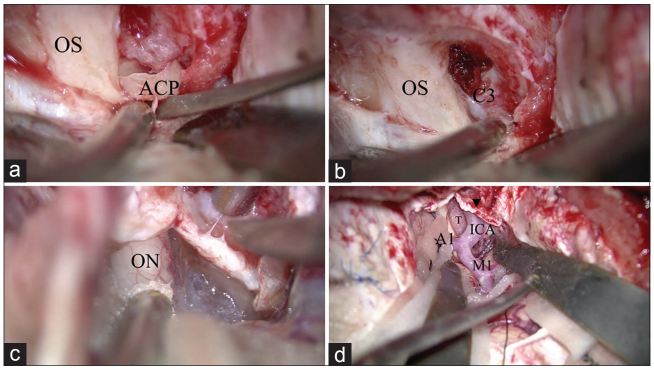

Figure 4: Surgical procedure of anterior clinoidectomy. (a) After drilling the inside of the anterior clinoid process (ACP), the ACP is removed using a small dissector. (b) After removing the ACP, the residual optic strut is drilled. The C3 portion of the internal carotid artery is identified. (c) The optic sheath is opened to decompress the optic nerve. (d) The operative view after anterior clinoidectomy, optic sheath opening, and proximal sylvian fissure opening. The tumor is identified in the opticocarotid space. OS: optic sheath, ACP: Anterior clinoid process, C3: C3 portion of the internal carorid artery, ON: Optic nerve, ICA: Internal caroid artery, M1: M1 portion of the middle cerebral artery, A1: A1 portion of the anterior cerebral artery, T: tumor

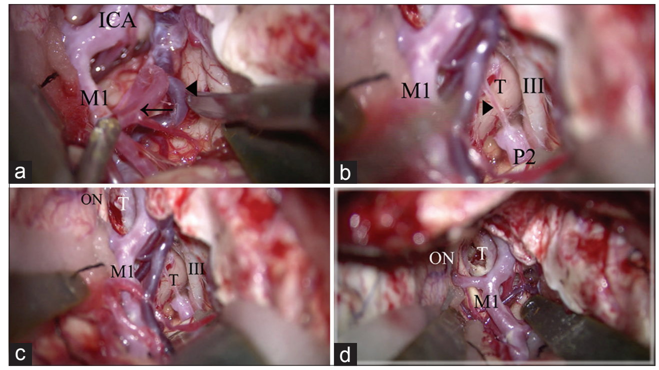

Figure 5: Surgical procedure of extradural anterior temporal approach. (a) The anterior temporal artery (arrow) and deep middle cerebral vein (arrow head) is freed from the temporal lobe to retract the temporal lobe. (b) The arachnoid trabeculae between the oculomotor nerve and the temporal uncus are cut. The posterior communicating artery is identified (arrow head). (c) The temporal lobe is retracted posterolaterally. The retrocarotid space is widely secured. (d) The operative view in the simple trans-sylvian approach before performing the above 2 steps (a, b). The retrocarotid space is narrow and cannot be seen from lateral trajectory compared to c. ICA: Internal carotid artery, M1: M1 portion of the middle cerebral artery, III: Oculomotor nerve, P2: P2 portion of the posterior cerebral artery, T: Tumor, ON: Optic nerve

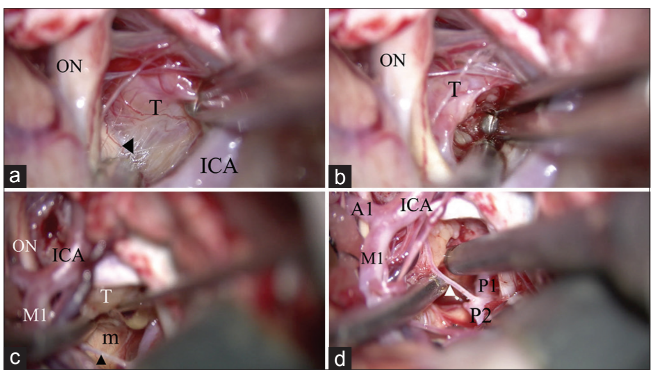

Figure 6: Removal of the craniopharyngioma through both the opticocarotid space and the retrocarotid space. (a) The tumor is dissected from the optic tract (arrow head) via the optico-carotid space. A good "look up" operative view is achieved. (b) Internal decompression of the tumor from the opticocarotid space. (c) The tumor is dissected from the mammillary body through the retro-carotid space, inferior to the posterior communicating artery (arrow head). A good "look up" operative view is established. (d) Internal decompression of the tumor from the retro-carotid space through the superior and inferior space of the posterior communicating artery (arrow head). ON: optic nerve, T: tumor, ICA: Internal carotid artery, M1: M1 portion of the middle cerebral artery, m: Mammillary body, A1: A1 portion of the anterior cerebral artery, P1: P1 portion of the posterior cerebral artery, P2: P2 portion of the posterior cerebral artery

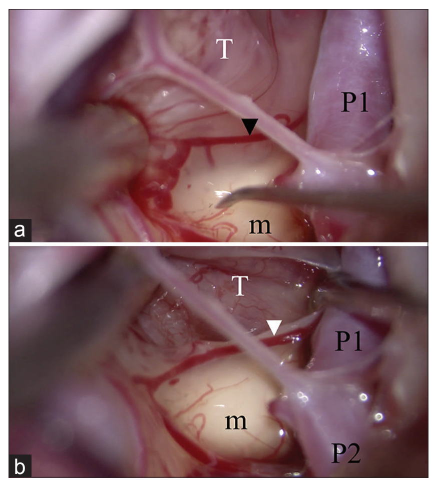

Figure 7: Identification of the cutting cleavage. (a) An inflammatory membrane covers both the tumor and normal tissue. The pial vessel (arrow head) belongs to the normal tissue. The dissecting plane is above the pial vessel. (b) The tumor capsule is identified and dissected from the normal structure. T: Tumor, m: Mammillary body, P1: P1 portion of the posterior cerebral artery, P2: P2 portion of the posterior cerebral artery

the oculomotor nerve and the temporal uncus were cut [Figure 5b], following which the temporal uncus could be retracted posterolaterally [Figure 5c and d].

Craniopharyngioma resection [Videos 3 and 4]

To remove the craniopharyngioma, the prechiasmatic space, opticocarotid space, and retrocarotid space should be used [Figure 6]. First, the tumor capsule was identified, and internal decompression was performed [Figure 6b and d]. Then, the outer membrane of the tumor was carefully dissected from the surrounding normal structures [Figure 6a and c]. Sometimes, the tumor and the surrounding normal tissues are covered by an inflammatory membrane, and it is difficult to identify the dissection layer [Figure 7a]. In such a case, identification of the pial vessels belonging to the normal tissue is useful. After that, the dissection layer can be easily identified [Figure 7b]. When dissecting

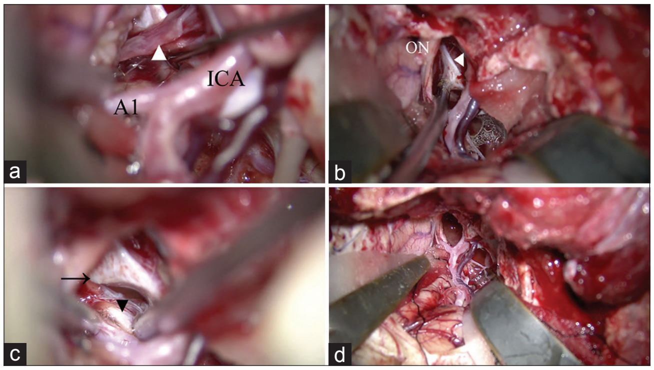

Figure 8: Removal of the tumor and identification of normal structures. (a) The pituitary stalk is identified as a thin compressed membrane (arrow head). (b) The distended diaphragma sellae is identified. (c) The contralateral posterior clinoid process (arrow) and oculomotor nerve (arrow head) are identified after removing the tumor. (d) All normal structures are secured after removal of the tumor. A1: A1 portion of the anterior cerebral artery, ICA: internal carotid artery, ON: optic nerve

from the hypothalamus, optic tract, "look up" and see the dissection layer is important. The pituitary stalk can sometimes be seen as a thin, compressed membrane [Figure 8a and b], and should be preserved during the operation. Postoperative MR images and size of craniotomy are shown in Figure 9.

RESULTS

The preoperative modified Rankin scale (mRS) score was 1 in 4 patients, 2 in 1 patient, and 3 in 2 patients. The clinical presentation before the operation included decreased visual acuity in 3 patients, headache in 3, galactorrhea and amenorrhea in 1, higher brain dysfunction in 2, and developmental disorder in 1 patient. Diabetes insipidus was not apparent in any of the patients at the preoperative evaluation. The mean follow-up period was 89.1 months (14–136 months). No tumor recurrence was observed in these patients during the follow-up period. One patient had a papillary-type craniopharyngioma, whereas 6 had the adamantimomatous type [Table 1].

The surgical approach was EDATA with zygomatic osteotomy in 4 patients, combined interhemispheric translamina terminalis approach and ATA in 2 patients, and interhemispheric translamina terminalis approach in 1 patient. Complete tumor resection was achieved in all 7 cases, with no recurrence during the follow-up period. The pituitary stalk was preserved in 2 cases.

The postoperative mRS score was 1 in 6 cases and 2 in 1 case. At the 6-month follow-up, the mRS score was 0 in 5 patients, 1 in 1 patient, and 2 in 1 patient. Transient morbidities included 2 cases of transient oculomotor nerve palsy on the operative side and 1 case of meningitis and hydrocephalus. The 2 cases of oculomotor nerve palsy improved within 3 months of the operation. There were 2 cases of permanent morbidity. One was that of hydrocephalus caused by meningitis and needing a ventriculoperitoneal shunt. The other was a case of blindness on the operative side. Preoperative ophthalmologic evaluation of the latter patient revealed typical bitemporal hemianopsia. Though the latter patient awoke from anesthesia with no deterioration in visual acuity and visual field, he lost vision suddenly 3 days after the operation. The ophthalmologic evaluation conducted at that time revealed no apparent abnormality in the anterior segment of the optic nerve or the retina and no optic nerve pallor. Posterior optic nerve neuropathy was diagnosed. In spite of corticosteroid administration, the visual acuity did not improve. The ophthalmic artery was found to be patent on CT angiography. The ophthalmologic evaluation at 2 weeks after the operation revealed right optic nerve atrophy and blindness. The left eye's temporal hemianopsia showed improvement.

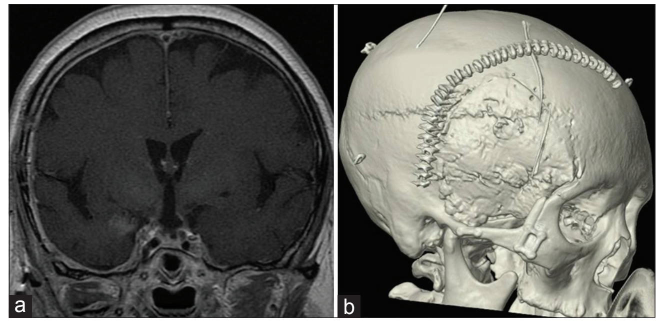

Figure 9: Postoperative MRI and size of craniotomy. (a) Tumor was totally removed. (b) Size of craniotomy

Though the pituitary stalk was preserved in 2 cases, all 7 cases needed total hormone replacement therapy (HRT) with prednisolone, levothyroxine, and desmopressin. The visual acuity and visual field improved in 4 patients, 2 showed no change, and 1 showed a deterioration.

DISCUSSION

Radical resection in the first operation is important for treating craniopharyngiomas because the recurrence rate increases dramatically if the resection is incomplete and tumor resection is more difficult in successive operations than in the first one. Though many patients complain of panhypopituitarism after radical resection, with the advancements in the field of endocrinology, the various pituitary hormones such as antidiuretic hormone, cortisol, growth hormone, and levothyroxine can be supplied externally; the patient can even conceive by using HRT. In addition, the pituitary stalk can sometimes be preserved even if total resection is performed. Jung *et al.*[15] reported 41 cases of craniopharyngiomas, of which, pituitary stalk

Table 1: Clinical characteristic of patients with craniopharyngiomas.

Case no.	Age (y)/ sex	Clinical presentation	Type of location	Type of tumors	Pthology	Surgical approach	Preoperative mRS	Postoperative mRS	6month mRS	Follow up period (m)	Pituitary stalk preservation	THRT	Morbidity
1	10/F	Headache/ developmenta disorder	D	Mixed/ calc	Adamantimomatous	IHTL + ATA	3	2	2	113	N/A	+	Meningitis/ hydrocephalus/ development disorder
2	66/F	Fatigue/higher brain dysfunction	F	Cystic	Adamantimomatous	IHTL	3	1	0	76	+	+	None
3	51/F	Decrease of visual acuity	C	Cystic	Adamantimomatous	EDATA	1	1	0	136	+	+	None
4	16/F	Headache/appetite loss	E	Cystic/ calc	Adamantimomatous	IHTL + ATA	1	1	0	106	-	+	None
5	32/M	Headache/ decrease of visual acuity	C	Mixed/ calc	Adamantimomatous	EDATA	2	1	1	90	-	+	Ipsilateral blindness/transient oculomotor palsy
6	32/F	Amenorrhea/ galactorrhea/ decrease of visual acuity	C	Cystic/ calc	Adamantimomatous	EDATA	1	1	0	89	-	+	None
7	70/F	Incidental/ enlargement during follow up	C	Solid	Papillary	EDATA	1	1	0	14	-	+	Transient oculomotor palsy

IHTL: trans-interhemispheric trans-lamina terminalis approach, EDATA: extradural anterior temporal approach with zygomatic osteotomy, ATA: anterior temporal approach, THRT: total hormone replacement therapy, N/A: could not identify under the medical record, modified rankin scale (mRS) preservation with total tumor resection was achieved in 18 cases. Among these 18 patients, 11 needed total HRT, 1 needed partial HRT, and 6 showed intact pituitary function. Although among our patients, the 2 patients with pituitary stalk preservation needed total HRT, there is a possibility of preserving pituitary function. Because our cases are small amount, we need sufficient volume of cases to obtain the rate of the pituitary function preservation with radical resection of tumor.

Although the reported surgical approaches for this challenging tumor are divided into four categories, namely, the "look down" approach, "look up" approach, anterolateral approach, and trans-sphenoidal approach, the EDATA should be categorized as a lateral approach. The "look down" approaches include the interhemispheric translamina terminalis approach, the transcortical transventricular approach, and the transcallosal transventricular approach. The trans-sylvian (pterional) and the subfrontal trans-lamina terminalis approaches are categorized into the antero-lateral category. The orbitozygomatic approach is categorized as an antero-lateral and "look up" approach. We categorized EDATA as a lateral approach, and EDATA with zygomatic osteotomy as a lateral and "look up" approach. Because the difference between the anterolateral approach such as classical trans-sylvian approach and EDATA is wide operative window of the retrocarotid space. The intradural manipulations in the EDATA, such as dissection of the arachnoid trabeculae in between the uncus and the oculomotor nerve, and retraction of the temporal lobe posterolaterally, are similar to those in the anterior temporal approach. The anterior temporal approach,[12,19] which is a variation of the trans-sylvian approach, can provide a better lateral view than the trans-sylvian approach, and can, better use the retrocarotid space. However, this approach is limited by the running course of the ICA, and sometimes by the sphenoparietal sinus. The EDATA can overcome these limitations. Posterolateral retraction of the sphenoparietal sinus, achieved by peering of the dura propria and circumferential dissection of the distal dural ring, ensures sufficient mobility of the ICA.[9] This implies that injury to the ICA is minimized. In addition, if the retrocarotid space is small, the opticocarotid space can be used, and vice versa. Because of the combination of zygomatic arch osteotomy and orbital unroofing, EDATA can ensure a good "look up" operative field. The orbitozygomatic approach also provides a "look up" operative field, and the site of tumor resection is the same—the retro-carotid space or the opticocarotid space. However, orbitozygomatic osteotomy alone is not sufficient because the retrocarotid space cannot be used widely, and the ICA cannot be moved. In addition, orbital osteotomy is not necessary because the route of approach is the retrocarotid space and the opticocarotid space, and the visual axis of the microscope is from the anterolateral or lateral direction. Hence, orbital unroofing by drilling is enough.

One limitation of this approach is its limited efficacy for intraventricular tumors. When the lamina terminalis is accessed via the lateral approach, the oblique trajectory of this route makes it difficult to visualize the posterior part of the third ventricle, especially the ipsilateral lateral wall of the hypothalamus.[3] This places the columns of fornix, supraoptic nuclei, organ vasculosum, and tuber cinereum at risk of retraction injury or perforating vessel damage.[8,27] For these tumors, a "look down" approach should be combined with the "look up" approach. Another limitation of EDATA is with respect to approaching intrasellar tumors. The ipsilateral approach side should be blind, and trans-sphenoidal approach should be considered. In addition, because of the rarity of the tumor, some centralization is needed to obtain sufficient volume to get acquainted with the different approaches and to be able to select the optimal approach.

The reported complications associated with this approach are rhinorrhea or pneumocephalus due to opening of the paranasal sinus,[1,14,16,29] visual disturbance, optic nerve injury, injury of the ICA, and oculomotor palsy.[30] Among our patients, we encountered cases of transient oculomotor palsy and delayed visual disturbance. Oculomotor palsy can be caused by peering of the dura propria from the inner cavernous membrane, compression of the carotico-oculomotor membrane when removing the anterior clinoid process, and direct compression when the tumor is removed through the retrocarotid space. However, this complication is usually transient and resolves within 3 months.

Immediate visual disturbance after the operation can be because of heat injury, direct injury to the optic nerve, or occlusion of the ophthalmic artery. However, our patients experienced delayed visual disturbance. Rizzo *et al*.[33] reported three cases of unexplained visual loss 12 h to 3 days after technically successful clipping of paraclinoid aneurysms. All three cases showed marked orbital edema and one case showed vasospasm of the ICA. It was postulated that the possible causes of visual loss in these patients were orbital syndrome due to obliteration of the large vessels that drain the orbit, direct neural injury such as thermal injury, injury to small dural vessels during drilling of the bone, and use of Surgicel and Gelfoam, which might have caused scarring or inflammation of the vasa nervosa. Matano *et al*.[28] reported 127 cases of paraclinoid aneurysm surgery, among which delayed visual disturbance was observed in 8 cases and the cause was hypothesized to be gradual compression of the ophthalmic nerves by a small hematoma, vasospasm of the superior hypophyseal artery, or bankruptcy microcirculation due to opening of the dural ring or optic canal.

Other complications such as rhinorrhea and injury to the ICA can be avoided by strict preoperative anatomic evaluation and meticulous manipulation.[31]

CONCLUSION

EDATA with zygomatic arch osteotomy can ensure sufficient mobility of the ICA, and a good lateral and "look up" operative view. Hence, this is an effective approach for radical resection of craniopharyngiomas via the opticocarotid and retrocarotid spaces.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Supplemental information

Previous presentations

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