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ORIGINAL ARTICLE - BRAIN TUMORS

Clinical applications of the endoscopic transorbital approach for various lesions

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Abstract

Background The endoscopic transorbital approach (ETOA) was recently added to the neurosurgical armamentarium. Although this approach could result in less injury to normal brain tissue, shorter operation times, and smaller scars, its clinical applications have not been fully investigated. We, therefore, sought to share our unique experiences of exploring the application of this approach in various diseases.

Methods From June 2017 to March 2019, we conducted ETOAs via the superior eyelid crease in 22 patients for the treatment of lesions confined to the middle fossa with and without slight extension to the posterior fossa. These lesions included 5 gliomas, 11 meningiomas, 3 schwannomas, 1 lymphoma, 1 cavernous hemangioma in the orbital wall, and 1 hemangiopericytoma mimicking schwannoma. Perioperative radiologic findings and clinical outcomes were recorded.

Results Gross total resection was accomplished in three (60%) patients with gliomas, nine (81.8%) with meningiomas, two (66.7%) with schwannomas, and one (33.3%) with another lesion. The mean bleeding count was 1051.4 ± 961.1 cc, and major complications were observed in only two (9.1%) cases (one major cerebral artery infarction and one reoperation due to a large amount of bleeding). A cerebrospinal fluid leak was reported in two (9.1%) patients, and transient eye movement palsy was noted in four (18.2%) patients without permanent disability.

Conclusions The endoscopic transorbital approach could be considered to be feasible for various lesions with different characteristics. After carefully considering the lesion anatomy, consistency, and vascular relationships, using this approach, we could achieve a satisfactory extent of resection without severe complications.

Keywords Endoscopic surgery · Transorbital surgery · Clinical application

Introduction

Orbitocranial lesions and tumors confined to the middle fossa with ocular manifestations can cause compressive optic neuropathy, exophthalmos, and extraocular movement disorder. The classic transcranial approach for lesion treatment requires extensive temporalis muscle manipulation and can cause bony defects. Iatrogenic complications are also more likely to occur with this approach because it requires retraction of the temporal lobe [1].

A transorbital approach has recently been added to the neurosurgical armamentarium in the area of endoscopic neurosurgery. This approach has been studied in cadavers and applied to various clinical situations, including trauma and orbitocranial tumor resection [2–5]. With a transorbital approach, the lateral compartment of the orbital rim is minimally bone-drilled, allowing access to the amygdalo-hippocampus and even the posterior fossa through a small corridor from the temporal pole. The endoscopic transorbital approach (ETOA) minimizes the retraction of normal structures and violation of the temporalis muscle in addition to minimizing postoperative scarring, as compared to the conventional approach. Also, lateralization is not limited by the optic nerve, internal carotid

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Prior presentation The results of this manuscript have not been presented in any form at any conference.

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artery (ICA), or cavernous sinus compared to the endoscopic endonasal approach (EEA) [6].

However, with the exception of cadaveric studies, a limited number of published clinical trials have investigated the use of the ETOA for middle fossa meningiomas or orbitocranial lesions [3, 7]. Because the eye must be pulled during the ETOA operation, there is concern that eyelid restriction causes increased intraocular pressure. However, there is a much lower risk of side effects, such as cerebrospinal fluid (CSF) leak, ocular movement dysfunction, and infection [8]. There have been no studies on the application of this technique in various pathologies, such as gliomas, meningiomas, and schwannomas that extend into the posterior fossa. Here, we share our surgical experiences of 22 patients with various pathological lesions that were treated using the ETOA.

Methods

From June 2017 to March 2019, we performed the ETOA on 22 patients with tumors localized to the middle fossa with and without involvement of the posterior fossa at Gangnam Severance Hospital. The inclusion criteria were extra-axial tumors in the orbit, extra-axial tumors confined predominantly within the middle cranial fossa, with or without slight posterior fossa extension, and intra-axial tumors limited to the middle cranial fossa. Patients with intra-axial tumors, who were not candidates for gross-total resection due to multiple lesions, or who asked for ETOA because of minimal scarring in contrast to conventional craniotomy, were also included. We excluded patients with intra-tumoral calcifications, severe adhesions, or involvement of surrounding neurovascular structures. In the cases of glioma patients, those who were not intended to achieve gross-total resection due to multiple lesion or those who wished ETOA rather than conventional craniotomy were included. All ETOAs were performed via a superior eyelid crease incision under neuro-navigation guide (Stealth Station S8 navigation system, Medtronic, Dublin, Ireland, and Navigation system II, Stryker, Michigan, USA) to confirm the position of the lateral wall of the cavernous sinus, superior orbital fissure, or the depth of the intra-axial resection cavity, by a single neurosurgeon (CKH), alongside a neuroplastic surgeon (ISY). MRI images for neuro-navigation were obtained a day before the surgery and included both T2- and contrast-enhanced T1-weighted images. The study was approved by the IRB and adhered to the declaration of Helsinki.

Preoperative MRI features, including peritumoral edema, ICA encasement, cavernous sinus invasion, middle cerebral artery (MCA) dislocation by the tumor, and tumor consistency, were evaluated. In particular, edema was assessed by FLAIR and T2-weighted images. An ICA encasement was defined as a tumor that enclosed the ICA over 180°. Cavernous sinus invasion was defined as tumor infiltration of the lateral cavernous sinus wall. An MCA dislocation occurred when asymmetry was observed beyond the Sylvian fissure of the opposite lobe (normal brain). Peritumoral edema and tumor consistency prediction was assessed with T2-weighted and FLAIR images.

The following clinical outcomes were assessed by examining the electronic medical record and postoperative MRI images: extent of resection (EOR), major complications, bleeding count, extraocular movement (EOM) dysfunction, and CSF leakage. EOR was classified as gross total removal (GTR), subtotal removal (STR), and partial removal (PR). GTR was defined as removal of 100% of the tumor, as confirmed by no evidence of the tumor on contrast MRI images and operative records. STR referred to cases in which more than 90% of the tumor was removed, as confirmed by MRI images and operative records. PR referred to cases in which less than 90% of the tumor was removed. Major complications were defined as complications greater than grade 2 on the neurosurgical complication classification [9]. CSF leaks and cranial palsy were also noted.

Surgical technique

After general anesthesia, the patient was placed in the supine position and a three-pin head fixation was performed. The face was painted with betadine and the eyes were wiped with saline. The plastic surgeon incised the crease line on patients. A skin incision was performed to expose only the lateral orbital wall and did not exceed the lateral canthus laterally and the midpupillary line medially. For patients whose tumors were located laterally to or deep in the orbital wall, an orbital rim resection was performed by the neurosurgeon and later reconstructed by a plastic surgeon. The orbital rim resection was performed with a 1.1-mm tapered drill, and bone margins were noted to prevent defects. This procedure prevented excessive retraction of the globe and helped to secure an angle to access Meckel’s cave. The superior, lateral, and inferior sides of the orbital wall were periosteal dissected with extreme caution to avoid injuring the periorbita and the orbit was retracted to the medial side. Retraction did not exceed 2 cm and exposed the lateral margin of the superior orbital fissure (SOF) and greater sphenoid wing. Using a coarse diamond drill, the bone was drilled from the lateral to medial side, first securing the temporal dura and then the frontal dura. The greater sphenoid wing was sufficiently drilled until the fronto-temporal fold, inferior side, and temporal base were fully exposed. This helped prevent later collisions between the instruments and secured a panoramic view.

The dura was opened and the tumors were internally debulked with an ultrasonic aspirator (Sonopet®, Stryker, MI, USA). The tumor margins were secured and detached with a hemostatic sheet (Surgicel®, Ethicon, OH, USA) and removed with an ultrasonic aspirator; this method was performed repeatedly until the lesion was fully aspirated. A duraplasty was performed by placing a collagen matrix (Duragen®, Integra, NJ, USA) and abdominal fat on the dura, suturing it by about two points, sealing it with a fibrin sealant patch (Tachosil®, Baxter, CA, USA), applying a fibrin sealant (TISSEEL®, Baxter, CA, USA), and introducing a tailored porous polyethylene implant (MEDPOR®, Stryker, MI, USA) outside the periorbita. The resected orbital rim was reconstructed with a screw and mini plate system by a plastic surgeon. Finally, the periosteum was repaired with 5-0 Polysorb and the skin closed with 6-0 Nylon sutures.

Statistical analysis was performed using IBM SPSS version 23 (IBM Corp., Armonk, NY, USA, 2015). But because the size of the patient group included in the study was too small, the statistically significance was not reached, so the statistical *p* value was not described

Results

We performed the ETOA without an endoscopic endonasal approach in 22 consecutive patients with middle fossa-related tumors. Both preoperative (Fig. 1) and postoperative MRIs (Fig. 2) of all tumors were recorded. Table 1 describes the demographics and preoperative radiological findings from each patient group, according to lesion pathology. The mean age of all patients was 52.5 ± 16.0 years (range, 24–74), and 45.5% were male. The average tumor size was 4.25 cm (range, 1.5–8.3), and their pathologies included 5 gliomas, 11 meningiomas, 3 schwannomas, and 3 other lesions, including 1 cavernous hemangioma, 1 hemangiopericytoma, and 1 lymphoma. The clinical outcomes are described in Table 2. GTR was achieved in 15 (68.2%), STR in 6 (27.3%), and PR in only 1 (4.5%) patient. The average amount of tumor bleeding was 1051.4 ± 961.1 cc (range, 50–4000). Ocular CSF leaks were observed in two (9.1%) patients (1 meningioma and 1 glioma), both of whom recovered well without any other neurological complications within 1 week after insertion of a lumbar drain. Transient EOM dysfunction was observed in four (18.1%) patients, specifically oculomotor palsy (3/4) and abducens nerve palsy (1/4). All subjects presented only partial nerve palsy. The spontaneous recovery was confirmed in the outpatient clinic, and ophthalmologic care was not required. The diplopia recovery time for each patient was 1.0, 1.3, and 2.4 months for oculomotor nerve palsy, and 3.2 months for abducens nerve palsy. Two (9.1%) patients had major surgical complications, one with a glioblastoma and the other with a hemangiopericytoma. The glioblastoma patient suffered from ischemic stroke in the posterior cerebral artery (PCA) territory without mortality (grade III complication); the infarction was observed between P1 and P2. With timely procedure and best support, the patient was mentally alert with motor aphasia. The hemangiopericytoma patient had high tumor vascularity, so the tumor could only be partially removed with the ETOA and required an open craniotomy 1 week after the first operation.

Meningioma

Nine of the 11 patients with meningiomas achieved GTR (Figs. 1b and 2b) and the remaining two achieved STR (Fig. 1, (9, 13); Fig. 2, (9, 13)). Two patients with STR had cavernous invasion; one patient had posterior fossa extension beyond the tentorium incisura and skull base erosion due to the tumor (notes on CT; Fig. 3a, b), but no hyperostosis associated with the posterior fossa. This hyperostosis was observed more frequently in the petrous skull base area as well as the greater sphenoid wing. Meningioma patients had the least average bleeding of all lesion pathologies (Table 2), suggesting that the feeder was mainly interrupted in the cranio-orbital foramen by a recurrent meningeal artery or meningolacrimal branch in the lateral aspect of the SOF [10].

Trigeminal schwannoma

Of the three patients with trigeminal schwannomas, one patient had type A (Fig. 1, (18)) and two had type C (Fig. 1, (17, 19)). GTR was achieved in two patients (Fig. 2, (17, 18)), while STR (Fig. 2, (19)) in one patient. The one patient with STR had a type C tumor and we were able to remove all tumors in Meckel's cave and the posterior fossa but had to leave some tumors because of difficulties with the endoscopic fine dissection and adhesion to the brain stem. In the case of schwannomas, petrous bone erosion (Fig. 3c, d) was observed together with removal of the tumor in the intradural phase, thus securing both the field of view to the posterior fossa and instrument degree of freedom.

Temporal lobe glioma

Surgeries were performed on gliomas confined to the temporal lobe, including one diffuse astrocytoma, IDH-wildtype (Fig. 1, (5); Fig. 2, (5)); two anaplastic astrocytomas, IDH-wildtype (Fig. 1, (1, 3); Fig. 2, (1, 3)); one anaplastic astrocytoma, IDH-mutant (Fig. 1, (4); Fig. 2, (4)); and one glioblastoma, IDH-wildtype (Fig. 1, (2); Fig. 2, (2)). GTR was achieved in three patients and STR in two (Fig. 2, (4, 5)). One of the STR (Fig. 2, (4)) patients had a recurrent anaplastic astrocytoma with multifocal tumor foci, so the preoperative plan did not include GTR. In the other STR patient, the diffuse astrocytoma was removed with total resection of the hippocampus and amygdala, but preservation of the basal ganglia (Fig. 2, (5)). Cavernous sinus invasion and ICA encasement were not observed, but MCA dislocation was observed in cases of severe swelling.

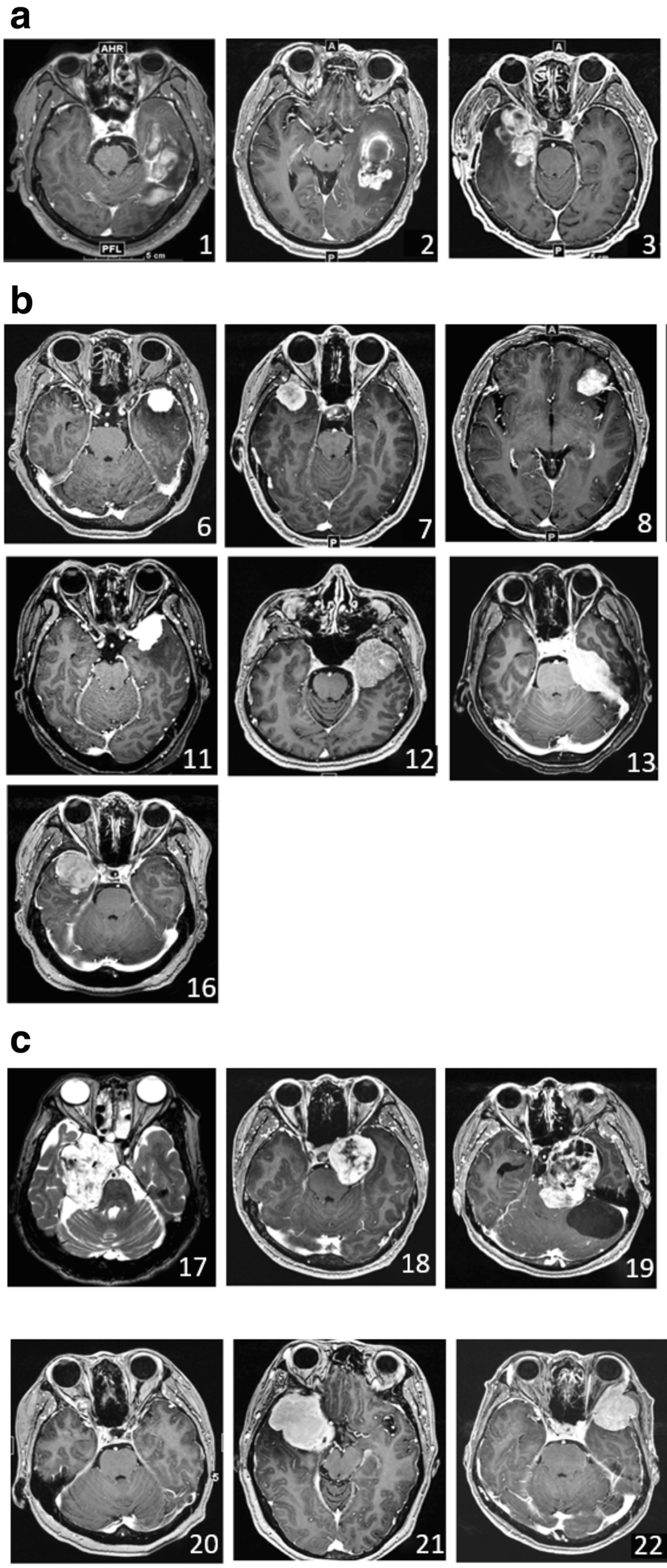

Fig. 1 Preoperative patient images. **a** Temporal lobe glioma (1–4: high-grade gliomas, 5: low-grade glioma), **b** Meningioma (mainly sphenoid ridge meningioma including a tentorial meningioma (8)), **c** Schwannoma, **d** Others (20: cavernous hemangioma; 21: hemangiopericytoma, grade 3; 22: plasma cell neoplasm, lymphoma)

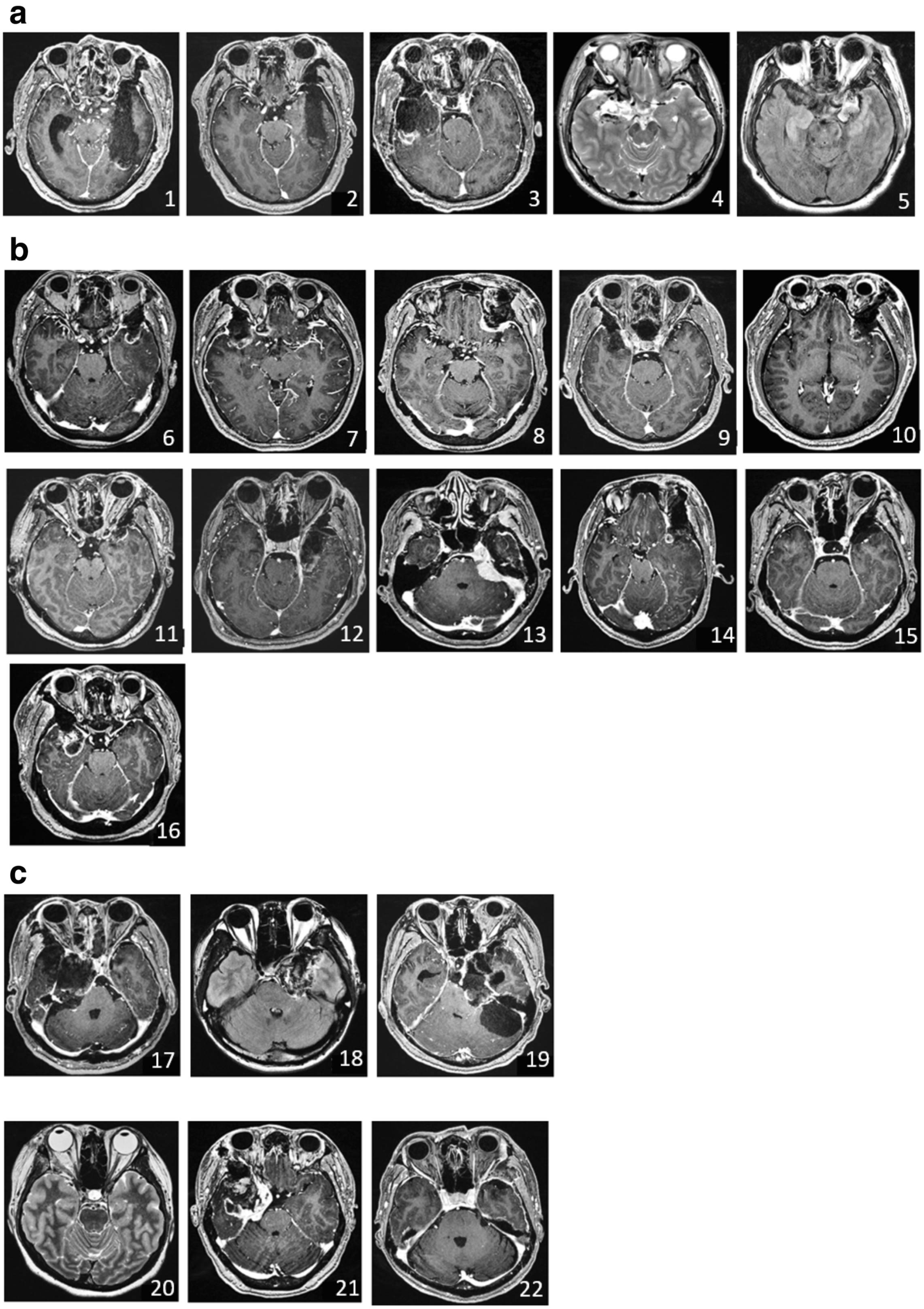

Fig. 2 Postoperative patient images. **a** Temporal lobe glioma (STR; 4-5: multiple lesions), **b** Meningioma (STR; 9, due to cavernous sinus invasion; 13, due to posterior fossa invasion), **c** Schwannoma (STR; 19, minimal residual tumor behind the facial nerve), **d** Others (STR; 21, due to excessive bleeding). STR, subtotal resection

Table 1 Demographics of patients treated with the ETOA

	Glioma	Meningioma	Schwannoma	Others	Total
No. of patients	5	11	3	3	22
Age, years	63 ± 15.22	52.1 ± 14.4	42.7 ± 22.1	46.0 ± 14.9	52.5 ± 16.0
Sex distribution, % M	100.0	27.3	66.6	0.0	45.5
Maximum tumor size, cm	5.54 ± 1.97	3.24 ± 1.08	5.83 ± 1.10	4.20 ± 2.17	4.25 ± 1.78
ICA encasement, n(%)	0 (0.0)	1 (9.1)	2 (66.6)	0 (0.0)	3 (13.6)
Cavernous sinus invasion	0 (0.0)	2 (18.2)	3 (100)	1 (33.3)	6 (27.3)
MCA dislocation	1 (20)	1 (9.1)	3 (100)	1 (33.3)	6 (27.3)
Edema	3 (60)	5 (45.5)	1 (33.3)	1 (33.3)	10 (45.5)
Tumor consistency					
Soft	3 (60)	5 (45.5)	3 (100)	1 (33.3)	12 (54.5)
Moderate	2 (40)	5 (45.5)	0 (0.0)	1 (33.3)	8 (36.4)
Hard	0 (0.0)	1 (9.1)	0 (0.0)	1 (33.3)	2 (9.1)

ICA internal carotid artery, *MCA* middle cerebral artery

Others

Upon MRI or CT review, three lesions were thought to be extraaxial tumors, such as a meningioma or schwannoma. But except for one case of a cavernous hemangioma, surgical pathology diagnosed the lesions as plasma cell neoplasm and hemangiopericytoma. In case of a patient with a hemangiopericytoma, calcification was observed upon preoperative evaluation, so the tumor was presumed to be very hard (Fig. 1, (21)); during surgery, however, the tumor was very firm with severe bleeding. After partial debulking, the ETOA was terminated and 1 week later, a craniotomy was performed to remove the tumor remnants.

Discussion

The ETOA has several advantages, such as no visible scars, a small craniotomy, and minimal retraction during surgery. Although the ETOA has been tried for various pathologies, the advantages and disadvantages of the approach were rarely reported. This paper describes the use of the ETOA for the resection of various pathological lesions related to the middle cranial fossa, including eleven meningiomas, five temporal lobe gliomas, and three schwannomas.

In 2010, Moe et al. [5] published 16 cases of transorbital neuroendoscopic surgery, after which some authors have attempted to treat lesions, including CSF leaks, traumatic fractures, meningoencephaloceles, hematomas, and tumors [7, 8, 11] with the ETOA.

Meningioma

The ETOA is a good option for cases of medial or middle-third sphenoid meningiomas located in the temporal tip. Branches of the middle meningeal artery, including the recurrent meningeal artery, frequently supply meningiomas located in the sphenoid wing or paraclinoid region [10]. Because the surgical path of the ETOA meets the arterial feeder before reaching the main mass, the surgeon can control the feeder before removing the main mass. By coagulating the feeder, the risk of bleeding during surgery is reduced, thereby

Table 2 Summary of postoperative results

	Glioma	Meningioma	Schwannoma	Others	Total
EOR					
GTR, n(%)	3 (60)	9 (81.8)	2 (66.7)	1 (33.3)	15 (68.2)
STR, n(%)	2 (40)	2 (18.2)	1 (33.3)	1 (33.3)	6 (27.3)
PR, n(%)	0 (0)	0 (0)	0 (0)	1 (33.3)	1 (4.5)
Bleeding, cc	880.0 ± 622.1	731.8 ± 567.1	1366.7 ± 970.0	2193.3 ± 1906.9	1051.4 ± 961.1
CSF leak	1 (20)	1 (9.1)	0 (0)	0 (0)	2 (9.1)
Transient 3rd nerve palsy	0 (0)	2 (18.2)	0 (0)	1 (33.3)	3 (13.6)
Transient 6th nerve palsy	0 (0)	0 (0)	1 (33.3)	0 (0)	1 (4.5)
Major complications	1 (20)	0 (0)	0 (0)	1 (33.3)	2 (9.1)

EOR extent of resection, *GTR* gross total resection, *STR* subtotal resection, *PR* partial resection, *CSF* cerebrospinal fluid improving vision of the surgical field and minimizing surgery time, thus improving postoperative outcomes. Consistent with this, meningiomas had the least amount of bleeding among the three pathologies (Table 2) in our study.

Medial third sphenoid meningiomas often involve the lateral wall of the cavernous sinus. In a conventional craniotomy, temporal lobe retraction is essential; however, when it is chronically compressed by a tumor, it can cause postoperative edema and intracerebral infarction [12]. Shrivastava et al. [13] reported that a spheno-orbital meningioma can be resected using a cranio-orbito-zygomatic approach; however, the excision of the dura, dissection of the optic nerve and SOF, and opening of the optic canal is a very invasive procedure involving the annulus of Zinn and extraocular muscle dissection. Such delicate procedures require reconstruction operations, such as orbital, temporalis muscle, and cranial bone reconstruction using a titanium plate. With the ETOA, unnecessary retraction of healthy tissue is not required to observe and access the lesion, thus leaving the temporal bridging veins and temporal lobe intact.

In case of en-plaque meningiomas, hyperostosis can cause proptosis or visual deterioration by compressing the optic canal, orbital compartment, or SOF. To avoid this, large areas of hyperostosis should be debulked; however, when performed with an endoscopic approach, this may not be ideal. In addition, if the dura tail is extended from the sphenoid ridge to the temporal or frontal dura, it may be difficult to remove the dura tail, making Simpson Grade I difficult to achieve.

Trigeminal schwannoma

According to Samii et al. [14], there are four types of trigeminal schwannomas: type A is an intracranial tumor, the main portion of which is in the middle fossa; type B is an intracranial tumor, the main portion of which is in the posterior fossa; type C is an intracranial dumbbell-shaped tumor involving the middle fossa and posterior fossa; and type D is an extracranial tumor with an intracranial extension. To assess Meckel's cave or the posterior fossa, conventional approaches, such as the anterior petrosal or lateral suboccipital approaches, are recommended. Using these approaches, a wide view can be achieved and the tumor can be accessed from both inside and outside of the dura, but it can cause extensive destruction of the skull base and soft tissue, resulting in a CSF leak, superficial temporal muscle atrophy, and longer recovery times. Using a different surgical angle, the ETOA can provide an extended view from the temporal pole to Meckel's cave, when dissecting the meningo-orbital band observed in the horizontal part of the SOF with the interdural technique [3]. Additionally, if a lateral orbital rim osteotomy is added, a much larger space and angle can be secured, allowing easy access to the middle fossa. Although the ETOA does not provide more extended

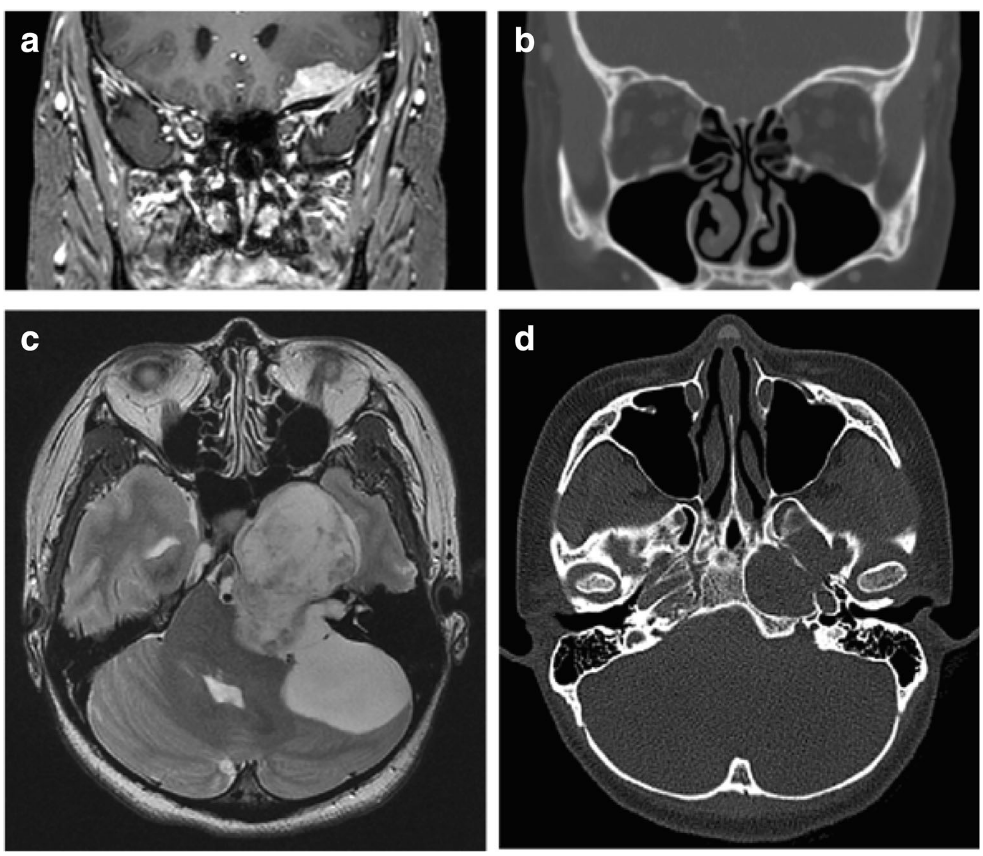

Fig. 3 Comparison of characteristics between meningioma and schwannoma tumors. **a** MRI of left cranioorbital meningioma, showing wide dura tail; **b** CT scan of left cranioorbital meningioma showing hyperostosis of the orbital roof; **c** MRI of left trigeminal schwannoma; **d** CT of left trigeminal schwannoma with extensive bony erosion

views or fine-tuned control, it is still the preferred technique, as both the middle and posterior fossa can be accessed with minimal damage to healthy tissue. This technique should be considered in patients with limited access to the posterior fossa due to recurrent cases or prominent sigmoid sinuses.

Drilling the petrous apex, exposing V2 and V3 nerves, and approaching the posterior fossa have all been recently studied in cadavers, but rarely reported in actual cases [15]. The ETOA may be best for type A patients; type C patients often have bony erosion, so they can be accessed through internal debulking, without drilling the petrous apex. However, because the distance to the posterior fossa is very long, the length of the endoscopic device must also be very long, and, therefore, this surgical procedure would require advanced endoscopic skills, as it is more difficult to delicately control surgical instruments than conventional skull base surgery.

Temporal lobe glioma

When considering the resection of a glioma confined to the temporal lobe, careful consideration must be given to the cortical spinal tracts and arcuate fiber. We first considered using the ETOA in these gliomas because we could avoid complications through the preservation of the superior-medial plane, as the corticospinal tract runs along the medial side of the insula, and the arcuate fiber drives the upper part of the superior temporal gyrus. Pre- and postoperative MRIs (Fig. 1, (1, 2); Fig. 2b, (1, 2)) show that temporal lobe tumors can be removed in parallel with the eyeball, even as far as the temporal stem. In our study, a tumor located in the hippocampus was removed with the help of navigation; if the arachnoid membrane inside the hippocampus is not violated, the third nerve and posterior communication artery can be visually confirmed and the medial margins can be sufficiently removed (Fig. 4). Of our five glioma patients, one glioblastoma patient had to undergo fluorescence staining for 5-aminolevulinic acid (5-ALA, Gliolan, Medac, Wedel, Germany), in which a microscope was temporarily used to confirm the margins during the endoscopic surgery. However, this visualization was not better than that of an endoscope, even if the microscope was enlarged in the view of a narrow entrance. Margins were usually removed by anatomy and the navigation guide.

Limitations

This study demonstrated that the ETOA can be used for various types of intracranial tumors. However, the present study has some limitations, including a small sample size to propose indications, longer follow-up, and best clinical outcomes. With further investigation, we can clearly elucidate the

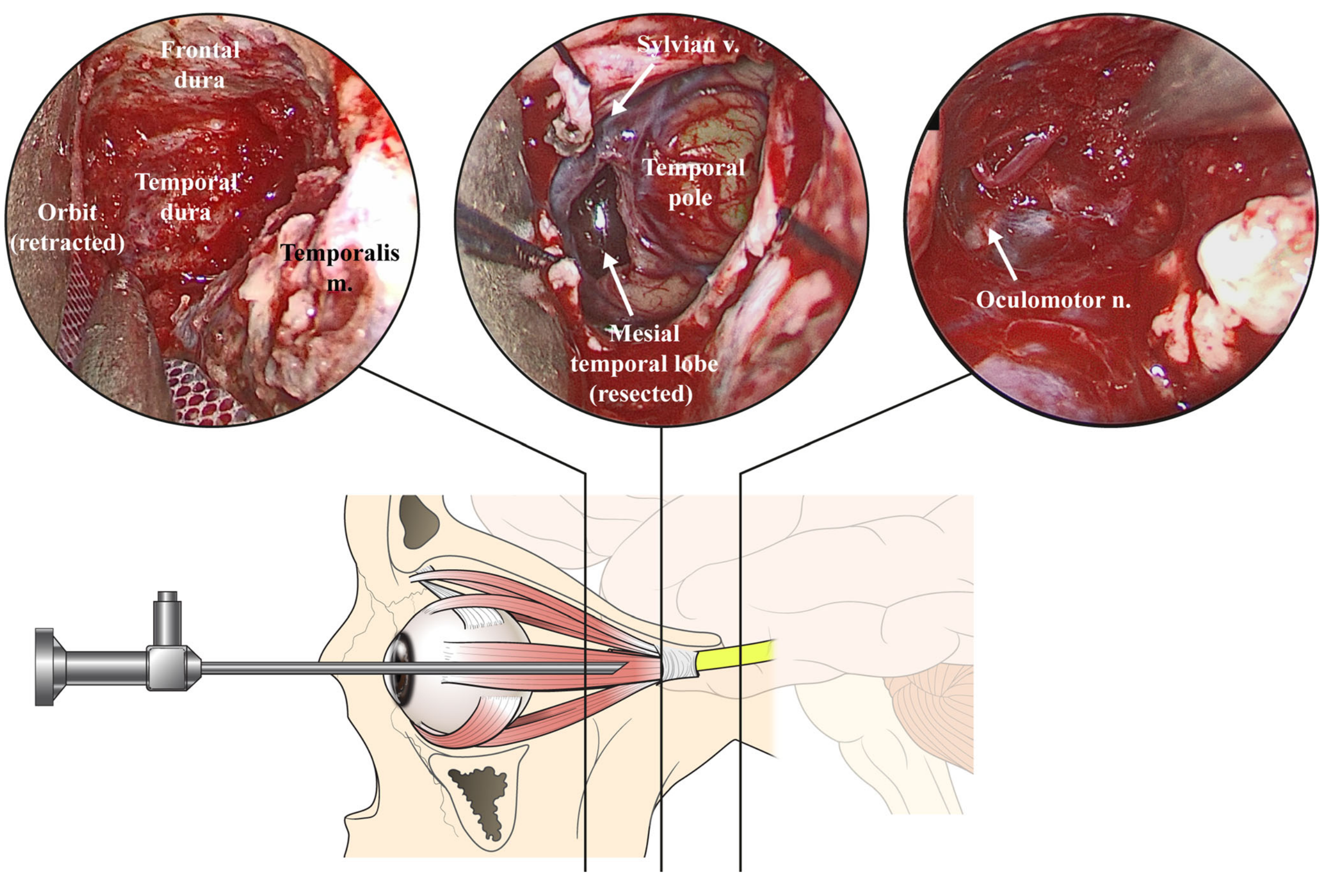

Fig. 4 Schematic illustration of the surgical approach, with intraoperative images at each surgical level

feasibility of the endoscopic approach compared to conventional transcranial approaches. With few published clinical trials, we had no choice but to operate, even if the indication was unclear. In most of our patients, however, GTR was accomplished without mortality. To our knowledge, this is the first study to report on the resection of various lesions, including meningiomas, schwannomas, and even gliomas in the middle cranial fossa, using the ETOA. For satisfactory outcomes, the ETOA requires a surgeon skilled in endoscopic surgery as well as a thorough understanding of the skull base anatomy and radiological analysis of tumor properties.

Conclusions

The endoscopic transorbital approach is a simple method that does not require the retraction of normal brain tissue or interruption of the neurovascular structures. With careful consideration of tumor vascularity, consistency, and anatomy through radiological findings, this route can be used to perform surgery on various lesions and can lead to a satisfactory extent of resection and less risk of bleeding and severe complications.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Written informed consent was obtained from all adult patients.

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Comments The authors describe their experience with the endoscopic transorbital approach as applied to 22 patients including gliomas, meningiomas and schwannomas. They describe good surgical results, with a high rate of complete resection and a relatively low rate of complications. In experienced surgeons this is clearly a useful approach for extra-axial lesions and further evaluation will be welcome.

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