Indications and outcomes of endoscopic transorbital surgery for trigeminal schwannoma based on tumor classification: a multicenter study with 50 cases

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OBJECTIVE Trigeminal schwannoma is a rare CNS tumor and involves the multicompartmental skull base. Recently, the endoscopic transorbital approach (ETOA) has emerged as a technique for minimally invasive surgery. The objective of this study was to evaluate the optimal indications and clinical outcomes of the ETOA for trigeminal schwannomas based on their tumor classification.

METHODS Between September 2016 and February 2022, the ETOA was performed in 50 patients with trigeminal schwannoma at four tertiary hospitals. There were 15 men and 35 women in the study, with a mean age of 46.9 years. All tumors were classified as type A (predominantly involving the middle cranial fossa), type B (predominantly involving the posterior cranial fossa), type C (dumbbell-shaped tumors involving the middle and posterior fossa), or type D (involvement of the extracranial compartment). Type D tumors were also subclassified by ophthalmic division (D1), maxillary division (D2), and mandibular division (D3). Clinical outcome was analyzed, including extent of resection and surgical morbidities.

RESULTS In this study, overall gross-total resection (GTR) was performed in 35 (70.0%) of 50 patients and near-total resection (NTR) in 9 patients (18.0%). The mean follow-up period was 21.9 (range 1–61.7) months. There was no tumor regrowth or recurrence during the follow-up period. Based on the classification, there were 17 type A tumors, 20 type C, and 13 type D. There were no type B tumors. Of the 13 type D tumors, 7 were D1, 1 D2, and 5 D3. For type A tumors, GTR or NTR was achieved using an ETOA in 16 (94.1%) of 17 patients. Eighteen (90.0%) of 20 patients with type C tumors attained GTR or NTR. Ten (76.9%) of 13 patients with type D tumors underwent GTR. Statistical analysis showed that there was no significant difference in the extent of resection among the tumor subtypes. Surgical complications included transient partial ptosis (n = 4), permanent ptosis (n = 1), transient diplopia (n = 7), permanent diplopia (n = 1), corneal keratopathy (n = 7), difficulties in mastication (n = 5), and neuralgic pain or paresthesia (n = 14). There were no postoperative CSF leaks or enophthalmos during follow-up.

CONCLUSIONS This study showed that trigeminal schwannomas can be effectively treated with a minimally invasive ETOA in all tumor types, except those predominantly involving the posterior fossa (type B). For the extracranial compartments, D2 or D3 tumor types often require an ETOA combined with the endoscopic endonasal approach, while D1 tumor types can be treated using an ETOA alone.

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KEYWORDS endoscopic transorbital surgery; trigeminal schwannoma; classification; skull base; tumor

Trigeminal schwannomas comprise 1% of all tumors involving the CNS.1–3 This tumor arises from the cisternal segment of the trigeminal nerve, along the gasserian ganglion, around Meckel’s cave, and to the distal division such as the ophthalmic, maxillary, and mandibular branches.4 Sometimes this tumor involves the multicompartamental skull base and, as a result, requires various surgical approaches.

Considering the complexity of anatomical involvement in trigeminal schwannoma, the optimal surgical approach
approach is the most recommended. However, for schwannomas posterior fossa, there is no debate that the retrosigmoid approach depends on the tumor location. For tumors involving the posterior fossa, there is no debate that the retrosigmoid approach is the most recommended. However, for schwannomas involving the middle cranial fossa, several surgical approaches such as the subtemporal extradural, anterior petrosal, and orbito-fronto-temporal zygomatic have been suggested as optimal. Dumbbell-shaped schwannomas involving both the middle and posterior fossa are especially challenging tumors that are difficult to remove via a single surgical corridor. In addition, tumors extending to the distal division of the trigeminal nerve, such as the ophthalmic or mandibular branches, often involve the orbit or infratemporal fossa area. As a result, these tumors require specific surgical approaches depending on the tumor involvement.

Since the endoscopic transorbital approach (ETOA) was first introduced as a choice of treatment for tumors involving Meckel’s cave and the cavernous sinus,5 indications for this novel approach have been increasingly extended to temporal parenchymal tumors, intraorbital pathologies, and petrous apex lesions when combined with an endoscopic endonasal approach (EEA).1,5–11 Among various indications for the ETOA, trigeminal schwannoma has been regarded as one of best indications because the surgical corridor of the ETOA is parallel to the long axis of the tumor, and it also provides a direct surgical corridor to the lesion. However, it remains unknown whether the ETOA can access all types of trigeminal schwannomas. In this study, our aim was to evaluate the optimal indications and clinical outcomes of the ETOA for trigeminal schwannomas, based on the classification by Samii et al.3 in their multicenter retrospective study.

Methods

Study Population and Data Collection

Between September 2016 and February 2022, the authors performed ETOAs for trigeminal schwannoma at four independent tertiary institutions in Seoul, Korea (Samsung Medical Center, Asan Medical Center, Gangnam Severance Hospital, and Seoul National University Hospital). All surgeries were performed by four independent surgeons (D.S.K., Y.H.K., Y.H.K., and C.K.H.) collaborating with oculoplastic surgeons. Medical records and the tumor registry of the patients were retrospectively collected and reviewed for demographic data, tumor characteristics, surgical outcomes, pre- and postoperative imaging, and surgical morbidity. The data were gathered and analyzed after obtaining informed consent from every patient. The study was approved by the IRB and conducted in accordance with the ethical guidelines of the Declaration of Helsinki. Twelve of the 50 patients with trigeminal schwannomas were reported in previous papers.1,5,7,11

There were 15 men and 35 women included in the study, with a mean age of 46.9 years. The size of the tumors ranged from 10 to 78 mm (average 31.1 mm) at their maximum diameter (Table 1). The tumors were classified according to their predominant or exclusive location in the middle cranial fossa, extracranial extension, middle and posterior cranial fossa (i.e., dumbbell-shaped), or posterior cranial fossa, as suggested by Samii et al.3 (Fig. 1). Tumors were classified as type A (predominantly involving the middle cranial fossa), type B (predominantly in the posterior cranial fossa), type C (dumbbell-shaped tumor involving both the middle and posterior cranial fossa), or type D (involvement of an extracranial compartment). Type D tumors were also subclassified by ophthalmic division (D1), maxillary division (D2), and mandibular division (D3), based on the subdivision of the trigeminal ganglion. The most common clinical manifestations included sensory changes such as ipsilateral facial numbness or paresthesia, difficulty in chewing caused by wasting of temporalis/masseter muscle, proptosis, or mild/moderate trigeminal neuralgic pain. For each type of tumor, a superior eyelid ETOA, preauricular transconjunctival transoral approach, or inferior transconjunctival approach with lateral canthotomy was applied based on the tumor involvement. Postoperative MRI was

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<td>GTR</td>
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<td>NTR</td>
<td>9 (18.0%)</td>
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<td>STR</td>
<td>3 (6.0%)</td>
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obtained within 48 hours and 6 months after surgery to evaluate the extent of resection. Gross-total resection (GTR) was defined as complete tumor removal, confirmed by the surgeon intraoperatively, and no evidence of residual tumor on immediate and 6-month postoperative MRI. Near-total resection (NTR) was defined as a thin layer of the tumor left behind on a vital structure. Subtotal resection (STR) and partial resection (PR) were defined as 90%–95% and < 90% tumor removal, respectively, on immediate and 6-month postoperative MRI. Using Fisher’s exact test, we analyzed the clinical outcome in this series, including the extent of resection and surgical morbidities.

**Surgical Approaches**

**Superior Eyelid ETOA**

The superior eyelid ETOA was the surgical approach most often selected for accessing trigeminal schwannomas. The patient was placed supine or in a slightly flexed position. While under general anesthesia, the patient was covered with a half dose of povidone. Then, a mixture of lidocaine with epinephrine was infiltrated along the superior eyelid. The skin incision was made on the lateral half of the superior eyelid, while a simultaneous division of the orbicularis muscle was also performed. It is critical to preserve the underlying orbital septum. The orbital septum is a membranous sheet that starts from the periosteum, covering the orbital fat tissue, and fuses with the levator aponeurosis; injury to the orbital septum is closely associated with postoperative ptosis. Soft-tissue dissection was performed under the orbicularis muscle until the lateral orbital rim was palpated. A periosteal incision using a monopolar coagulator along the laterosuperior orbital rim should be performed. Then, periosteal-periorbital elevation could expose the greater sphenoidal wing composing the lateral orbital wall. The periorbita was dissected from the lateral wall of the orbit until the orbital apex was reached. Based on the anatomical landmark of the superior and inferior orbital fissures, the lateral orbital wall was drilled from the lateral part to the medial side with a 3- or 4-mm coarse diamond drill bit. Often, opening the orbital surface of the zygomatic bone exposed the temporalis muscle, which was a good landmark for orientation. The trapezoidal-shaped greater sphenoidal wing should be drilled off until the anterior temporal dura is exposed. To access the infratemporal fossa or base of the temporal lobe, the basal portion of the greater sphenoidal wing should be drilled away. After full exposure of the anterior surface of the temporal dura, the medial wall of the greater sphenoidal wing (the so-called vertical or sagittal crest) should be removed to expose the anteromedial triangle of the cavernous sinus (i.e., the space between V1 and V2). In type A, C, and D1 tumors, the anteromedial triangle was the favored route for cavernous sinus entry. Exposure and division of the meningo-orbital band were followed by interdural dissection using the peel-off technique. The dural propria of the temporal lobe was peeled off to expose the lateral membrane of the cavernous sinus. In type A and C tumors, the lateral cavernous sinus was bulging out due to tumor involvement. However, in some tumors involving the posterior cavernous sinus, a normal cavernous sinus wall was found. In these cases, more careful dissection should be performed to avoid injuring the internal carotid artery. In type D3 tumors extending to the infratemporal fossa, the anterolateral triangle (space between V2 and V3) was selected. To access this area, a subtemporal ridge should be drilled to flatten it. Once the tumor was exposed, ring curettage or an ultrasonic cavitation aspirator (Sonopet, Stryker) was used to debulk the tumor. Trigeminal fascicles with tumor involvement should be preserved as much as possible (Figs. 2 and 3).

**Inferior Transconjunctival ETOA With Lateral Canthotomy**

The inferior transconjunctival ETOA with lateral canthotomy was used once to access the tumor extending to the infratemporal fossa (type D3 tumor; Fig. 4). Unlike with the superior eyelid ETOA, an inferior conjunctival...
incision was made in collaboration with the oculoplastic surgeon. In addition, a lateral canthal 1- to 2-cm incision was made to widen exposure of the surgical field. Similarly, the greater sphenoidal wing was exposed. This surgical approach could show the wide exposure around the temporal base (Video 1).

VIDEO 1. Clip showing an endoscopic transconjunctival transorbital approach for a schwannoma involving the infratemporal fossa (type D3). © Doo-Sik Kong, published with permission. Click here to view.

Precaruncular Transconjunctival ETOA

The precaruncular transconjunctival ETOA should be optimal for accessing medial orbital lesions based on their relationship with the optic nerve. With the assistance of an oculoplastic surgeon, we made a medial transconjunctival incision through the caruncle to reach the lamina papyracea. Compared with the other ETOA procedures, this approach provides a small opening and relatively narrower surgical corridor. From the medial part of the orbit, a periorbital incision was performed. For orbital apex lesions, opening of the periorbita should be made at the proximity of the orbital apex to reduce the protruding periorbital fat tissue (Video 2).

VIDEO 2. Clip showing an endoscopic transcaruncular transconjunctival approach for a type D1 schwannoma. © Doo-Sik Kong, published with permission. Click here to view.
Reconstruction Technique

Whereas the ETOA for meningioma usually requires a fat tissue graft or lumbar drainage of CSF for a wide dural opening, the ETOA for trigeminal schwannoma resection did not always require additional lumbar drainage (5 patients) or fat tissue graft (10 patients) for the dural defect. As we accumulated experience with the ETOA for trigeminal schwannomas, we found that the fat graft was not necessary in all cases, in contrast to meningioma cases. To obstruct the dural opening, we first obstructed the porus trigeminus (outlet to the posterior fossa cistern) with a DuraGen matrix (Integra). No sealing agents such as Gelfoam (Pfizer) or Surgicel (Johnson & Johnson) were used to fill the empty space within the cavernous sinus and Meckel’s cave. A button-layer technique using an allodermal graft or autologous fascia was applied to the dural inlet defect on the lateral membrane of the cavernous sinus. TachoSil (Takeda Pharma) or Surgicel was placed and fixed on the grafted area. Placement of a polymerized absorbable buttress for the prevention of postoperative enophthalmos was optional, according to surgeon preference. Lumbar drainage of CSF diversion was not performed in any patients. Finally, the peristeum and the eyelid were closed with a 5-0 absorbable suture and a 6-0 fast-absorbing plain gut suture, respectively.

Results

The mean follow-up period was 21.9 (range 1–61.7, median 20.0) months. Based on the tumor classification system, tumors predominantly involving the middle cranial fossa were present in 17 patients (34.0%, type A), dumbbell-shaped tumors involving the middle and posterior cranial fossa in 20 patients (40.0%, type C; Fig. 2), and tumors with extracranial extension in 13 patients (26.0%, type D; Table 1). There was no case of tumor predominantly in the posterior cranial fossa (type B). Tumor extension into the orbit along the superior orbital fissure was found in 7 patients (14.0%, type D1; Fig. 3), extension along the maxillary division of the nerve in 1 patient (2.0%, type D2), and extension along the mandibular division through the foramen ovale in 5 patients (10.0%, type...
D3). Forty-five patients had newly diagnosed schwannomas and 5 patients had recurrent tumors. In the 5 patients with recurrent tumors, 4 had a previous history of Gamma Knife radiosurgery and 1 patient previously underwent resection. Overall, GTR was performed in 35 (70.0%) of 50 patients and NTR was attained in 9 patients (18.0%), while STR or PR was performed in 6 patients (12.0%).

During the same study period, we performed transcranial surgeries in 30 patients with trigeminal schwannomas. In these 30 patients, there were 24 type B and 6 type C tumors. Transcranial surgeries consisted primarily of a retrosigmoid approach with or without suprameatal drilling.

**Application of the ETOA**

In this study, GTR or NTR was performed in 44 (88.0%) of 50 patients. Three patients underwent STR and 3 others received PR. The reasons for PR included thick adherence to the surrounding tissue or profuse bleeding from the tumor. For the remaining tumors, Gamma Knife radiosurgery was performed in 4 patients. During the follow-up period, there was no tumor regrowth or recurrence in any patient. We performed a superior eyelid ETOA in 48 of 50 patients with all types of tumors. Two of 48 patients underwent superior eyelid ETOA combined with endoscopic endonasal transpterygoid surgery for extracranial tumors (type D2 and D3). Of the 2 other patients, 1 patient received a medial transcaruncular ETOA for a type D1 tumor medially located on the optic nerve (Fig. 4), and the other patient underwent an inferior transconjunctival ETOA with a lateral canthotomy for a type D3 tumor (Fig. 5; this case was previously described1). Nineteen of 20 patients with dumbbell-shaped tumors involving both the middle and posterior cranial fossa (type C) received a superior eyelid ETOA alone, and only 1 patient underwent a staged surgical retrosigmoid approach after a superior eyelid ETOA.

**Clinical Outcome Based on Tumor Classification**

For tumors predominantly in the middle cranial fossa (type A), we performed GTR/NTR in 16 (94.1%) of 17 patients. For dumbbell-shaped tumors involving the middle and posterior cranial fossa (type C), we performed GTR/NTR in 18 (90.0%) of 20 patients. For tumors extending into the extracranial compartments (type D), GTR/NTR was achieved in 10 (76.9%) of 13 patients. Statistical analysis showed that there was no significant difference in the extent of resection among the tumor subtypes.

Furthermore, we analyzed the tumor involving the extracranial components (type D) according to the involvement of distal branches. For tumors extending to the ophthalmic division (type D1), GTR/NTR was achieved in 5 (71.4%) of 7 patients. In 1 patient with a type D3 tumor, a combined ETOA and EEA was performed and GTR was achieved. In patients with tumors extending to the mandibular division (type D3), GTR/NTR was achieved in 4 (80.0%) of 5 patients. After a combined ETOA with an endoscopic endonasal transpterygoid infratemporal fossa approach, we performed GTR in a patient with a type D3 tumor.

**Surgical Morbidities After the ETOA**

After the ETOA, surgical morbidities were grouped as ophthalmological and neurosurgical issues. Ophthalmological complications included transient partial ptosis in 4 patients, permanent ptosis requiring levator muscle resection in 1 patient with a type D1 tumor, transient diplopia including transient fourth cranial nerve palsy in 7
patients, permanent diplopia requiring resection of lateral rectus muscle in 1 patient with a type D1 tumor, and corneal keratopathy (dry-eye syndrome) in 7 patients with type A, C, and D tumors. During surgery, no iatrogenic injury to the abducens nerve has occurred. Neurosurgical issues included difficulties in mastication in 5 patients, and neuralgic pain or paresthesia requiring medication for pain control in 14 patients. Two patients were treated with intravenous antibiotics for a skin wound (eyelid) infection. There were no postoperative CSF leaks or enophthalmos during the follow-up period. There were also no operative deaths or long-term disabilities in this series.

Discussion

Although trigeminal schwannomas represent approximately 0.8%–1% of all intracranial tumors,1,4,5,15 their anatomical complexity and variety require several surgical approaches. In the literature, many authors have classified these tumors according to their locations;2,3,15 popular classifications include the middle fossa type (type A), posterior fossa type (type B), dumbbell-shaped type (which has both middle and posterior fossa components; type C), and tumors that extend into the extracranial compartment (type D). Depending on the division of cranial nerve V involved, type D tumors were further subclassified into ophthalmic division (D1), maxillary division (D2), and mandibular division (D3).

Considering the innate characteristics of these tumors, conventional transcranial approaches have been proposed by many excellent surgeons.2,4,15,16 However, traditional transcranial surgery, regardless of tumor size, may require excessive retraction of the temporalis muscle, a wide skin incision, and a bone opening. Recent advances in endoscopic skull base surgery have led to the development of a novel and pioneering surgical corridor to reach these deep-seated skull base tumors.3,14,17–27 The EEA has demonstrated the potential of minimally invasive surgery for accessing middle cranial fossa schwannomas (type A) or for the pterygopalatine fossa involving schwannomas (type D2). The EEA has several advantages over transcranial approaches, because it does not require a skin incision or retraction of the temporalis muscle and brain,18,28 but the EEA still has some limitations. First, the surgical corridor of the EEA should cross the internal carotid artery, which makes it difficult to reach the lateral part of middle fossa tumors and the posterior fossa component of dumbbell-shaped tumors. Second, the EEA does not provide a direct surgical view to the tumor extending to the orbit (type D1) or posterior cranial fossa (type C). In addition, the EEA should cross the abducens nerve, which obliquely passes the internal carotid artery. Third, the EEA carries the risk of damage to the vidian nerve, which causes xerophthalmia (dry-eye syndrome). In addition, inadvertent damage to the ascending palatine nerve may occur during transpterygoid dissection, which may result in sensory changes.

Thus, the ETOA has many advantages over the EEA for accessing trigeminal schwannomas.10 To achieve a remarkable increase in surgical maneuverability, the ETOA, like the EEA, requires instruments that are ergonomically designed specifically for endoscopic surgery. A more direct field of view, shorter working distance, and a surgical corridor parallel to the tumor axis of the ETOA facilitate the free manipulation of the tumor and promote safe and maximal resection of trigeminal schwannomas. Dumbbell-shaped tumors often have smooth erosion of the petrous
apex and an enlargement of the porus trigeminus, providing a front door to the posterior cranial fossa. Through use of this method, the surgical trajectory of the ETOA can be easily extended to the posterior fossa components. In addition, the posterior fossa component of the tumor is not inherently subarachnoid as is generally recognized in dumbbell-shaped tumors, but has a well-defined dura mater from the dura of the middle fossa or petrous apex. The surgical trajectory of the ETOA also avoids traversing the internal carotid artery and causing damage to the vidian nerve and ascending palatine nerve. From a cosmetic viewpoint, the ETOA is comparable to the EEA, although it does leave minimal scarring on the eyelid. Finally, it is noteworthy that there were no CSF leaks after using the ETOA in this series. One of the most prominent advantages of the ETOA is the minimal chance of postoperative CSF leakage after trigeminal schwannoma removal. This advantage is probably because the orbital globe does not create a large dead space after tumor removal, and unlike the EEA, the effect of hydrostatic pressure due to gravity is decreased. However, the ETOA has a critical limitation in approaching the posterior fossa schwannoma (type B), because tumors of trigeminal nerve root origin from the posterior fossa do not often widen the porus trigeminus. Resection of the tumor predominantly in the posterior cranial fossa in these circumstances may be rather difficult. Therefore, it should be kept in mind that this subtype was excluded in the indication for the ETOA in this study. As noted in the literature, a lateral orbitotomy may provide wider access and allow for more standard microsurgical dissection. A lateral orbitotomy requires retraction of the temporalis muscle and lateral orbital rim resection in all cases. The surgical approach and methods should be selected depending on the surgeon’s experience and familiarity with endoscopy.

Limitations of the Study

This study has some inherent limitations of a retrospectively designed study. In trigeminal schwannoma, NTR may be the preferred surgical strategy over GTR, because the extent of resection is second in priority to preserving the functioning trigeminal nerve fibers. Therefore, long-term stability with a good quality of life should be pursued first. In this regard, the ETOA can contribute to the reduction of postoperative morbidity by providing clear vision through an endoscope and free manipulation using dedicated instruments. However, this multicenter retrospective study had limitations in evaluating the exact relationship between endoscopic surgery and postoperative morbidity. In addition, this study showed that type D tumors had worse clinical outcomes than all other tumor types, even though a statistically significant difference was not found. This result indicates that orbital tumors or tumors extending to the infratemporal fossa will be more complex lesions to remove.

Conclusions

ETOA is a good alternative treatment modality for varying kinds of trigeminal schwannomas (types A, C, and D), except tumors primarily involving the posterior cranial fossa (type B). Trigeminal schwannomas involving the orbit (type D1) are especially indicated for the ETOA, and tumors involving infratemporal fossa (type D3) can be successfully removed using the ETOA alone or a combined ETOA with the EEA.

References


**Disclosures**

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**

Conception and design: Hong, Kong. Acquisition of data: Kong. Analysis and interpretation of data: Kong, Lee. Drafting the article: Kong. Critically revising the article: Lee, Young-Hoon Kim. Reviewed submitted version of manuscript: Hong, Yong Hwa Kim. Statistical analysis: Hong, Yong Hwa Kim.

**Supplemental Information**

**Videos**


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