

Midterm Outcomes of the Endoscopic Endonasal Approach for Treating Tuberculum Sellae Meningiomas: The Impact of Malleable Forceps and Predictors of Surgical Success

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Abstract

Objective To evaluate the midterm surgical outcomes and factors associated with the extent of resection (EOR), postoperative visual improvement, and risk factors for postoperative cerebrospinal fluid (CSF) leaks in cases of the endoscopic endonasal approach (EEA) for tuberculum sellae meningiomas (TSMs), including cases utilizing the malleable forceps.

Design Retrospective clinical study.

Setting Single-center tertiary referral hospital.

Participants Twenty-two patients who underwent the EEA for TSMs between November 2013 and April 2024.

Main Outcome Measures Patient characteristics, intraoperative findings, and postoperative outcomes were evaluated. Predictors of the EOR, postoperative visual improvement, and postoperative CSF leaks were investigated.

Results The median age was 58 years, with 77.2% being women. The median follow-up was 70.5 months, and the mean tumor size was 23.5 mm. Gross total resection (GTR) was achieved in 18 patients (81.8%), with no recurrence. Adhesion to the optic nerve was significantly associated with the EOR ($p = 0.001$). The malleable forceps were used in 14 out of 22 cases, and the GTR rate increased to 92.8% (13 out of 14 cases) with this instrument. Postoperative visual improvement was achieved in 16 of 19 patients (84.2%) and was significantly associated with tumor size ($p = 0.02$) and the duration of preoperative visual disturbances ($p = 0.002$). Two patients (9.0%) experienced postoperative CSF leaks, significantly associated with sex ($p = 0.04$) and Simpson grade ($p = 0.032$).

Keywords

- tuberculum sellae meningiomas
- endoscopic endonasal approach
- midterm outcomes
- visual impairment
- cerebrospinal fluid leaks
- malleable forceps

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Conclusion The EEA yielded favorable outcomes and significant postoperative visual improvement for TSMs, supporting early intervention for symptomatic TSMs and radical treatment for GTR. The malleable forceps can enhance the management of complex procedures.

Introduction

Tuberculum sellae meningiomas (TSMs) constitute approximately 5 to 10% of all intracranial meningiomas and are predominantly prevalent in women.^{1–3} These tumors can compress the optic chiasm and invade the optic canal, causing significant visual impairment and complicating tumor management, owing to the surrounding neural and vascular anatomy. Therefore, the aim of surgical treatment for TSMs is maximal tumor removal and optimal decompression of the optic nerve.^{4–6} Several transcranial approaches (TCAs) have been previously used to address TSMs.^{7–11} Over the last two decades, the endoscopic endonasal approach (EEA) has gained popularity due to the advancements in surgical techniques and technology.^{12–16} The EEA provides close-up visualization, direct access to the tumor base, early devascularization, and prompt decompression of the optic nerve, while eliminating brain retraction.^{17,18} Moreover, it allows direct access to the medial optic canal, a common site of TSM invasion.¹⁹ A meta-analysis indicated that the EEA is safer and more effective compared with TCAs, and it is associated with better visual outcomes.³

To optimize surgical outcomes and further improve safety, continuous innovation of the equipment used and investigation of factors contributing to the extent of resection (EOR) and postoperative visual improvement, which are the ultimate goals of treatment, are crucial. The development of specialized instruments, such as the malleable forceps used in this study, is particularly beneficial. These forceps were designed to facilitate delicate dissection and separation of tissues, especially in challenging areas with complex anatomy. This study aimed to identify midterm outcomes, factors of EOR, and postoperative visual improvement in the case of EEA for TSMs, including cases utilizing the malleable forceps.

Materials and Methods

Patient Population

Following approval from the Institutional Review Board of our hospital (approval number: 1621), the medical files and imaging studies of patients who underwent the EEA for TSMs between November 2013 and April 2024 were retrospectively reviewed. This study was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki. Informed consent was obtained through an opt-out process on the website. The exclusion criteria included eye diseases, such as cataracts or severe amblyopia, and incomplete follow-up. While the initial cohort comprised 25 patients, three were excluded due to incomplete follow-up information. Although the primary indication for surgery was visual

impairment, three patients underwent surgery due to tumor enlargement after consultation.

Pre- and Postoperative Evaluation

All clinical, radiological, and ophthalmological data were collected from computerized medical records. Ophthalmological examinations, including visual acuity (VA) and visual field (VF) tests, were performed by an ophthalmologist at diagnosis and after surgery. The visual impairment score (VIS) was used to quantify the patients' visual status pre- and postoperatively.¹⁸ Three patients without visual impairment were excluded from the postoperative visual improvement evaluation. In the postoperative assessment, improvement was defined as an increase of 0.2 or more in VA or a change of 25% or greater in VF. Deterioration was defined as a decrease of 0.2 or more in VA or a change of 25% or greater in VF.^{20,21} The “no change” and “deterioration” groups were combined for statistical analysis.

Each patient underwent pre- and postoperative magnetic resonance imaging (MRI) scans, including T1-weighted images with and without gadolinium enhancement, and T2-weighted or fluid-attenuated inversion recovery. The maximum diameter, characteristics, anatomical location, and extent of the tumors were determined using MRI. Based on the University of California, San Francisco (UCSF) scoring system, tumors were categorized into three levels using criteria that include tumor size, optic canal invasion, and artery encasement.²² According to the UCSF system, tumors measuring 17 mm or less received zero points, whereas those exceeding 17 mm received one point. For optic canal invasion, tumors with no, unilateral, and bilateral invasions earned zero, one, and two points, respectively. Regarding arterial involvement, zero points were assigned for no contact with the internal carotid artery (ICA) or the anterior cerebral artery (ACA). One point was assigned to a contact of less than 180 degrees with the artery, whereas two points were given to a contact of 180 degrees or more, however without enclosing the artery entirely.

The EOR was defined radiographically as gross total resection (GTR), subtotal resection (>80%), or partial resection for anything less than 80%. Postoperative imaging was typically performed with computed tomography on postoperative days 1 and 7, and contrast-enhanced MRI at 1 or 2 months after surgery, followed by an assessment every 6 months, for 1 year. In all cases, postoperative ophthalmological testing, endocrinological investigations, and clinical examinations were conducted to determine the clinical outcomes following the EEA. Tumor recurrence was defined as the appearance of a new lesion or an increase in the size of the residual tumor, as detected through MRI.

Surgical Procedures

All patients underwent the EEA under general anesthesia at our institution. Additionally, two patients underwent simultaneous combined surgery using the EEA and the supra-orbital keyhole approach (SKA). The intraoperative endoscopic photographs and video are shown in ►Fig. 1 and ►Supplementary Video 1 (available in online version only).

Supplementary Video S1

Endoscopic endonasal surgery for tuberculum sellae meningiomas using malleable forceps. Openings were made in the bone and dura. After detachment and internal decompression, extracapsular dissection was performed, and the arachnoid plane was preserved as much as possible using malleable forceps. The superior hypophyseal artery was carefully peeled from the residual tumor and meticulously preserved. Multilayer reconstruction was performed after tumor removal. Online content including video sequences viewable at: <https://www.thieme-connect.com/products/ejournals/html/10.1055/a-2505-8048>.

Under endoscopic guidance, the sella was accessed using the right nasal septal approach. The rostrum of the sphenoid sinus was drilled flat to maximize the working space and allow the nasoseptal flap to fully cover the defect with minimal dead space. Adequate lateral exposure was achieved by opening the posterior ethmoid. The bone opening was expanded to include the medial opticocarotid recesses and the medial optic canals. The planum sphenoid bone was removed to the anterior extent of the tumor (►Fig. 1A).

After dural dissection, the attachment was devascularized. Until 2018, attachments were typically removed as extensively as possible to achieve a Simpson Grade 1. However, since 2019, attachment has been primarily treated via coagulation (►Fig. 1B, C). Internal decompression of the tumors was accomplished using suction or a Sonopet ultrasonic surgical aspirator (►Fig. 1D). The anterosuperior margin of the tumor was dissected free above the planum, where it is lowest, to encounter a cortical blood vessel. Extracapsular dissection was performed while maintaining the arachnoid plane as much as possible to preserve the neuroanatomy and vasculature (►Fig. 1E). Small vessels related to the optic nerve were mobilized by careful manipulation (►Fig. 1F). Malleable forceps (Mizuho Medical Innovation) were used for complicated procedures (►Fig. 2).

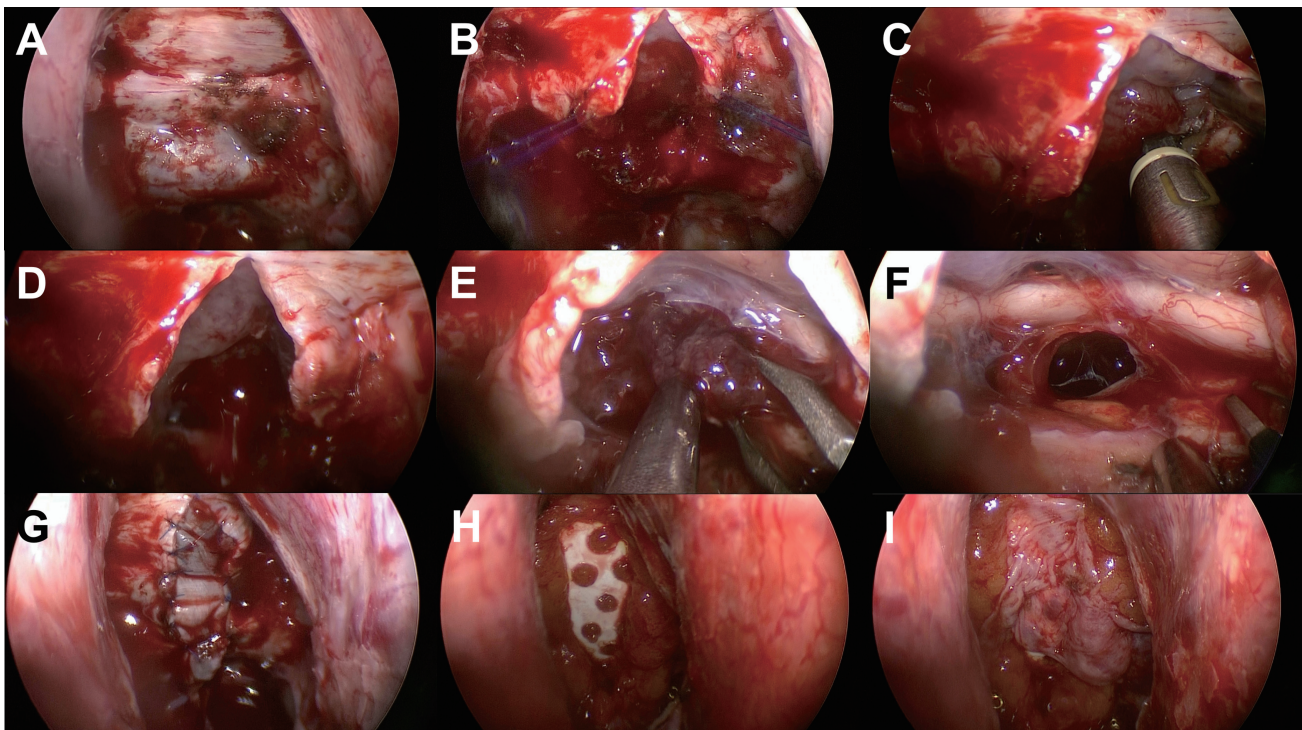


Fig. 1 Surgical procedure for removal of the tumor. (A) The planum sphenoidale bone was removed to the anterior extent of the tumor. (B) A vertical incision was made in the dura mater. (C) The attachment was primarily treated through coagulation. (D) Internal decompression of the tumor was performed using suction or a Sonopet ultrasonic surgical aspirator. (E) Extracapsular dissection was performed, preserving the arachnoid plane as much as possible. (F) Small vessels related to the optic nerve were carefully preserved through meticulous manipulation. (G) After anchoring the fascia at the front end of the dural incision and inserting it into the subarachnoid space, continuous suturing of the dura and fascia was performed from the planum sphenoidale to the bottom of the sellar region on both sides, with tight ligation at the bottom. (H) Fat was applied to the surface of the dura and fascia, and bioabsorbable plates or septal bone were used for rigid reconstruction. (I) A mucosal flap, such as a nasoseptal or sphenoid sinus mucosal flap, was used.

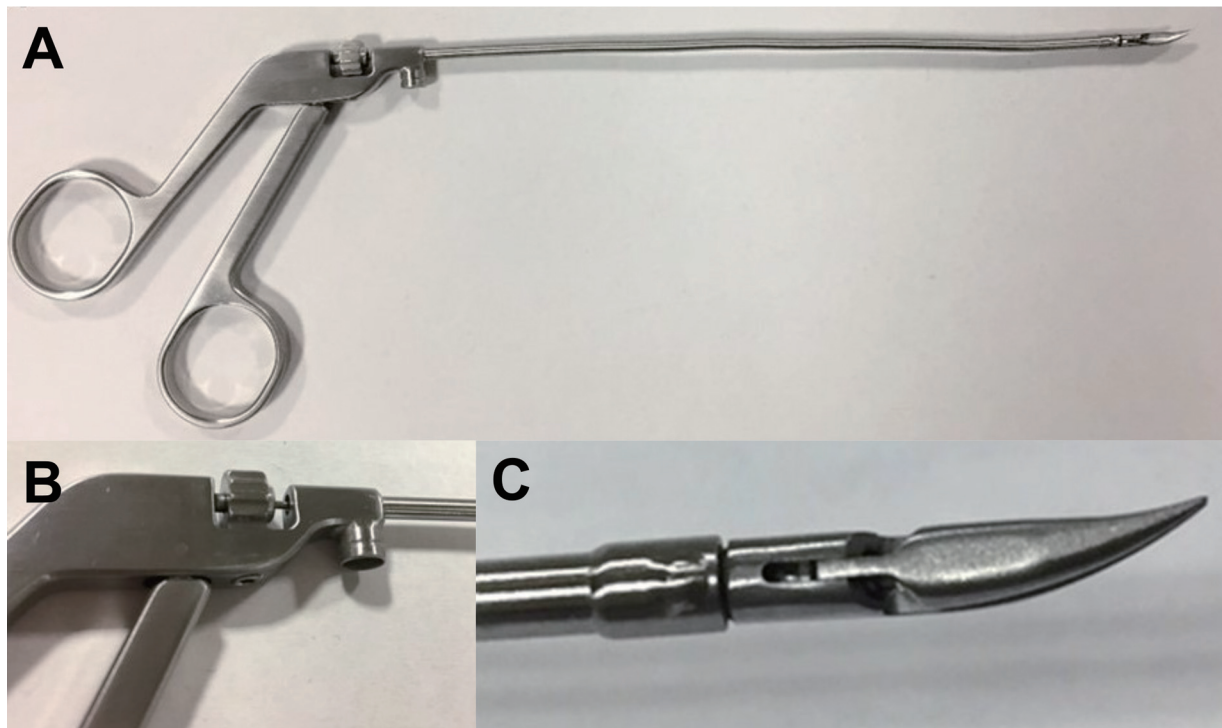


Fig. 2 Malleable forceps. This image is a courtesy of Mizuho Medical Innovation. This instrument was typically used as a specialized tool for delicate tissue peeling. (A) Full view of the instrument. The instrument design allows for easy transmission of force from the handle to the tip, enhancing its effectiveness in manipulation. Additionally, forceps have a flexible shaft that can be bent at any angle. (B) The tip can be rotated 360 degrees by adjusting the dial near the handle. (C) Owing to their blunt and strong gripping tip, the forceps are suitable for tissue separation and peeling.

Tumors that adhered firmly to the optic chiasm were dissected carefully to protect the optic nerve, leaving only a minimal amount of tumor connected to the optic nerve.

Closure was performed in accordance with previously published methodology.²³ Therefore, the fascia was anchored at the front end of the dural incision and inserted into the subarachnoid space. Continuous suturing of the dura and fascia was performed from the planum sphenoidale to the bottom of the sellar region on both sides, with tight ligation performed at the bottom (►Fig. 1G). Subsequently, fat was applied to the surface of the dura and fascia, and either bioabsorbable plates (LactoSorb, Gunze Medical, Osaka, Japan) or septal bone was used for rigid reconstruction (►Fig. 1H). Finally, the fibrin glue was sprayed over the surface. A mucosal flap, such as a nasoseptal or sphenoid sinus mucosal flap, was used routinely (►Fig. 1I). No lumbar drain was placed perioperatively.

Statistical Analysis

Patient demographics, clinical presentations, surgical outcomes, and prognostic factors for visual function after surgery were analyzed using descriptive statistics. Continuous variables were compared using either the Student's *t*-test or the Mann-Whitney U test, depending on their normality distribution. Categorical variables were cataloged in contingency tables based on the outcomes studied and compared using the chi-square test. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SPSS

for Windows (version 26.0; IBM Corp., Armonk, New York, United States).

Results

Patients' Characteristics

This study enrolled 22 consecutive patients, with ages ranging from 32 to 81 years (mean age, 58 years), of which 17 (77.2%) were women (►Table 1). The median postoperative follow-up period was 70.5 months, ranging from 6 to 135 months. Fourteen patients were followed up for over 5 years. Two patients (9.0%) had undergone previous surgical treatment. Visual impairment was observed in 86.4% of cases. The mean maximal diameter of the tumor was 23.5 ± 4.8 mm (mean $\pm$ standard deviation). The tumor size was larger than 17 mm in 19 cases (86.4%), but it never exceeded 30 mm. Medial unilateral or bilateral tumor extension into the optic canal was confirmed in 15 patients (67.1%). Vascular encasement was identified on preoperative imaging and confirmed in 14 cases (63.6%). None of the patients received radiotherapy pre- and postoperatively.

Surgical Outcomes

The EEA was performed in all patients, and two of these patients underwent a simultaneous combined the EEA and the SKA (►Table 2). GTR was achieved in 18 patients (81.8%), and no recurrences were encountered during the follow-up. Four cases (18.2%) showed a Simpson grade 1, whereas 14 (63.6%)

Table 1 Demographic and clinical characteristics

Variable	Study population (%)
Sex, female	17 (77.2)
Age (y, range)	58.0 (32–81)
Follow-up (mo, range)	70.5 (6–135)
Previous treatment	2 (9.0)
Ophthalmological data	
Loss of visual acuity	17 (77.2)
Visual field defect	19 (86.4)
No visual defect	3 (13.6)
Mean symptom duration (mo, range)	17.4 (1–96)
Symptom duration >6 mo	10 (52.6)
Tumor size (mm)	22.5 ± 4.8
≤17	3 (13.6)
> 17	19 (86.4)
Radiological optic canal invasion	
Unilateral	7 (31.8)
Bilateral	8 (36.3)
No reported involvement	7 (31.8)
Radiological vascular involvement	
< 180 degrees	8 (36.4)
≥180 degrees	14 (63.6)

presented a grade 2 and four (18.2%) a grade 4. The malleable forceps were used in 14 out of 22 cases. GTR was achieved in 13 out of 14 cases with the use of the forceps, compared with 5 out of 8 cases without them. The pathological findings included 16 meningotheial meningiomas, 6 transitional meningiomas, 1 angiomatous meningioma, 1 fibrous meningioma, and 1 psammomatous meningioma (21 classified as grade 1 and 1 as grade 2, according to the World Health Organization classification). Seven patients (31.8%) had soft tumors. Adhesion to the optic nerve was observed in seven patients (31.8%). A univariate analysis revealed that adhesion to the optic nerve ($p = 0.001$) affected the EOR (► **Table 3**). No other factors, such as sex, age, tumor size, previous treatment, hardness, optic canal invasion, ICA/ACA encasement, or UCSF scores, were associated with the EOR.

Postoperative Visual Improvement

Sixteen of 19 patients with visual impairment (84.2%) exhibited postoperative symptom improvement; visual status remained unchanged in two patients (10.5%), whereas one patient (5.2%) experienced symptoms exacerbation. Univariate analysis revealed that postoperative visual improvement was correlated with tumor size ($p = 0.02$) and duration of visual disturbances prior to surgery ($p = 0.002$; ► **Table 4**). No other factors, including age, sex, preoperative VIS score, hardness, adhesion to the optic nerve, optic canal invasion, or EOR, were associated with recurrence.

Table 2 Surgical outcomes

Variable	Study population (%)
Surgical approaches	
Endoscopic endonasal approach	20 (90.9)
Combined approach	2 (9.1)
Extent of resection	
GTR	18 (81.8)
STR	4 (18.1)
PR	0 (0)
Simpson grade	
1	4 (18.2)
2	14 (63.6)
3	0 (0)
4	4 (18.2)
5	0 (0)
Pathology	
Meningothelial meningioma	16 (72.7)
Transitional meningioma	3 (13.6)
Psammomatous meningioma	1 (4.5)
Fibrous meningioma	1 (4.5)
Angiomatous meningioma	1 (4.5)
Hardness	
Soft	7 (31.8)
fibrous	15 (68.1)
Adhesion with optic nerve	7 (31.8)
Postoperative visual outcome ($n = 19$)	
Improvement	16 (84.2)
Unchanged	2 (10.5)
Worse	1 (5.2)
Surgical complications ($n = 3$)	
CSF leak	2 (9.1)
Overpacking (fat)	1 (4.5)
Endocrine deficit	0 (0)
Recurrence	0 (0)

Abbreviations: CSF, cerebrospinal fluid; GTR, gross total resection; PR, partial resection, STR, subtotal resection.

Complications and Prognostic Factors for Postoperative Cerebrospinal Fluid Leaks

Two patients (10.5%) experienced postoperative cerebrospinal fluid (CSF) leaks and underwent surgical repair. Overpacking was observed in one patient (5.2%). No postoperative endocrine deficits were seen. A univariate analysis revealed that postoperative CSF leaks were associated with sex ($p = 0.04$) and Simpson grade (grade 1 vs. grades 2–4; $p = 0.007$; ► **Table 5**).

Table 3 Univariate analysis of factors associated with the extent of resection

Variable	Total cases (n = 22)	GTR	STR	Univariate p-Value
Age	58	55.5	51.5	0.97
Sex				1
Female	17	14	3	
Male	5	4	1	
Tumor size (mm)	22.5	23	25.5	0.12
Previous treatment				0.34
Yes	2	1	1	
No	20	17	3	
Hardness				0.26
Yes	15	11	4	
No	7	7	0	
Optic canal invasion				0.27
Unilateral	7	6	1	
Bilateral	8	5	3	
No reported involvement	7	7	0	
Internal carotid artery/anterior cerebral artery encasement				0.25
Yes	14	10	4	
No	8	8	0	
UCSF score				0.57
1	2	2	0	
2	2	2	0	
3	1	1	0	
4	1	1	0	
5	9	8	1	
6	7	4	3	
Adhesion with optic nerve				0.001 ^a
Yes	8	4	4	
No	14	14	0	

Abbreviations: GTR, gross total resection; STR, subtotal resection; UCSF, University of California, San Francisco.

^ap-Value < 0.05.

Discussion

Surgical Outcomes of the Endoscopic Endonasal Approach for Tuberculum Sellae Meningiomas

GTR is an important goal in the surgical management of TSMs because of its association with a decreased recurrence rate. A recent meta-analysis reported a GTR rate of 80.9% for the EEA

and 79.8% for the TCA, with no significant difference between the two approaches ($p = 0.53$).²⁴ Other studies have shown a recurrence rate of 5.3 to 13.6% for the EEA.^{25,26} In a multi-center analysis, the GTR rates were 68.2% for the EEA and 71.2% for the TCA, also with no significant difference ($p = 0.54$). In our study, the GTR rate was 81.8% (18/22), and no recurrence was detected over a median follow-up of 70.5 months.

The EEA is more suitable for tumors that are smaller in size (<30 mm), have limited lateral extension, and involve the optic canal.³ The limitations of the EEA for resection of TSMs include vascular encasement of major arteries, tumor location lateral to the carotid artery or optic nerve, and extensive dural attachment. However, the TCA has advantages, especially it is more suitable for larger tumors and those with lateral extension.^{4,5} Sasaki et al reported that endoscopic SKA for TSMs allowed resection of lesions, including tumors extending outward and above the optic canal, with a good surgical view. However, this approach is challenging for tumors located inferior to the optic nerve and for lesions attached to the diaphragm sellae.²⁷ In a few cases that circumferentially envelop the optic nerve, as illustrated in ►Fig. 3, we selected a simultaneous combined surgery using SKA and EEA.^{28,29} This approach achieves radical tumor resection and ensures safe tumor removal. Complicated lesions can obstruct the surgical view when using both the EEA and SKA, particularly when critical structures adhere to the superolateral and posterior aspects of the tumor. Blind removal of such tumors can result in severe surgical complications, making the identification of these blind areas during both approaches necessary, to ensure safe tumor removal.

Adhesion to the optic nerve significantly affected the EOR, as confirmed through a univariate analysis ($p = 0.001$). This finding emphasizes the technical challenges posed by adhesions, which can limit the extent of safe tumor removal and potentially affect visual outcomes. In such cases, it is crucial to dissect tumors attached to neurovascular structures using precision instruments, such as malleable forceps, without traction or injury on vital structures, to minimize complications and optimize surgical outcomes.

Malleable Forceps

The primary features of the malleable forceps we developed include a strong gripping mechanism and an extremely fine, blunt tip, specifically designed for effective tissue separation and peeling. The forceps also feature a flexible shaft and a 360-degree rotation capability, enabling access to lesions in various anatomical locations depending on the surgical situation. This was particularly valuable in our cases, as it allowed for precise dissection of tumors from nerves and small vessels such as the superior hypophyseal artery.

The introduction of the malleable forceps has not only enhanced the surgical technique but also significantly impacted patient outcomes. With this instrument, the GTR rate has increased to 92.8%, with 13 out of 14 cases achieving GTR, contributing to no recurrences over a median follow-up period of 70.5 months.

Table 4 Univariate analysis of factors associated with postoperative visual improvement

Variable	Total cases (n = 19)	Improved group	Nonimproved group	Univariate p-Value
Age				0.29
Sex				0.53
Tumor size (mm)	22.5	22.3	28.7	0.02 ^a
Previous treatment				0.16
Preoperative VIS	24.6	24.8	23	0.88
Duration of preoperative visual symptoms (mo)	17.4	7.2	72	0.002 ^a
Hardness				1
Soft	5	4	1	
Not soft	14	12	2	
Adhesion with optic nerve	8	6	2	0.3
Optic canal invasion				0.3
No invasion	5	5	0	
Unilateral	6	4	2	
Bilateral	8	7	1	
EOR				0.53
GTR	15	13	2	
STR	4	3	1	

Abbreviations: EOR, extent of resection; GTR, gross total resection; STR, subtotal resection; VIS, visual impairment score.

^ap-value < 0.05**Table 5** Univariate analysis of factors associated with postoperative cerebrospinal fluid leak

Variable	Total cases (n = 22)	CSF	No CSF	p-Value
Age	58	60	52.5	0.69
Sex				0.04 ^a
Female	17	0	17	
Male	5	2	3	
Tumor size (mm)	22.5	18.5	24.5	0.21
Previous treatment				1
Yes	2	0	2	
No	20	2	18	
Simpson grade				0.007 ^a
1	4	2	2	
2	14	0	14	
4	4	0	4	
Hardness				1
Yes	15	1	14	
No	7	1	6	
Approach				1
EEA	2	0	2	
Combined	20	2	18	

Abbreviations: CSF, cerebrospinal fluid; EEA, endoscopic endonasal approach.

^ap-value < 0.05.

Postoperative Visual Improvements and Prognostic Factors

Another concern in treating TSMs is their potential for visual improvement. In our study, resection of TSMs with the EEA yielded favorable outcomes, with 84.2% of patients experiencing improved vision. A recent meta-analysis reported a visual improvement rate of 86.6% (258/298) and 65.4% (261/399) with the EEA and TCA, respectively, showing a significant benefit for using the EEA ($p < 0.01$).²⁴ Bove et al analyzed VIS and reported an 82.9% rate of visual improvement in the EEA.¹⁸

Various factors have been proposed as prognostic indicators for visual outcomes in parasellar meningiomas, including age, duration, and severity of visual deficits, presence of optic atrophy, tumor size, encasement of the optic nerve or tumor adhesion to the undersurface, and the EOR.³⁰ Our study showed that tumor size and duration of preoperative visual disturbances are significantly associated with postoperative visual improvement. Similarly, Duan et al identified a <10-month duration of preoperative visual symptoms and a tumor size ≤ 27 mm to be significant predictors of favorable visual outcomes.²⁰ These findings are supported by previous reports also indicating that shorter durations of preoperative visual impairment are closely associated with better postoperative visual outcomes.^{2,10,20,21,31}

Complications of the Endoscopic Endonasal Approach for Tuberculum Sellae Meningiomas

Recently, the prevalence of CSF leaks has been greatly reduced with advancements in skull base reconstruction technology, such as the soft gasket technique³² and dural sealants.³³ However, CSF leak rates with the EEA have remained comparatively high over time, indicating that further improvement in skull base repair is needed.^{4,18,34} A recent large multicenter cohort reported CSF leak incidences of 17.5 and 2.2% with the EEA and TCA, respectively.⁵ Additionally, Ivan et al reported an 11% incidence of CSF leaks in a review including 98 patients.³⁵ Our study showed a 9.0% CSF leak rate, with a correlation between the Simpson grade and CSF leak prevalence. Reports on skull base reconstruction following the EEA indicate that dural defects >1 cm are associated with a higher risk of postoperative CSF leaks.^{36–38} Therefore, depending on the extent of the dural defect, a more advanced reconstruction may be needed.

Limitations

This study has some limitations. First, this was a retrospective analysis based on a small case series from a single institution, which may limit the generalizability of the findings. Second, the follow-up period may be relatively short for assessing recurrence in TSMs, highlighting the need for additional long-term

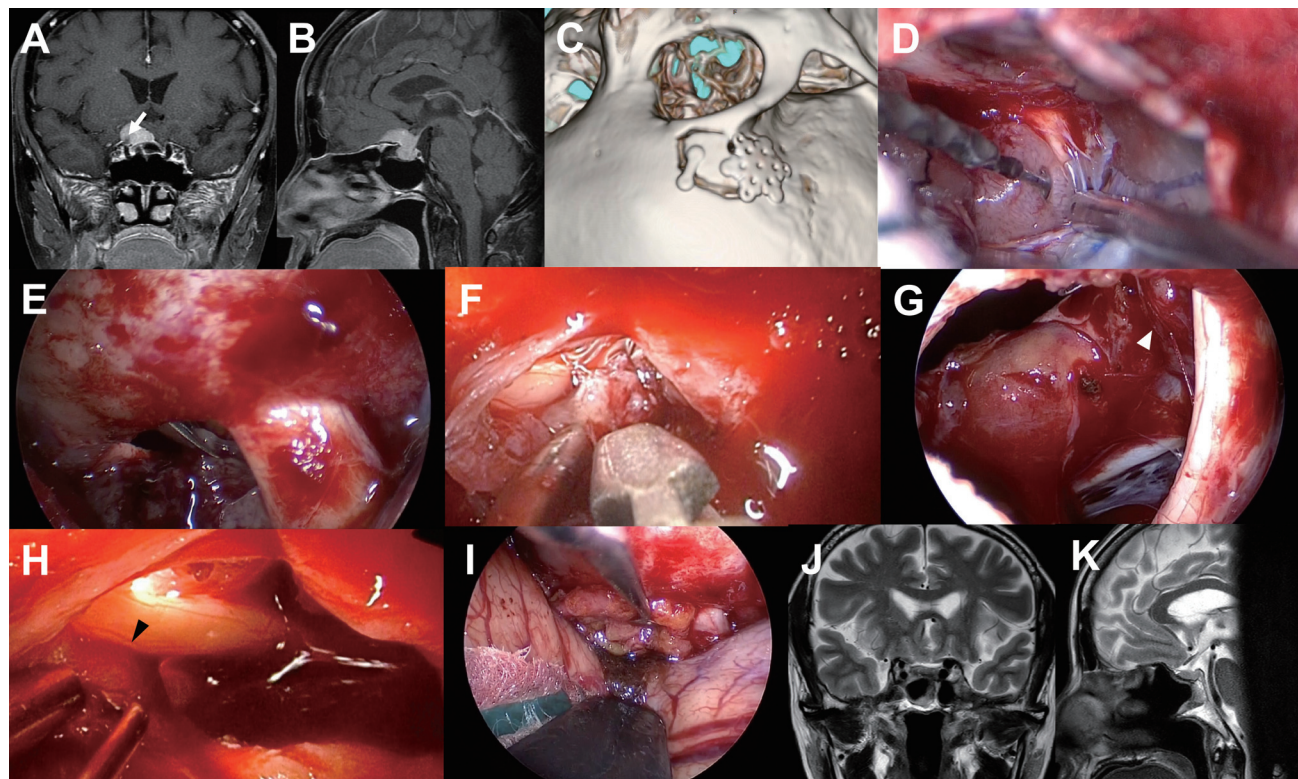


Fig. 3 Magnetic resonance imaging (MRI) and intraoperative findings of the illustrative case. (A, B) Preoperative contrast-enhanced T1-weighted MRI showing a mass extending from the tuberculum sellae to the planum sphenoidale and reaching the supralateral aspect of the optic nerve (white arrow). The tuberculum sellae angle is relatively sharp. (C) A supraorbital keyhole craniotomy was performed. (D) View from the cranial side showing the tumor progressing to the supralateral aspect of the optic nerve. (E) The tumor, located on the inferomedial aspect of the optic nerve, was not visible on the cranial side. (F) The tumor was resected using the endoscopic endonasal approach (EEA). (G) Although most of the tumor was removed, a residual portion was observed within the optic canal (white arrowheads). (H) The tumor within the optic canal was removed using the EEA (black arrowhead). (I) During reconstruction, the fat graft and inner fascia were checked and adjusted from the cranial side. (J, K) Postoperative T2 weighted MRI acquired 6 years after surgery, showing gross total resection without recurrence.

data to accurately evaluate recurrence rates. Third, visual outcomes were analyzed at various postoperative intervals, potentially introducing variability in the assessment of visual improvement. Fourth, the study focused on patients with tumors averaging 23.5 mm in diameter with minimal lateral extension beyond the plane of the ICA; only two tumors in our series extended beyond the ICA. This may affect the applicability of the results to patients with larger or more laterally extended tumors. Finally, the sample size for our study was relatively small, limiting the statistical power to detect differences in outcomes and risk factors. Future studies should include larger multicenter cohorts with standardized follow-up protocols to validate and expand upon these findings.

Conclusion

This study indicates that the EEA for TSMs results in positive outcomes and improves postoperative vision. These findings strongly advocate for early surgical intervention for symptomatic TSMs, and radical treatment aimed at achieving GTR. The introduction of malleable forceps can enhance the management of complex procedures.

Authors' Contributions

All authors contributed to the study conceptualization and design. Formal analysis and investigation: K.N., T.N.; writing—original draft preparation: K.N., T.N.; writing—review and editing: K.N., T.N., T.I.; supervision: N.K., Y.I., T.M., Y.S., H.Y., T.T., Y.S., Y.A., T.N., Y.S.

Data Availability

The data supporting the findings of this study are available from the corresponding author, T.N., upon reasonable request.

Code Availability

The code supporting the findings of this study is available from the corresponding author upon reasonable request.

Conflict of Interest

None declared.

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