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# *Current Status of Endoscopic Endonasal Surgery for Skull Base Meningiomas: Review of the Literature*

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## Abstract

**Endoscopic endonasal approach (EEA) is expected to be ideal for the paramedian ventral skull base meningiomas, allowing wide access to the ventral skull base regions and realizing early devascularization of the tumor without retraction of the brain. We searched clinical reports of EEA for skull base meningiomas, written in English language, published before October 2014, using the PubMed literature search on the website. Skull base meningiomas are subdivided by the site of occurrence, olfactory groove (8 articles including 80 cases), tuberculum sellae (14 articles, 153 cases), cavernous sinus (2 articles, 8 cases), petroclival region (4 articles, 10 cases), and craniofacial region (2 articles, 5 cases), and the surgical outcomes of EEA were analyzed. In anterior skull base regions, EEA contributed to effective improvement of the symptoms in small and round-shaped meningiomas, but 25% of the patients had postoperative cerebrospinal fluid rhinorrhea. In cavernous sinus and petroclival regions, successful surgical removal largely depended on tumor consistency, and the extent of the surgical resection proportionally increased the risks of serious complications. Thus, judicious endoscopic resection with adjuvant radiotherapy or radiosurgery remains to be the most reasonable treatment option. To decrease the risks of surgical complications, the surgeons must master the closure techniques of dural defect and meticulous microsurgical procedure under endoscopic vision. Further progress will depend on the progresses of surgical technique in neurosurgeons engaging this potentially "minimally invasive" surgery.**

Key words: endoscopic endonasal surgery, skull base meningioma, tuberculum sellae, olfactory groove, cavernous sinus

## Introduction

Meningioma is one of the most common ventral skull base tumors, which is often fibrous, vascularized, and adherent to the surrounding anatomies, and radical surgical treatment includes the management of dural tails to completely eliminate the risks of recurrence.[1,2] Despite recent progress of endoscopic technologies in the neurosurgical field, surgical resection of skull base meningiomas through narrow nasal corridors is still a challenge. While there are numerous reports about endonasal endoscopic approaches, most of them were small case series of olfactory groove meningiomas or tuberculum sellae meningiomas,[3–11] and it is still unclear that, for which cases, the endonasal surgery should be preferentially recommended. Furthermore, as for the meningiomas in other skull base regions such as cavernous sinus, petroclival regions, and craniofacial regions, application of endoscopic endonasal surgery is reported in the limited cases. Thus, the role of endonasal endoscopic surgery for meningiomas is still controversial.[12,13]

In this article, we review the reports of endoscopic endonasal approach (EEA) for skull base meningiomas in the past literature, and its current role and future possibility to further application are discussed.

## Materials and Methods

We searched the clinical reports of EEA for skull base meningiomas, written in English language, published before October 2014, using the PubMed literature search on the website (http://www.ncbi.nlm.nih.gov/pubmed). Skull base meningiomas are subdivided by the site of occurrence as the following: "olfactory groove," "tuberculum sellae," "cavernous sinus," "petroclival or clival" region, and "orbit or craniofacial" region. The three keywords, "meningioma or meningiomas," "endonasal," "endoscopic," and one of the site of occurrence above are selected

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as search terms, which are retrieved in the title or the abstract of the reports using the advanced search function. Each report is carefully verified, and the reports which are not related to the surgical outcome of EEA for meningioma in the location of the assigned search term are removed. Then, the surgical outcomes were analyzed.

## Results

With the search term of "meningioma or meningiomas," "endonasal," and "endoscopic," there are 79 articles found on the PubMed literature search, and the reports describing the clinical cases were subdivided in the following categories, by adding the site of occurrence in the search term.

### I. Olfactory groove meningioma

Sixteen articles were identified, in which eight were excluded because two were case reports about schwannomas, three technical reports without detailed case description, two articles about the literature review or meta-analysis, and one comment for the previous article. Thus, the outcome of endoscopic endonasal surgery for meningiomas in this region was analyzed in the remaining 8 articles including 80 cases (1 to 50 cases in each article, median 5 cases, Table 1).[4–7,14–17] The mean diameter of treated tumors was 3.1 cm and one-third of the patients presented with visual symptoms (26 patients).

Gross total resection (GTR) or subtotal resection (STR) was achieved in 70 patients (87.5%, GTR: 49 patients, 61.2%, STR: 21 patients, 26.3%). Improvement of visual function was observed in 24 patients (92.3%), and no one showed visual deterioration after surgery. As surgical complications, 21 patients (26%) had postoperative cerebrospinal fluid leak requiring additional treatments and 7 (8.8%) had serious neurological deficits associated with surgical procedure such as cerebral hemorrhage (3 patients),[5,6,15] brain abscess (3),[6] and 10 (12.5 %) had possibly fatal systemic complications such as pulmonary embolisms or deep venous thrombosis.[6] In a report of the largest clinical series, the overall complication rate of 90% was reported.[6] The average length of their surgery was 9 hours, and more than two surgeries were performed in almost 40% of the patients to achieve the better rate of GTR, which may be the reason for such high rate of complications.

### II. Tuberculum sellae meningiomas

Thirty articles were identified, of which 16 were excluded from the analysis because three were case reports about meningiomas in other regions, four about the literature review or the meta-analysis, four technical reports without the description of the clinical course of the presented case, one comment for the previous article, and one republished article in the same journal. In three articles of two authors, same subjects presented in the previous reports were reanalyzed in the subsequent reports and latest ones were adopted in this analysis. Thus, the outcome of endoscopic endonasal surgery for meningiomas in this region was analyzed in the 14 articles including 153 cases (1 to 75 cases in each article, median 5 cases, Table 2).[5,7,10,15,18–27] The mean diameter of treated tumors was 2.4 cm and 120 patients (78.4%) presented with visual symptoms.

Of them, GTR or STR was achieved in 150 patients (98.0%, GTR: 119 patients, 77.8%, STR: 31 patients, 20.3%). Improvement of visual function was observed in 102 patients (85.0%), but on the contrary, visual deterioration occurred in 3 (2.5%).[10,20] As other surgical complications, 37 patients (24.3%) had postoperative cerebrospinal fluid leak requiring additional treatments[5,7,10,18–23,25,27] and 7 (8.8%) had diabetes insipidus,[5,7,10,23,27] and 3 hyponatremia.[15,19,20] Possibly fatal systemic complications occurred in two patients (1.3%), one severe hepatic dysfunction[21] and one pulmonary embolism.[10]

### III. Cavernous sinus meningiomas

Twelve articles were found, in which seven were excluded because three were reports about other pathologies or meningiomas in the other regions, two technical reports without case description, one about the usefulness of a surgical device, and one about the experience of endonasal microsurgery. Among the remaining four articles,[28–31] two reports were about endonasal biopsy for the cavernous sinus lesions of which histological diagnosis revealed meningiomas (total 4 cases).[28,29] Thus, there were two articles conducting the radical resection of the cavernous sinus meningiomas (Table 3).[30,31] In one article, the authors reported their experience of endoscopic endonasal resection of various cavernous sinus tumors including 10 pituitary adenomas, 6 meningiomas, 5 schwannomas, 3 carcinomas, and 1 chondrosarcoma.[31] They made a vertical incision on the medial wall of the cavernous sinus and the anterior wall was occasionally removed. The cavernous sinus and the internal carotid artery were widely exposed, and the tumors were approached medially and laterally to the internal carotid artery. In this approach, they reported excellent resection rates, 5 of 6 meningiomas were totally or subtotally resected (GTR 4, STR 1) without neurological complications. However, along with wide exposure of the cavernous sinus, the blood loss was not

**Table 1 Outcomes of endoscopic endonasal surgery for olfactory groove meningiomas in the past literature**

| Author, published year | n | M:F | Age (mean, years) | Maximum diameter (mean, cm) | Extent of resection | | Visual symptom | | Follow-up (mean, months) | Recurrence | Surgical complications |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GTR | STR | Improved | Worsened | | | |
| de Divitiis et al., 2008[14] | 4 | 1:3 | 49.3 | 3.7 | 4 | 0 | 1/2 | 0 | 9.8 | NA | CSF rhinorrhea 1 (ROP), blood transfusion required 3 |
| Gardner et al., 2008[5] | 15 | 3:12 | 57.9 | | 7 | 3 | 8/8 | 0 | | 0 | CSF rhinorrhea 4 (ROP 3, LD 1), postoperative cerebral hemorrhage 2 |
| Webb-Myers et al., 2008[17] | 1 | 1:0 | 46 | 5.8 | 1 | 0 | 1/1 | 0 | | 0 | None |
| Liu et al., 2011[24] | 3 | 0:3 | 45.3 | 4 | 2 | 1 | 0/0 | 0 | 5.5 | 0 | None |
| Padhye et al., 2012[15] | 8 | 2:6 | 52.1 | 3.3 | 8 | 0 | 1/4 | 0 | 23.6 | 1 | CSF rhinorrhea 3 (ROP 1, LD 1, OBS 1), cerebral hemorrhage 1 |
| Khan et al., 2014[7] | 6 | 0:6 | 53.7 | 3.9 | 4 | 2 | 2/2 | 0 | 4 | 1 | CSF rhinorrhea 2 (ROP 2), average blood loss was 1,000 cc |
| Koutourousiou et al., 2014[6] | 50 | 28:22 | 57.1 | 4.2 | 30 | 15 | 13/15 | 0 | 32 | 1 | CSF rhinorrhea 15, sinus infection 5, brain abscess 3, meningitis 1, stroke 1*, hydrocephalus 1, PE or DVT 10 |
| Rosen et al., 2014[16] | 1 | 0:1 | 39 | 2.3 | 1 | | | | 7 | NA | None |
| Total | 88 | 35:53 | 55.5 | 3.2 | 57 (64.8%) (GTR + STR 88.6%) | 21 | 26/32 (81.3%) | 0 (0%) | 26.0 | 3 (3.4%) | CSF rhinorrhea 25 (28.4%), Serious neurological complications 7 (8.0%) |

CSF: cerebrospinal fluid, DVT: deep venous thrombosis, F: female, GTR: gross total resection, LD: treated with lumber drainage, M: male, n: number, NA: not assessed, OBS: treated with conservative observation, PE: pulmonary embolism, ROP: surgical repair was performed, STR: subtotal resection. *: this patient suffered a stroke and transient hemiparesis after the fronto-orbital artery pseudoaneurysm rupture.

**Table 2 Outcomes of endoscopic endonasal surgery for tuberculum sellae meningiomas in the past literature**

| Author, published year | n | M:F | Age (mean, years) | Maximum diameter (mean, cm) | Extent of resection | | Visual symptom | | Follow-up (mean, months) | Recurrence | Surgical complications |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GTR | STR | Improved | Worsened | | | |
| Laufer et al., 2007[23] | 3 | 0:3 | 63.3 | 2.7 | 2 | 1 | 3/3 | 0 | 9 | NA | CSF rhinorrhea 1 (OBS), DI 1, |
| Prevedello et al., 2007[25] | 1 | 0:1 | 52 | 2.1 | 1 | | 1/1 | 0 | | NA | CSF rhinorrhea 1 (ROP+LD) |
| de Divitiis et al., 2008[21] | 7 | 3:4 | 58.7 | | 6 | 1 | 5/7 | 0 | 24 | NA | CSF rhinorrhea 2 (ROP), Fatal intraventricular hemorrhage 1 |
| Gardner et al., 2008[5] | 13 | 1:12 | 52.2 | | 11 | 2 | 11/11 | 0 | 24 | 0 | CSF rhinorrhea 8 (ROP+LD) |
| Wang et al., 2010[27] | 12 | 4:8 | 56.7 | 3.1 | 11 | 1 | 11/11 | 0 | 25.2 | NA | CSF rhinorrhea 1 (POP+LD), transient DI 1, |
| Liu et al., 2011[24] | 2 | 0:2 | 50 | 2.9 | 2 | | 2/2 | 0 | | 0 | None |
| Attia et al., 2012[18] | 4 | 2:2 | 54 | 2 | 3 | 0 | 1/1 | 0 | 19.4 | 0 | Anosimia 1 |
| Bohman et al., 2012[19] | 5 | 2:3 | 53.2 | 2 | 4 | 1 | 4/5 | 0 | 7.8 | 0 | CSF rhinorrhea 1 (ROP), transient hyponatremia 2 |
| Chowdhury et al., 2012[20] | 6 | 2:4 | 39.5 | 3.5 | 5 | 1 | 4/6 | 1 | 7 | 0 | CSF rhinorrhea 1 (OBS), hyponatremia 2, visual deterioration 1 |
| Padhye et al., 2012[15] | 2 | 0:2 | 65.5 | 1.7 | 2 | | 2/2 | 0 | 3 | 0 | Hyponatremia 1 |
| Prosser et al., 2012[26] | 1 | 0:1 | 61 | 2.5 | 1 | | 1/1 | 0 | | NA | None |
| Gadgil et al., 2013[22] | 5 | 2:3 | 50.6 | 2 | 4 | 1 | 2/2 | 0 | 24 | 0 | CSF rhinorrhea 1 (ROP), meningitis 1, transient DI 2 |
| Khan et al., 2014[7] | 17 | 3:14 | 61.5 | 2.3 | 11 | 6 | 9/14 | 0 | 9.4 | 1 | CSF rhinorrhea 2 (ROP), transient DI 2, |
| Koutourousiou et al., 2014[10] | 75 | 14:61 | 57.3 | 2.3 | 57 | 16 | 48/56 | 2 | 29 | 4 | CSF rhinorrhea 19 (ROP 17, single 11, multiple 6, LD 1, OBS 1), meningitis 4, hydrocephalus 2, DI 1, PE 1, |
| Total | 153 | 33:120 | 56.3 | 2.4 | 120 (78.4%) | 30 | 104/122 | 3/155 | 22.8 | 5/129 (3.9%) | CSF leak 37 (24.2%), DI 7 (4.6%), hyponatremia 5 (3.3%) |
| | | | | | (GTR+STR 98.0%) | | (85.2 %) | (1.9%) | | | |

CSF: cerebrospinal fluid, DI: diabetes insipidus, F: female, GTR: gross total resection, LD: treated with lumber drainage, M: male, n: number, NA: not assessed, OBS: treated with conservative observation, PE: pulmonary embolism, ROP: surgical repair was performed.

**Table 3 Outcomes of endoscopic endonasal surgery for cavernous sinus and petroclival meningiomas in the past literature**

| Author, published year | n | M:F | Age (mean, years) | Maximum diameter (cm) | Extent of resection | | Follow-up (mean, months) | Surgical complications |
|---|---|---|---|---|---|---|---|---|
| | | | | | GTR | STR | | |
| Cavernous sinus meningiomas | | | | | | | | |
| Zhang et al., 2014[31] | 6 | 1:5 | 51.2 | | 4 | 1 | 37 | None |
| Yano et al., 2014[30] | 2 | | | | 1 | 0 | | None |
| Petroclival meningiomas | | | | | | | | |
| Kassam et al., 2008[33] | 2 | 1:1 | 56 | | 0 | 0 | | CSF rhinorrhea 1 (ROP), transient DI 1, |
| Prosser et al., 2012[26] | 1 | 1:0 | 21 | 3.9 | 0 | 1 | | Bilateral abducent nerve palsy |
| Fernandez-Miranda et al., 2014[32] | 5 | 1:4 | 47.8 | | | | | Transient DI 1 |
| Khan et al., 2014[29] | 2 | 1:0 | 70.5 | | 0 | 2 | | Brainstem stroke resulting in hemiparesis and hearing loss 1 |

CSF: cerebrospinal fluid, DI: diabetes insipidus, F: female, GTR: gross total resection, M: male, n: number, ROP: surgical repair was performed, STR: subtotal resection.

negligible, 900 ml to 2,500 ml in the illustrative cases, and in their figures of the illustrative case, they described that the enhancing mass lesion in the cavernous sinus was "completely removed," but the postoperative magnetic resonance imaging clearly disclosed a residual enhancing mass in the cavernous sinus. Thus, their criteria of "total resection" might be controversial. In another article, the authors performed endonasal approach for nine cavernous sinus tumors, of them two were meningothelial meningiomas.[30] They widely opened the sphenoid rostrum, and the cavernous sinus lesions were removed mainly under 30 degree endoscope. One was totally removed, and in another case, they found it difficult to dissect from the internal carotid artery, and the tumor was partially removed.

**IV. Petroclival (clival) meningiomas**

Sixteen articles were identified and 12 were excluded because 6 were reports about other pathologies or meningiomas in other regions, 5 technical reports without the description of the clinical course of the presented case, and 1 anatomic study. Thus, the outcome of endoscopic endonasal surgery for meningiomas in this region was analyzed in the 4 articles including 10 cases (1 to 5 cases in each article, median 2 cases, Table 3).[26,29,32,33] Among them, two of them applied a technique of pituitary transposition to sufficiently expose the tumor.[32,33] In all of them, the purpose of the surgery is "decompression of the brainstem," and radical resection was not intended. Thus, two of the nine cases were subtotally resected, however, of whom, one patient had a brainstem stroke resulting in hemiparesis and unilateral hearing loss,[29] and another suffered bilateral abducent nerve palsies after surgery.[26]

**V. Orbital or craniofacial meningiomas**

Five articles were identified, of which one was an anatomic study and another one was a report about the usefulness of a surgical device. Among the remaining three articles, two reports were about combined cranionasal surgery for spheno-orbital meningiomas in total five patients, and endonasal approach was performed additionally to the transcranial approach to remove the tumor components extending into the paranasal sinus.[34,35] Another report was about the usefulness of optic nerve decompression for eight meningiomas invading into the orbit (four spheno-orbital meningiomas, three optic nerves, one orbital apex).[36] In all the reports, the role of endonasal surgery is adjunctive for transcranial approach or radiotherapy.

## Discussion

Endoscopic surgery allows wide access to the ventral skull base regions and realizes detachment of the tumor from the dural attachment in the initial step of the surgical procedures without further retraction of the brain tissue.[3,21,37] Thus, the endoscopic endonasal surgery is expected to be ideal for the paramedian ventral skull base meningiomas. However, reviewing the previous reports about the endoscopic endonasal surgery, the surgical outcomes failed to support this

theoretical concept but only to confirm that we should be more careful to apply this potentially "minimally invasive" approaches.[12,13] The discrepancies between the theory and the reality are caused by the specific characteristics of meningiomas. Different from other tumors originated in ventral skull base lesions, such as pituitary adenomas, craniopharyngiomas, chordomas, and chondrosarcomas, the skull base meningiomas frequently involve the surround tissues and are adherent to the arachnoid, the pia matter, the cranial nerves, and the vessels. In endoscopic endonasal surgery, early devascularization of the tumor can be achieved in the most of the cases, whereas dissection from the ventral cerebral anatomies including the brain tissue, the important veins and arteries, which necessitates the most meticulous and careful surgical technique, becomes more difficult in the deepest part of the narrow surgical corridor. Thus, for the meningiomas in the anterior cranial bases, when the tumors are large or shaped lobar, they often break through the arachnoid membranes,[10,29] and it is very important to balance between the extent of resection and the anatomical preservation to avoid vascular injuries and the serious neurological complications. Considering the current situation in endoscopic endonasal surgery for meningiomas, further refinement of surgical technique may be the key to overcome the problems. The concept of "endoscopic microsurgery" will become more important to achieve the maximal surgical resection with preservation of the important anatomies.

Ideal indication of the endonasal endoscopic surgery for the anterior skull base meningiomas is the small round-shaped tumors presenting neurological symptoms (Fig. 1).[10,12,13,38] However, such small lesions are simultaneously very good candidates for transcranial surgery, and comparing the associated risks of complications between the transcranial approach and the endonasal approach, the reported risk of cerebrospinal fluid rhinorrhea associated with endonasal endoscopic surgery is hardly "less" than that of brain retraction or nerve injury associated with transcranial surgery. Also, in endonasal surgery, when the nasoseptal flap is used, postoperative nasal morbidity associated with large mucosal dissection, such as olfactory impairment, crusting, or discharge, is inevitable, which continues several months and persist even after mucosalization of the denuded mucosal surface. For the moment, despite such sacrifice, the rate of CSF leak requiring additional treatment is unacceptably high in the reports of endoscopic endonasal surgery, which may be the time to reconsider this reconstruction technique itself. Average risks of CSF leak associated with transcranial surgery are around 4–6% in patients with anterior cranial base meningiomas.[38] Thus, if the surgeon reasonably recommends the endonasal approach for their patients with those meningiomas, they have to be sure about mastering the closure techniques of dural defect, achieving a CSF leak rate less than 5%, and meticulous microsurgical procedure under endoscopic vision.[12,13,38] Also, the tumors should be small enough to remain outside the arachnoid membrane, otherwise, depending on the tumor consistency and adherence to the surrounding anatomy, surgery should be stopped at STR.

For the meningiomas in the other skull base lesions such as the cavernous sinus, the petroclival region, and the craniofacial region; the role of endoscopic endonasal surgery is still controversial. Only a few clinical studies included the experience of the radical resection, in which successful surgical removal largely depends on tumor consistency, and the extent of the surgical resection seems to proportionally increase the risks of serious complications.[26,29] When surgical removal remained only a decompression from the cranial nerves or the brain stem, it commonly led to improve presenting symptoms, which facilitated the adjuvant radiotherapy, achieving an excellent tumor control.[39–42] Thus, in these complex lesions, following the lessons from the multidisciplinary strategy of open transcranial surgery with radiosurgery in the last decade, judicious endoscopic resection or decompression with adjuvant radiotherapy or radiosurgery will be the most reasonable treatment options. On the other hand, in those areas, the internal carotid arteries are involved and in jeopardy, but it is very difficult to radiographically confirm tumor invasion to the arterial wall. Thus, techniques of intraoperative hemostasis and subsequent treatment strategy should be well established and discussed before surgery to avoid the uncommon but possibly fatal complications.[43]

As conclusions, endoscopic endonasal surgery can contribute to effective improvement of the symptoms caused by the meningiomas in the paramedian ventral skull base regions. To decrease the risks of surgical complications including postoperative CSF leaks, the surgeons engaging this surgery must master the closure techniques of dural defect and meticulous microsurgical procedure under endoscopic vision, on which further progress of this surgical approach largely depends.

## Conflicts of Interest Disclosure

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

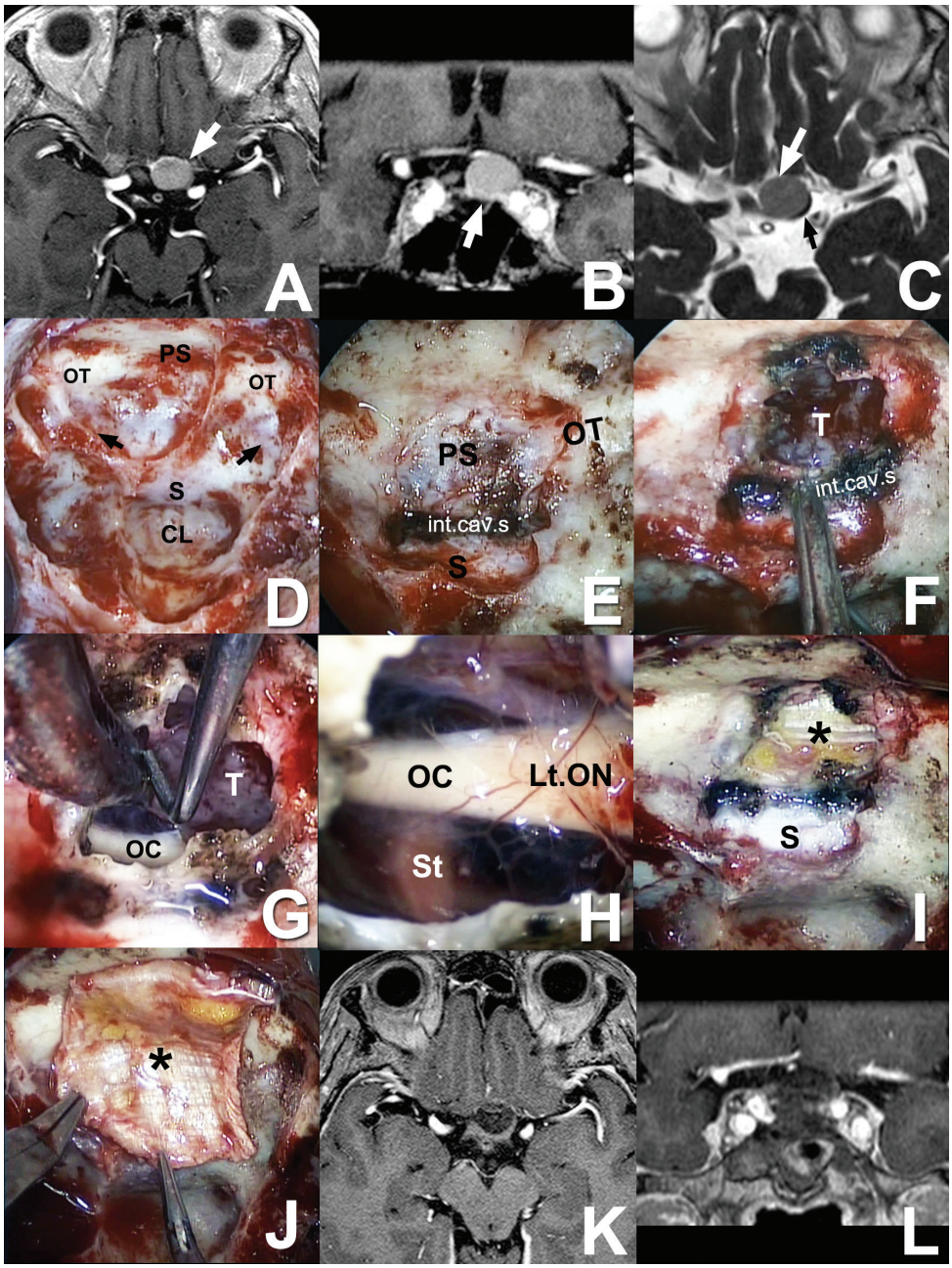


**Fig. 1 Ideal case of endoscopic transnasal surgery for tuberculum sellae meningioma in an 80-year-old woman with significant visual deterioration of the left eye. A–C: Magnetic resonance imaging (MRI, $T_1$-weighted image with gadolinium enhancement: A, axial section; B, coronal section, $T_2$-weighted image: C, axial section) showed an enhanced lesion on the tuberculum sellae (*white arrows* in A–C), compressing the left optic nerve (*black arrow* in C). D: After wide sphenoidotomy, the anatomical indexes were disclosed in the sphenoid sinus under the vision of 0 degree scope E: Skull base bone of the sella and the planum sphenoidale were removed, and the intercavernous sinus (int.cav.s) was coagulated with bipolar forceps. F: After coagulation of the dura matter, it was opened to reveal the devascularized tumor (T) on the tuberculum sellae. G, H: Under the vision of 30-degree scope, the tumor was carefully dissected and removed piece by piece along the arachnoid membrane in front of the optic chiasma (OC). After complete removal, the OC, the left optic nerve (Lt.ON), and the pituitary stalk (St) were clearly observed. I, J: Fascia lata (*) was harvested and was placed in and out of the dural defect. The balloon catheter was inserted in the sphenoid sinus and the outlaid fascia was compressed by the inflated balloon for several days. K, L: After the surgery, $T_1$-weighted MRI (A, axial section; B, coronal section) with gadolinium enhancement showed total removal of the tumor, and her visual symptom completely improved. CL: clivus, OT: optic canal, PS: planum sphenoidale, S: sella turcica, *black arrows*: carotid prominence.**

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