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## Original Article

# Outcomes of Endoscopic Endonasal Surgery for Tuberculum Sellae and Planum Sphenoidale Meningiomas: A Retrospective Study

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**ABSTRACT:** ***Background:*** To evaluate clinical outcomes and volumetric changes following endoscopic endonasal approach (EEA) for tuberculum sellae (TS) and planum sphenoidale (PS) meningiomas. Key objectives included evaluating pre- and postoperative tumor volumes, visual assessments and EEA-related complications. ***Methods:*** A single-center retrospective study was conducted at Foothills Medical Centre, University of Calgary, Canada, from 2009 to 2022 including 24 patients meeting inclusion criteria for midline skull base tumors, confirmed as WHO Grade I or II meningiomas with optic canal extension. ***Results:*** EEA achieved gross total resection in 87.5% of cases, with a mean tumor volume reduction of 92.24%. Postoperatively, 91.67% exhibited visual improvement or stability. Cerebrospinal fluid leaks occurred in 12.5% of cases, necessitating revision surgery in one case. Persistent postoperative endocrine dysfunction affected 4.17%. Preoperative tumor volume did not demonstrate a correlation with complications. ***Conclusions:*** This study delivers reproducible data for pre- and postoperative tumor volume following the EEA after TS or PS meningiomas. The EEA demonstrated favorable radiographic and clinical outcomes in TS and PS meningiomas, achieving gross total resection with minimal morbidity.

**RÉSUMÉ : Résultats cliniques de la chirurgie endoscopique endonasale pour les méningiomes du tubercule de la selle et du planum sphénoïdal : une étude rétrospective.** ***Contexte :*** Évaluer les résultats cliniques et les changements volumétriques après une chirurgie endoscopique endonasale (CEE) pour les méningiomes du tubercule de la selle (TS) et du planum sphénoïdal (PS). Les objectifs clés de cette étude comprenaient l'évaluation des volumes tumoraux pré et postopératoires, des évaluations visuelles de même que des complications liées à la CEE. ***Méthodes :*** Il s'agit d'une étude rétrospective monocentrique menée au *Foothills Medical Centre* de l'Université de Calgary (Canada) de 2009 à 2022. Cette étude incluait 24 patients répondant à des critères d'inclusion pour des tumeurs de la ligne médiane de la base du crâne. On a aussi confirmé que ces tumeurs étaient des méningiomes de grade I ou II selon l'OMS et qu'elles comportaient une extension du canal optique. ***Résultats :*** La CEE a permis une résection totale brute dans 87,5 % des cas ainsi qu'une réduction moyenne du volume tumoral de 92,24 %. En contexte postopératoire, 91,67 % des patients ont donné à voir une amélioration ou une stabilité de leurs capacités visuelles. Des fuites de liquide céphalorachidien (LCR) sont survenues dans 12,5 % des cas, ce qui a nécessité une reprise chirurgicale dans un cas. Un dysfonctionnement endocrinien postopératoire persistant a par ailleurs été observé dans 4,17 % des cas. Enfin, le volume tumoral préopératoire n'a pas montré de corrélation avec les complications subséquentes. ***Conclusions :*** Cette étude a fourni des données reproductibles sur le volume tumoral pré et postopératoire après une CEE pour des méningiomes du TS ou du PS. La CEE a aussi révélé des résultats radiographiques et cliniques favorables dans le cas des méningiomes du TS et du PS, permettant ainsi une résection totale brute avec une morbidité minimale.

**Keywords:** clinical outcomes; endoscopic endonasal approach; meningiomas; planum sphenoidale; skull base; tuberculum sellae; volumetric outcomes

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### Highlights

- High gross total resection rate for tuberculum sellae and planum sphenoidale – meningiomas using the endoscopic endonasal approach.
- In total, 91.67% of patients experienced improved or stable vision postoperatively, demonstrating significant visual outcomes.
- Minimal morbidity with only 12.5% cerebrospinal fluid leak rate, effectively managed with advanced reconstruction techniques.

## Introduction

Tuberculum sellae (TS) and planum sphenoidale (PS) meningiomas, constituting 10%–15% of all intracranial tumors, are challenging neurosurgeons due to their intricate anatomical location within the skull base.[1–3] Surgical decompression is the therapy of choice for symptomatic patients with the aim of addressing optic pathway decompression and preserving vital

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blood vessels.[4,5] According to Magill et al., an increased tumor size in meningiomas, irrespective of their location, is associated with atypical meningioma (WHO Grade II) and male sex.[6] TS and PS meningiomas are particularly notorious for inducing visual impairment often leading to a chiasmal syndrome in patients.[7–9] Surgical intervention for these meningiomas encompasses both transcranial approaches (TCA) and endoscopic endonasal approaches (EEAs). The latter, evolving from its initial use for pituitary adenomas, has progressively extended its purview to include TS and PS meningiomas over the last two decades.[10–15] The EEA offering access between the olfactory groove and the odontoid process, demonstrates potential superiority in visual outcomes and overall complication rates.[16,17] While EEA is associated with a higher incidence of cerebrospinal fluid (CSF) leaks compared to TCA, recent studies indicate a decreasing trend, with approximately 4% of EEA-treated patients experiencing CSF leaks. Consequently, EEA has emerged as an effective treatment option.[10,14,18–25] Gross total resection (GTR) of the TS or PS tumor is described in 56%–100% of EEA studies.[26] Better rates of resection, postoperative visual improvement and preservation of olfaction emerge as potential benefits of EEA for TS or PS meningiomas.[27] This study is dedicated to assessing clinical outcomes in TS and PS meningiomas after the EEA, with a specific emphasis on reproducible pre- and postoperative tumor volume measurements, visual assessments and EEA-related complications. The primary focus is on demonstrating the validity of EEA as an effective approach for skull base surgeons in TS and PS meningiomas, underscored by an exhaustive single-center analysis conducted at our institution.

## Methods

A single-center, retrospective analysis was performed at the Department of Neurosciences, Foothills Medical Centre, University of Calgary, Canada, over a 12-year period spanning from 2009 to 2022. Institutional review board approval was obtained for the study. Individual consent for the study was waived. The study cohort included 24 patients who underwent endoscopic endonasal surgery for TS or PS meningiomas. The authors define PS and TS meningiomas primarily based on their anatomical location. PS meningiomas originate from the PS at the anterior skull base, located in front of the sella turcica and behind the cribriform plate. TS meningiomas arise from the TS, situated at the junction of the anterior clinoid process and sella turcica, directly above the pituitary gland. When it is difficult to distinguish between both types, the impact on surrounding structures is considered: PS meningiomas affecting the frontal lobes and olfactory structures due to their more anterior position and TS meningiomas more often extending into the optic canal. The surgeries were consistently performed by the same surgeon, Y.P.S, with the collaboration of an ear-nose-throat (ENT) surgeon for the opening and closure procedures. All endoscopic approaches conducted during this period were performed exclusively by the author Y.P.S. Other TS and PS meningiomas were operated on at the neurosurgical department during this timeframe using TCAs. Each participating ENT surgeon utilized a surgical approach involving middle turbinectomy and the procedure included establishing a surgical corridor through the creation of a Hadad–Bassagasteguy flap with the removal of both the posterior bony septum and the anterior cartilaginous septum, shoulder osteotomy and removal of the vomer. All patients underwent preoperative and postoperative cranial magnetic resonance imaging (MRI) assessments, both with and without contrast enhancement.

### Inclusion criteria

The study's inclusion criteria encompassed endoscopic approaches for tumors situated on the midline with extension into the optic canal and vessel encasement. The indication for EEA was tumors that did not extend beyond the medial orbital walls, anterior to the posterior wall of the frontal sinus, or posterior to the posterior clinoid. The primary criterion for suitability for EEA was the ability to achieve a durable reconstruction. Specifically, our study encompassed cases of TS and PS meningiomas that underwent surgery during the mentioned period. These cases underwent a histopathological analysis at the time of surgery and were classified as Meningiomas World Health Organization (WHO) Grade I or II. Of note, due to the retrospective nature of the study, the 24 patients had been evaluated according to the latest WHO classification for tumors of the nervous system at the time of their surgery, including WHO classification versions of 2007, 2013, 2016 or 2022.

### Preoperative and postoperative data assessment

Preoperative and postoperative data of these patients were evaluated retrospectively, including demographics, clinical manifestations, image data, endocrine functions, ophthalmological assessments, operative records and clinical and surgical complications. The indication for surgery was based on visual impairment or interval growth on stated tumors observed on repetitive MRI scans. For ophthalmological assessments, visual acuity testing as well as peripheral field testing were conducted. The objective peripheral field testing was based on Humphrey 24–2 protocol, and Humphrey Field Analyzer II. As preoperative ophthalmological assessment, the last available testing before surgery was defined as preoperative data. The study assessed visual impairment in patients with TS and PS meningiomas using pre- and postoperative ophthalmological evaluations conducted separately for each eye. Criteria for visual field changes were based on Humphrey Visual Field Analyzer tests, defining improvement, worsening or stability based on changes in mean deviation (MD) values. Visual field changes were defined based on MD values from Humphrey Visual Field Analyzer tests: improvement was indicated by an increase in MD value of more than 1.0 dB, worsening by a decrease of more than 1.0 dB, and stability by changes within ± 1.0 dB. Visual acuity and field impairment were classified as unchanged, improved, worsened or completely recovered postoperatively. All visual acuity improvements (e.g., from 25/20 to 20/20) were considered as improvements. The postoperative ophthalmological assessment was carried out 1 year after surgery. The pre- and postoperative endocrinological management encompassed various critical elements, including continuous monitoring of urine output on an hourly basis. Additionally, biochemical and endocrine reviews for electrolytes, serum osmolality and pituitary hormone panel were conducted. All patients underwent endocrinological follow-up evaluations during the hospital admission, at 6–8 weeks, at 6 months and at 1 year after surgery to monitor for endocrinological changes. Persistent endocrine dysfunction was determined as persistent medical supplementation for pituitary dysfunction or diabetes insipidus at the 6-month endocrinological assessment. Hyposmia was assessed by patient history during the most recent clinic visit. We asked for a binary response to "Can you smell things like coffee?" and no scales or objective tests were used. The cranial MRI leading to indication to surgery was defined as

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preoperative MRI. Postoperative MRI was performed in 48 hours and 6–12 months postoperatively. We defined the postoperative volume as no tumor or capsule remnant on postoperative MRI examination and measured the postoperative volume in $cm^3$ in case of subtotal resection or in case of capsule remnant. Preoperative and postoperative volume assessments were carried out using Horos ® software. The volumetric analysis involved a cut-by-cut evaluation and volume computation of the pre- and postoperative tumor volume data. The EEA was tailored to excise the dural tail and the dural tail was included in the pre- and postoperative tumor volume measurements. Pre- and postoperative volume were computed by the first author (L.A.S). Postoperative complete resection was defined as 0.000 $cm^3$ of postoperative tumor volume and tumor volume under or equal to 0.500 $cm^3$ was described as GTR. Postoperative tumor reduction was calculated in percentage.

### Surgical procedure and postoperative care

Patients underwent general anesthesia with orotracheal intubation and were positioned supine with the head secured using a Mayfield head clamp. Cranial neuronavigation was used for interoperative navigation if needed. A free-fat graft from either the thigh or the belly was prepared. Aseptic techniques were employed during draping, and the nasal cavity was prepared with neuro patties soaked in adrenalin for a minimum of 5 minutes to reduce bleeding. Surgical procedures involved the use of 4-mm rigid endoscopes with 0° and 30° angled lenses through both nostrils. A surgical corridor was established through middle turbinectomy, the creation of a Hadad–Bassagasteguy flap with the removal of both the posterior bony septum and the anterior cartilaginous septum, shoulder osteotomy and removal of the vomer. The dura was opened in a curvilinear fashion, and the tumor was exposed at the TS or PS. After devascularization using bipolar cautery along the floor of the planum and tuberculum, the tumor was debulked with careful microdissection to avoid interruption of the arachnoid membrane and vascular structures as much as possible. Skull base defect reconstruction was achieved by using a free fat graft from the abdomen or the thigh and a nasoseptal flap, potentially with the addition of fibrin, to further prevent CSF leaks. In instances where a postoperative CSF leak was identified, a lumbar drain was placed for a duration of 5 days. If the CSF leak persisted despite lumbar drainage, it served as an indication for revision surgery after the initial 5-day period.

### Statistical analysis

The data were analyzed by SPSS 26.0. Descriptive statistics were used to present demographics. Presentation of descriptive or inferential statistics involved the use of tables or charts for selected measures. Continuous variables were presented as mean values with standard deviation and categorical variables were described as percentages (%). Numerical values were presented with the precision up to the second decimal place, and rounding was applied to the third decimal place, with values equal or greater than 5 being rounded up. Group comparisons were evaluated by Chi-square test in categorical valuables. The independent *t*-test was used comparing the percentage reductions in tumor volumes. Correlations were analyzed using the Pearson correlation coefficient. A Receiver Operating Characteristic (ROC) analysis was performed to evaluate the ability of tumor volume to predict the presence of complications (endocrine dysfunction, visual dysfunction, presence of a CSF leak or hyposmia).

The value of $p < 0.05$ was regarded as statistically significant difference.

## Results

### Demographic characteristics

In our study, 24 patients underwent EEA for TS and PS meningiomas between 2010 and 2022. The majority of patients were female (87.5%), with a mean age of 51.04 years. The age distribution in our cohort is evenly balanced across gender and tumor localization (PS or TS). Most cases (87.5%) were diagnosed as meningioma WHO Grade I, with a remaining of three cases (12.5%) that were classified as meningioma WHO Grade II. The primary indication for MRI studies was visual deterioration in 75% of cases, while 25% had incidental findings during initial imaging. The mean follow-up duration was 1906.08 days, and the average hospital stay postsurgery was 5.88 days. There were 14 TS meningiomas and 10 PS meningiomas included in the patient cohort.

Preoperative tumor volumes for PS and TS meningiomas averaged 4.724 $cm^3$, reducing significantly postoperatively to 0.215 $cm^3$, with a mean percentage reduction of 92.24%. The range of the preoperative tumor volumes was 12.593 $cm^3$, with the smallest tumor measuring 0.791 $cm^3$ and the largest 13.384 $cm^3$. GTR was achieved in 87.5% of cases. Mean percentage of tumor volume reduction in TS meningiomas was 94.06% and in PS meningiomas 89.88%. The range of the postoperative tumor volumes was 1.056 $cm^3$, with the smallest postoperative volume being 0.000 $cm^3$ and the largest postoperative volume being 1.056 $cm^3$. Of the 24 patients, two had recurrent meningiomas after their initial surgery in their follow-up.

There was no statistically significant difference in volume reduction between TS and PS meningiomas ($p = 0.451$). No correlation between WHO Grading and preoperative tumor volume is observed in this study. No correlation between gender and tumor volume was seen.

The observed correlation between patient age and preoperative tumor volume in our study cohort is 0.405, indicating a moderate positive correlation ($p = 0.055$).

### Ophthalmological assessment and visual outcome

The study assessed visual impairment in patients with TS and PS meningiomas using pre- and postoperative ophthalmological evaluations conducted separately for each eye. Visual outcomes varied, with all TS meningioma cases exhibiting preoperative visual impairment, while 30% of PS meningioma patients showed no impairment preoperatively. Unilateral preoperative symptomatology was present in 58.33% of cases, and both eyes were affected in 29.17% of patients. In total, 12.5% of all patients showed no visual impairment.

Postoperatively, 75% of patients experienced improved visual conditions in either visual acuity or their temporal field vision at the 1-year follow-up. 16.66% of the study cohort remained stable in regard to their preoperative assessment. The three patients classified as stable postoperatively either had one or two eyes that were initially unaffected and remained unaffected, or they had eyes that were initially affected and remained stable in their postoperative visual assessments. There were no cases of initially unaffected eyes worsening after the surgery. Notably, a small percentage of 8.33% (two patients) exhibited a deterioration in their visual fields after surgery. One patient had worsened right-sided temporal field impairment and one patient exhibited

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worsened bilateral temporal field impairment after surgery. Both patients who suffered from deteriorated visual fields after surgery had visual field impairment preoperatively. The patients with worsened visual fields had improved visual acuity but were overall classified as having worsened vision postoperatively. No decline in the visual acuity in overall patients was seen in the postoperative ophthalmological assessment. There was no transient postoperative decline in visual acuity or visual fields during the follow-up period.

Correlation analyses indicated no significant association between preoperative tumor volume and visual acuity or temporal field vision ($p = 0.272$). However, a significant correlation was found between preoperative visual impairment and postoperative visual impairment (worsened or stable) for tumors with a preoperative volume greater than 3 $cm^3$ ($p = 0.001$).

### *Postoperative complications*

Postoperative complications included CSF leaks in 12.5% of cases with only one patient (4.17%) requiring revision surgery. 8.33% were successfully treated with a lumbar drain. The was no statistically significant correlation between the tumor localization (TS or PS) and the occurrence of a CSF leak. The CSF leak rate was reduced with the more frequent use of the Hadad–Bassagasteguy flap, and the one revision surgery of the cohort occurred on the second EEA surgery performed at the department in 2010. Endocrine dysfunction affected 25% of the patients postoperatively. Only one patient (4.17%) had a persistent endocrine dysfunction (diabetes insipidus for this patient) with 20.84% of the cohort having transient endocrine dysfunction, which resolved during their hospital stay. The patients with transient endocrine dysfunction showed transient hyponatremia and low AM cortisol during their hospital stay. There was no correlation between endocrine dysfunction and tumor volume. Preoperative tumor volumes were not predictive of postoperative complications like endocrine dysfunction, visual impairment or CSF leak, as indicated by the low Area Under the Curve of 0.0435 in the ROC analysis. A single case of postoperative meningitis and a single case of olfactory dysfunction (4.17%) was documented. Notably, the study cohort had no vascular injuries, new neurological deficits, seizures or postoperative mortality.

## Discussion

Our investigation into the endoscopic endonasal approach for TS and PS meningiomas present valuable insights into the treatment paradigm for these challenging lesions.[10–12] The choice between lower (EEA) and higher (transcranial) surgical routes demands careful consideration of tumor characteristics, patient factors and adjacent structures involvement.[27–29] Our study advocates for EEA, emphasizing its viability as an alternative to transcranial approaches, especially in carefully selected patients.[11,28–34] GTR in PS and TS extra-axial tumors is achieved in 80–95% as reported in the literature.[11,32,33,35] Favorable outcomes were observed in terms of the extend of tumor resection, which is a crucial predictor for recurrence, with GTR achieved in 87.5% of cases.[6,36] We used reproducible criteria for assessing pre- and postoperative tumor volumes by cross-verifying our findings with the corresponding pre- and postoperative radiology reports. By moving away from the Simpson grading system, which has low validity for these tumor entities, a reproducible assessment of the intraoperative resection volume for both TS and PS meningiomas was achieved.[37,38] Additionally, a mean tumor size reduction of 92.24% after surgery was observed, further supporting the efficacy of EEA, which is comparable to transcranial approaches.[39] Current research and grading scales advocate for the use of EEAs in managing small (<3 $cm^3$) and midline anterior fossa meningiomas, a practice in line with our center's decision-making process.[40,41] Although the primary focus of EEA is on smaller-sized TS or PS meningiomas, our center has also achieved favorable outcomes for larger tumor volumes. Our analysis did not find any correlation between preoperative tumor volumes and postoperative complications. Larger initial tumor size could not be correlated with a meningioma being WHO Grade II or male gender in this cohort.[6] Visual impairment, a primary clinical manifestation in these meningiomas, was effectively addressed through EEA, with 87.5% of patients initially presenting with visual deficits.[7–9,42] Postoperatively, 91.67% either improved or maintained stable vision, demonstrating the procedure's efficacy in treating the primary symptom.[39,43–46] Of note, two cases witnessed a reduction in their previously affected temporal field vision. A decline in temporal field vision after surgery has been reported in similar case studies in the literature, underscoring the complexity and variability of outcomes in these cases.[12,31,47] The clinical significance of temporal field vision decline in patients is considered more critical than nasal field vision decline and should be factored in when evaluating these conditions. However, a weighting factor for temporal field decline was not included in this retrospective study or similar studies.[48] Importantly, there were no new occurrences of newly assessed temporal field defects or worsening of visual acuity after endoscopic, endonasal surgery in our study cohort. Complications, particularly CSF leaks – a common concern in EEA – were observed in 12.5% of our cases aligning with the average percentage reported in EEA-treated TS and PS meningioma populations.[18,19,21,22,31,47,49] Recent findings from a meta-analysis suggest a decreasing trend in postoperative CSF leaks, attributed to improved closure techniques, which is consistent with our results.[23,50,51] Our study emphasizes that the occurrence of a CSF leak as a possible complication should not deter the consideration of EEA. The low complication rates in our study affirm the proficiency of the surgical approach employed by ENT surgeons using the "3-F" technique and Hadad–Bassagasteguy flap significantly reducing postoperative CSF leaks. Postoperative complications beyond CSF leaks were infrequent, with only 4.17% experiencing persistent endocrine dysfunction. In the case under discussion, the patient exhibited persistent diabetes insipidus, no anterior gland hypopituitarism was seen in our patient cohort. EEAs have been associated with significant implications for olfaction in TS or PS meningiomas, particularly when extended procedures are undertaken.[45,52,53] Olfactory dysfunction emerges as postoperative complication in both EEA and TCA for PS and TS meningiomas. Published literature indicates diverse rates of postoperative hyposmia following EEA and TA, ranging anywhere from 10% to 65% of patients experiencing impaired olfaction.[11,54] In our study, we observed a minimal postoperative hyposmia rate of only 4.17%, highlighting the overall safety of EEA for olfaction in TS and PS meningiomas.[12] The study's strength lies in its single-center, single-surgeon design, ensuring surgical homogeneity and comprehensive patient outcomes understanding. The extended follow-up duration, no patient loss in follow-up and the novel inclusion of pre- and postoperative volumetric measurements contribute valuable insights. However, limitations, such as a relatively small cohort, the retrospective nature of the study and the absence of information regarding the duration of visual symptoms before surgery affect the generalizability of our findings. Another limitation of the recent study

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is the absence of a standardized visual assessment tool, such as the Unified Visual Function Scale (UVFS), which would facilitate easier comparison between treatment groups and allow for a more accurate evaluation of the clinical relevance of visual impairment or improvement.[55] Despite these limitations, this study provides substantial evidence supporting EEA as a safe and effective option for selected TS and PS meningiomas.

## Conclusions

In summary, this study seeks to advance our understanding of endoscopic endonasal surgery outcomes for TS and PS meningiomas. Through an examination of our patient cohort from a single center, we emphasize the effectiveness of minimally invasive endoscopic skull base techniques in yielding favorable clinical and resection outcomes. Our study demonstrates promising visual and endocrinological outcomes, coupled with a minimal incidence of CSF leaks and olfactory dysfunction, further supporting the safety of this approach. Importantly, there was no statistically significant correlation between preoperative tumor volumes and postoperative complications, highlighting the robustness of the endoscopic endonasal approach across varying tumor sizes. These findings contribute to the solidification of this approach for managing TS and PS meningiomas. However, the significance of these results warrants additional scrutiny through larger, multicenter studies for this tumor entity.

**Author contributions.** LAS: Literature search, drafting the article, conception and design, acquisition of data, analysis and interpretation of data.
YPS: Drafting the article, conception and design, acquisition of data.

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