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ORIGINAL ARTICLE

Factors influencing postoperative visual improvement in 208 patients with tuberculum sellae meningiomas

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Abstract

Objective Tuberculum sellae meningiomas (TSMs) usually compress the optic nerve and optic chiasma, thus affecting vision. Surgery is an effective means to remove tumors and improve visual outcomes. On a larger scale, this study attempted to further explore and confirm the factors related to postoperative visual outcomes to guide the treatment of TSMs.

Methods Data were obtained from 208 patients with TSMs who underwent surgery at our institution between January 2010 and August 2022. Demographics, ophthalmologic examination results, imaging data, extent of resection, radiotherapy status, and surgical approaches were included in the analysis. Univariate and multivariate logistic regressions were used to assess the factors that could lead to favorable visual outcomes.

Results The median follow-up duration was 63 months, and gross total resection (GTR) was achieved in 174 (83.7%) patients. According to our multivariate logistic regression analysis, age < 60 years (odds ratio [OR] = 0.310; $P = 0.007$), duration of preoperative visual symptoms (DPVS) < 10 months (OR = 0.495; $P = 0.039$), tumor size ≤ 27 mm (OR = 0.337; $P = 0.002$), GTR (OR = 3.834; $P = 0.006$), and a tumor vertical-to-horizontal dimensional ratio < 1 (OR = 2.593; $P = 0.006$) were found to be significant independent predictors of favorable visual outcomes.

Conclusion Age, DPVS, tumor size, GTR, and the tumor vertical-to-horizontal dimensional ratio were found to be powerful predictors of favorable visual outcomes. This study may help guide decisions regarding the treatment of TSMs.

Keywords Tuberculum sellae meningiomas · Visual outcomes · Transcranial approaches · Complications · Extent of resection

Introduction

Meningiomas originate from arachnoid epithelial cells and are the most common primary tumors of the central nervous system, accounting for approximately 37% of intracranial tumors [8, 23, 31, 34]. These tumors are highly prevalent in females, and characteristically exhibit slow progression, with most presenting as benign and only a rare subset manifesting malignant behavior. Tuberculum sellae meningiomas (TSMs), which originate from the sphenoid ridge, chiasmatic groove, and tuberculum sellae near the midline of the suprasellar and inferior optic chiasma, account for approximately 5–10% of intracranial meningiomas and are most common in females [6, 21, 39]. Compression of the optic chiasm may cause superior and lateral displacement, and some tumors may also invade the optic canal [6, 39], thus causing visual impairment, which is the most prominent symptom.

The neural and vascular anatomy are complex and thus complicate the management of this disease. Surgical intervention remains the primary treatment modality for TSMs, aiming to alleviate pressure, enhance visual acuity, and prevent further deterioration of vision. Previous studies with small sample sizes had investigated several factors related to postoperative vision and other aspects, but there is still some controversy. The aim of the present study is to further

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explore and confirm the factors related to postoperative visual acuity, on a larger scale, to guide the treatment of TSMs.

Materials and methods

Data collection

This retrospective cohort study included the clinical data of 208 patients who underwent surgical procedures at our institution between January 1, 2010 and August 31, 2022 (Fig. 1). The inclusion criteria were as follows: (1) patients age > 18 years; (2) patients with midline meningiomas originating from the sellar tubercle and diaphragmatic regions; (3) patients who underwent surgery via transcranial approaches (TCAs) under microscopic visualization; (4) patients presenting with preoperative visual impairment; and (5) patients with complete preoperative and 1-year postoperative magnetic resonance imaging (MRI) data. The exclusion criteria included the following: (1) patients with anterior clinoid process meningiomas or sphenoid ridge meningiomas; (2) patients who underwent surgery via the endoscopic endonasal approach (EEA); (3) patients with severe ophthalmic diseases (such as glaucoma); (4) patients with other pituitary diseases (such as pituitary adenomas); (5) patients with recurrent tuberculum sellae meningiomas; and (6) patients with incomplete research data or who refused to join the study. The study was approved by the Ethics Committee of Zhengzhou University, and informed consent was obtained from all patients.

Ophthalmologic evaluations

All patients in our study underwent comprehensive preoperative and postoperative visual acuity (VA) and visual field (VF) examinations conducted by ophthalmologists. VA assessments were performed using an international standard visual acuity chart, with corrected visual acuity serving as the reference. The VF test was performed using Humphrey static automatic perimetry (Carl Zeiss Meditec, Jena, Germany) or Goldman kinetic perimetry [15]. In this study, improvement in visual outcome was defined as a 0.2 or higher increase in VA or a 25% or greater increase in VF at one year post surgery; vision outcomes were considered stable if there was a decrease or increase in VA < 0.2 or a decrease or increase in VF $< 25\%$ at one year post surgery; deterioration in visual outcomes was characterized by a decrease in VA ≥ 0.2 or a VF change $\geq 25\%$ [15]. Postoperative visual outcomes were categorized into improved and nonimproved groups, with the nonimproved group including both stable and deteriorated visual results. In cases of bilateral impairment, the eye with the most severe impairment was included in the analysis [15].

In this study, the duration of preoperative visual symptoms (DPVS) was categorized as median duration (short-term (< 10 months) or long-term (≥ 10 months), and a preoperative VA ≤ 0.5 was defined as poor VA [15].

Imaging assessment

A tumor with a maximum diameter ≤ 27 mm was defined as "small," and a tumor with a maximum diameter > 27 mm was defined as "large." The median diameter was set as the cutoff. Peritumoral edema (degree 0 of Trittmacher criteria) [32], signal intensity (T2-weighted MRI) [13, 15], and integrity of the brain-tumor interface (arachnoid completeness around the tumor) were assessed using preoperative MRI.

The maximum diameter of the tumor was defined as the maximum diameter of the three spatial sequences on enhanced MRI. The integrity of the brain-tumor interface

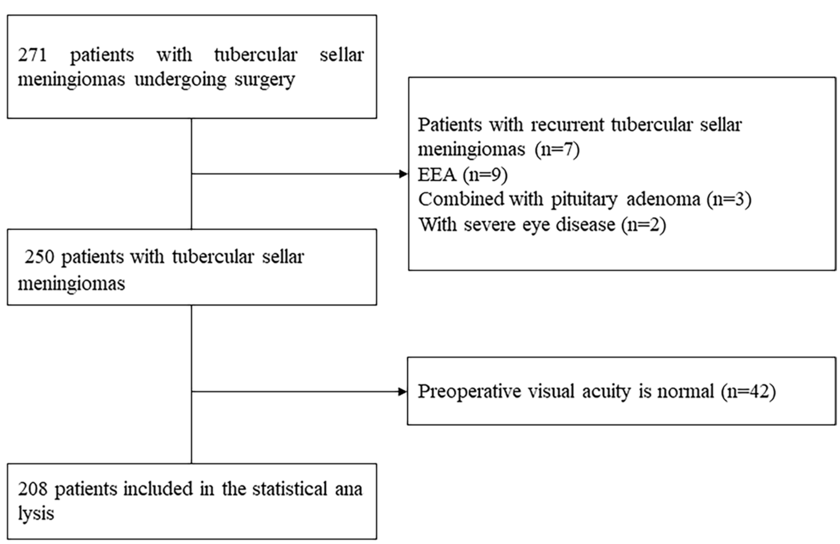

Fig. 1 Patient selection in this study

was judged by observing whether there was a circular cerebrospinal fluid signal (CSF cleft sign) between the tumor and brain tissue on T2-weighted MRI [10]. TSMs involving the optic canal were identified based on preoperative MRI and intraoperative exploration (Supplementary Fig. 1) [5]. The vertical-to-horizontal ratio of the tumor was defined as the maximum vertical diameter divided by the maximum horizontal diameter[26].

Perioperative period and follow-up

The TCAs most commonly performed at our institution include pterional, lateral supraorbital, and subfrontal approaches. The choice of surgical approach was determined by a combination of factors, including the basic condition of the patients and the growth characteristics of the tumor. The Simpson grading system was used to evaluate the extent of resection, classifying grades I–III as gross total resection (GTR) and grade IV as subtotal resection (STR)[4, 26]. Additionally, postoperative WHO grade and complication data were collected. Follow-up information, such as visual outcomes and tumor progression, was obtained through the review of MRI data and telephone interviews. Tumor recurrence was defined as the appearance of a new lesion or significant growth in the size of a residual tumor (exceeding 25%) on MRI scan [31, 34, 35].

Statistical analysis

IBM SPSS Statistics 26 and R 4.1.0 software were utilized for the statistical analyses. Univariate and multivariate logistic regression analyses were conducted to assess the associations between predictive factors and visual outcomes. The confidence interval (CI) of each variable was 95%, and a two-tailed P value < 0.05 was considered to indicate a statistically significant difference.

Results

Demographic characteristics and follow-up

The clinical data of 208 patients (Fig. 1), with an average age of 50.5 years (range 19–78 years) were included in this study. There were 175 females and 33 males (F:M = 5.3:1). There were 98 patients (47.1%) who presented with symptoms of headache and dizziness, while 15 patients (7.2%) experienced nausea and vomiting. All patients had varying degrees of visual impairment preoperatively, with 42 patients (20.2%) having a preoperative VA > 0.5. A total of 161 patients (77.4%) exhibited preoperative visual field defects, including 107 patients (51.4%) with symmetrical loss of the binocular visual field, encompassing both bitemporal deficits and complete binocular visual field loss.

One hundred patients (48.1%) had tumors with maximum diameters > 27 mm, and 130 patients (62.5%) had tumor vertical-to-horizontal dimensional ratios < 1. Peritumoral edema was observed in 24 patients (11.5%), and a complete brain-tumor interface was present in 167 patients (80.3%). GTR was achieved in 174 patients (83.7%), and STR was achieved in 34 patients (16.3%). Postoperative pathology indicated that 197 cases (94.7%) were WHO grade I and 11 cases (5.3%) were WHO grade II.

The median follow-up duration was 63 months (12–152 months). The 1-year postoperative follow-up assessment showed that visual outcomes improved in 104 patients (50%) and did not improve in 104 patients (50%). Additionally, 10 patients (4.8%) experienced tumor recurrence. The patient characteristics are listed in Table 1. The correlation between any two characteristics was low (Supplementary Fig. 2).

Predictors of visual outcomes

Univariate logistic regression analysis (Table 2) revealed that age < 60 years, preoperative VA > 0.5, duration of DPVS < 10 months, tumor size ≤ 27 mm, tumor-to-horizontal dimensional ratio < 1, complete brain-tumor interface, absence of peritumoral edema, and GTR were associated with favorable visual outcomes ($P < 0.05$). In contrast, other features did not significantly differ between the improved and nonimproved groups.

Multivariate logistic regression analysis of the aforementioned eight factors (Table 2) revealed that age < 60 years (odds ratio [OR] = 0.316; 95% CI [0.133;0.725]; $P = 0.007$), DPVS < 10 months (OR = 0.495; 95% CI [0.254;0.966]; $P = 0.039$), tumor size ≤ 27 mm ([OR] = 0.337; 95% CI [0.169;0.672]; $P = 0.002$), GTR (OR = 3.834; 95% CI [1.467;10.018]; $P = 0.006$), and tumor vertical-to-horizontal dimensional ratio < 1 ([OR] = 2.593; 95% CI [1.313;5.120]; $P = 0.006$) were associated with favorable visual outcomes.

Discussion

Since Cushing et al. performed the first surgery for a TSM in 1918, previous studies have reported visual improvement rates ranging from 27 to 91% [2, 12, 13, 15, 18, 19, 22, 24–27]. Our study of the clinical data of 208 patients with visual impairment due to TSMs showed a postoperative visual improvement rate of 50%. A series of surgical treatments for TSMs reported in the literature are displayed in Table 3. This study is the largest analysis thus far, with a median follow-up time of 63 months and reporting the long-term outcomes of these patients.

Table 1 Demographic and clinical characteristics

Characteristic	*n* (%)
Patients	208 (100)
Sex	
Male	33 (15.9)
Female	175 (84.1)
Age	
< 60 years	165 (79.3)
≥ 60 years	43 (20.7)
Associated symptoms	
Headache and dizziness	98 (47.1)
Nausea and vomiting	15 (7.2)
Others	46 (22.1)
Visual acuity	
≤ 0.5	166 (79.8)
> 0.5	42 (20.2)
Duration of preoperative visual symptoms (month)	
< 10	102 (49.0)
≥ 10	106 (51.0)
Visual field defect	
Normal	47 (22.6)
Asymmetrical	54 (26.0)
Symmetrical	107 (51.4)
Tumor size (mm)	
≤ 27	108 (51.9)
> 27	100 (48.1)
Vertical-to-horizontal dimensional ratio	
< 1	130 (62.5)
≥ 1	78 (37.5)
Signal intensity on T2-weighted images	
High	122 (58.7)
Low or equal	86 (41.3)
Peritumoral edema	
Present	24 (11.5)
Absent	184 (88.5)
Brain-tumor interface	
Complete	167 (80.3)
Incomplete	41 (19.7)
Excision grade (Simpson)	
I	22 (10.6)
II	73 (35.1)
III	79 (38.0)
IV	34 (16.3)
Follow-up time (month)	
Median	63
IQR	36.25–94.75
Range	12–152
Recurrence	
Yes	10 (4.8)
No	198 (95.2)
Postoperative radiotherapy	
Yes	9 (4.3)
No	199 (95.7)
Optic canal	
Free	176 (84.6)
Involved	32 (15.4)
Surgical approaches	
Pterional approach	27 (13.0)
Subfrontal approach	132 (63.4)
Lateral supraorbital approach	49 (23.6)
Visual Outcome	
Improved	104 (50)
Stable	86 (41.3)
Deteriorated	18 (8.7)

Influencing factors of postoperative visual outcomes

According to our findings, age is a prognostic factor for postoperative visual outcomes. The same conclusion has been reached in several reported studies, suggesting that patients aged younger than 60 years have a better chance of visual recovery [12, 18, 26]. We believe that, compared to younger patients, older patients are prone to surgical trauma due to less resilient optic nerves and surrounding vasculature. Although the primary goal of surgery is to improve or maintain existing vision, unavoidable mechanical and ischemic factors may cause vision to deteriorate postoperatively [26]. Additionally, older patients often have ocular and systemic comorbidities, which collectively lead to a decreased tolerance for invasive surgeries.

DPVS is another strong predictor of postoperative visual acuity. Palani [25] and Leclerc [15] reported significant improvement in postoperative vision when visual symptoms persisted for no longer than 6 months ($p < 0.05$). Another study also revealed a correlation between DPVS and postoperative visual outcomes [26]. This correlation could be explained by prolonged compression of the optic nerve, which causes demyelination of nerves beyond the capacity for self-repair. Therefore, our study suggested that early medical attention and timely surgery upon the onset of visual symptoms could salvage vision. Surgery should be considered promptly after MRI confirms the presence of a TSM, following an individualized assessment of the patient's condition by a surgeon.

Tumor size is also a topic worth discussing. Consistent with our findings, some authors believe that patients with smaller tumors are more likely to have better visual outcomes than those with larger tumors [15, 18, 26]. Using the median size of 27 mm as a threshold for comparison, we found significant differences in visual outcomes between

Table 2 Univariate analysis and multivariate analysis of the postoperative visual outcomes of patients with tuberculum sellae meningiomas

Variable	Visual Outcome					
	Univariate analysis			Multivariate analysis		
	OR	95% CI	*p*	OR	95% CI	*p*
Sex (female vs. male)	0.600	0.281–1.281	0.187			
Age, years (< 60 vs. ≥ 60)	0.307	0.147–0.640	0.002*	0.310	0.133–0.725	0.007*
VA (≤ 0.5 vs. > 0.5)	2.081	1.032–4.194	0.041*	1.336	0.596–2.994	0.482
VF (normal vs. abnormal)	1.847	0.950–3.591	0.070			
Duration of preoperative visual symptoms, month (< 10 vs. ≥ 10)	0.331	0.188–0.583	< 0.001*	0.495	0.254–0.966	0.039*
Tumor size, mm (≤ 27 vs. > 27)	0.215	0.120–0.387	< 0.001*	0.337	0.169–0.672	0.002*
Preoperative hypopituitarism (Yes vs. No)	0.580	0.278–1.208	0.145			
Extent of resection (GTR vs. STR)	4.000	1.715–9.329	0.001*	3.834	1.467–10.018	0.006*
Signal intensity (High vs. Low or equal)	1.374	0.790–2.391	0.261			
Peritumoral edema (Present vs. Absent)	0.369	0.146–0.933	0.035*	0.511	0.176–1.479	0.216
Brain-tumor interface (complete vs. incomplete)	2.964	1.416–6.205	0.004*	2.038	0.868–4.785	0.102
Vertical-to-horizontal dimensional ratio (< 1 vs. ≥ 1)	1.784	1.011–3.151	0.046*	2.593	1.313–5.120	0.006*
WHO grade (I vs. II)	1.212	0.358–4.103	0.757			
Postoperative radiotherapy (Yes vs. No)	1.263	0.329–4.841	0.734			
Optic canal (Free vs. Involved)	1.346	0.630–2.872	0.443			
Surgical approaches						
Pterional approach	1.089	0.485–2.446	0.837			
Subfrontal approach	0.606	0.343–1.072	0.085			
Lateral supraorbital approach	1.814	0.943–3.487	0.074			

*Statistical significance. OR, odds ratio; CI, confidence interval; p, p value; VA, visual acuity; VF, visual field; GTR, gross total resection; STR, subtotal resection

patients with tumors larger than 27 mm and those with tumors smaller than 27 mm ($p = 0.003$). This finding suggested that in the confined space of the sellar region, larger tumors are more likely to exert pressure on the surrounding optic nerves and chiasm and are associated with more severe mechanical damage. Moreover, our study showed that patients with tumors showing a predominantly nonvertical growth pattern (vertical-to-horizontal dimensional ratio < 1) had better visual outcomes. Another study reported similar findings, suggesting that the direction of tumor growth in the three-dimensional space holds more clinical significance than simply comparing tumor sizes [26]. In our study, the rate of visual improvement was lower in patients with tumors primarily growing vertically than in patients with tumors growing horizontally ($p = 0.007$).

In our study, GTR was found to be beneficial for postoperative visual recovery ($p = 0.008$). According to previous literature, the total resection rates are 73.2–92.5% [6, 8, 12–18, 29]. GTR should not be pursued if the risk of surgical complications will be increased. Other studies have reported a significant difference in postoperative visual outcomes between patients with GTR and patients with STR [15, 26]. However, this approach is controversial because the tumor might be closely located to the optic nerve and internal carotid artery (ICA), which can lead to unavoidable vascular damage during surgery. GTR is associated with greater surgical risks for patients and requires extensive surgical expertise.

TSMs tend to involve the adjacent optic canal. Previous studies and the present study suggested that tumor involving the optic canal was not related to visual outcomes[15, 16]. However, optic canal decompression is a controversial factor. Several studies suggested that optic canal decompression was not related to visual outcomes [15, 16]. While Chen et al. and Arai et al. showed that intraoperative optic canal opening is the key to improving postoperative visual outcomes [1, 5]. In this study, thirty-two patients had tumors involving the optic canal. In the cohort of patients who received and did not receive optic canal decompression, 50% (5/10) and 45.45% (10/22) of the patients improved their visual acuity after surgery, respectively. In our experience, decompression of the optic canal may lead to cerebrospinal fluid leakage, and the mechanical heat injury during the operation may also cause secondary damage to the optic nerve. In addition, the latest research indicated that optic nerve-canal bending angle (ONCBA) was associated with best-corrected visual acuity (BCVA) and visual field impairment [37, 38]. We believe that relevant imaging studies can

Table 3 Literature review of surgical treatment for tuberculum sellae meningioma

Investigator	Patients (n)	GTR (%)	Preoperative visual impairment (%)	Visual Improvement (%)	Predictors of postoperative visual outcome improvement	Recurrence (%)	Death (%)
Pamir et al.[26], 2005	42	83.3	81	59.5	Age < 60 years, DPVS < 1 year, vertical to horizontal dimensional ratio < 1, visual impairment score > 20, absence of peritumoral edema, clear brain-tumor interface, GTR	2.4	NR
Mathiesen et al.[12], 2006	29	89.7	82.8	91.7	Early optic nerve decompression by extradural clinoidectomy and optic canal unroofing, age < 60 years	NR	0
OTANI et al.[24], 2006	32	87.5	100	78.1	SEAC	0	0
Bassiouni et al.[2], 2006	62	90.3	87.1	53.2	The severity of preoperative deficits, a thin atrophic optic nerve, encasement of the nerve, or tumor adhesion to its undersurface predict an unfavorable visual outcome	4.8	NR
Park et al.[27], 2006	30	76.7	100	66.7	Favorable short-term visual outcome	13.3	0
Nozaki et al.[22], 2008	22	72.7	86.4	52.6	Early optic canal unroofing	0	0
Kim et al.[13], 2008	27	74.1	100	44.4	High signal on T2-weighted images	7.4	0
Palani et al.[25], 2012	41	73.2	100	27	DPVS ≤ 6 months, absence of peritumoral edema, absence of arterial encasement, a clear brain-tumor interface, GTR, favorable short-term visual outcome	NR	4.9
Margalit et al.[18], 2013	51	88.2	82	40.8	Visual functions on admission, better KPS on admission, smaller tumor size, and young age	NR	2
Mortazavi et al.[19], 2016	27	92.5	77.8	90.5	NR	0	0
Leclerc et al.[15], 2021	50	88	100	60	DPVS < 6 months, preoperative VA > 0.5, the absence of optic atrophy, a smaller tumor size, high signal intensity on T2-weighted images, the absence of bone hyperostosis, a soft tumor, a clear brain-tumor interface, RNFL thickness > 80 µm, GCC thickness > 70 µm	10	NR
Present study, 2023	208	83.7	100	50	Age < 60 years, DPVS < 10 months, tumor size ≤ 27 mm, GTR, vertical-to-horizontal dimensional ratio < 1	4.8	1

GTR: gross total resection; DPVS: duration of preoperative visual symptoms; NR: not reported; SEAC: selective extradural anterior clinoidectomy; VA: visual acuity.

help explain the causes of preoperative visual impairment in TSMs and improve the effectiveness of surgical treatment.

Surgical techniques and complications

The aim of surgical treatment for TSMs is to remove the tumor and decompress the optic nerve as much as possible [9, 17, 33]. Despite its invasiveness, the transcranial approach (TCA) is the most frequently chosen method [11, 19, 39]. The surgical complications observed in our cohort are summarized in Table 4. The TCAs mainly performed at our center were pterional, lateral supraorbital, and unilateral or bilateral subfrontal approaches. This study showed that the choice of surgical approach was not associated with favorable visual outcomes. We believe that the choice of surgical approach should be based on the specific clinical and imaging characteristics of the patient as well as the surgeon's proficiency in performing a particular approach.

The subfrontal access is associated with a larger surgical field and allows direct exposure of the surrounding optic nerves, adjacent ICA, and anterior cerebral artery. However, this approach probably requires the frontal sinus to be opened, which increases the risk of cerebrospinal fluid (CSF) leakage [7]. Effective repair of frontal sinus openings using autologous fat grafts can reduce the incidence of CSF leakage and does not necessarily result in serious complications [36]. Nakamura mentioned that olfactory impairment is common with the subfrontal approach, particularly with those performed bilaterally [21]. However, other approaches are prone to this unavoidable issue. One study reported that of 34 patients who underwent surgery via the subfrontal approach, 20 patients underwent unilateral olfactory sacrifice, and none experienced CSF leakage [7]. In our study, 15.2% (20/132) of patients who underwent surgery via the subfrontal approach experienced postoperative olfactory disturbances, with only 2 patients developing CSF leakage postoperatively.

Table 4 Complications of surgery for TSMs

Complication	*n* (%)
Hypopituitarism	51 (24.5)
Thyroidal	46 (22.1)
Adrenal	25 (12)
Gonadotropic	2 (1)
Hyperprolactinemia	8 (3.8)
Transient or permanent diabetes insipidus (DI)	48 (23.1)
Seizures	5 (2.4)
Cerebrospinal fluid (CSF) leakage	3 (1.4)
Language or motor dysfunction	5 (2.4)
Meningitis	17 (8.2)
Dysfunction of eye movement	6 (2.9)
Hyposmia	34 (16.3)

The pterional approach, as a standard cranial base approach, is also suitable for treating TSMs. This approach can achieve complete tumor resection and is associated with relatively low rates of olfactory nerve damage and CSF leakage. Lateral tumors are easiest to reach via the pterional approach [21, 36]. However, a blind spot is located medially to the ipsilateral optic nerve, where tumor remnants can easily be left behind [33, 36]. Another study noted that for tumors invading the optic canal, contralateral approaches were associated with a 94% rate of complete tumor removal, which was significantly greater than the 75% rate for ipsilateral approaches ($p = 0.04$) [33].

The lateral supraorbital approach is an improvement of the pterional approach and has its own advantages. Postoperatively, compared to the pterional approach, the lateral supraorbital approach is associated with a shorter surgery time, smaller bone flap, and more aesthetically pleasing results and is less likely to cause temporal muscle atrophy, facial nerve damage, and impairment of masticatory function [28, 29]. Although the pterional approach is associated with a larger and better view of the surgical field, the tumor size, origin, and extent must be given priority in determining the extent of tumor resection, not the degree of tumor exposure during surgery [28].

Previous experience suggested that EEA had a higher risk of CSF leakage and dysosmia [9]. In a large multicenter cohort of 947 patients, cerebrospinal fluid leakage was 17.5% in EEA and 2.2% in TCA [17]. With the improvement of skull base reconstruction technology, CSF leakage via EEA had been greatly reduced [3, 9, 20]. A meta-analysis showed that postoperative visual improvement of patients via EEA (85.7%) was better than TCA (55.1%) [39]. In general, EEA is more suitable for tumors with small size (< 30 mm), limited lateral extension and involvement of the optic canal [39]. Compared with TCA, EEA has the advantage of transforming deep skull-base tumors into superficial convex tumors, and can also resect the invaded bone and dura to achieve Simpson grade-I resection [14, 30, 40]. Moreover, EEA provides a bottom-up view of the neurovascular structure of the suprasellar and infrachiasmatic areas. This contributes to deal early with the blood supply of the tumor base, and reduce the risk of intraoperative hemorrhage [40]. TCA is the common procedure, can be used in almost all hospitals and applied to almost all TSMs. On the contrary, application of EEA has certain limitations. Of course, TCA has advantage especially for the larger tumor and the tumor with lateral extension [9, 17].

Study limitations

Our study has several limitations. First, this was a single-center retrospective study, which inevitably led to missing data. Second, although we analyzed many factors, we did not provide corresponding descriptions of the factors related to the ophthalmic data and preoperative MRI features, such as the conditions of the retinal nerve fiber layer, ganglion cell complex and optic nerve-canal bending angle (ONCBA) [6]. Additionally, the visual outcomes of one year after operation were analyzed in this study. With the extension of time, the visual outcomes may be further improved.

Conclusion

In summary, this study is based on the clinical data from 208 patients with TSMs. We found that age < 60 years, DPVS < 10 months, tumor size ≤ 27 mm, GTR, and the vertical-to-horizontal dimensional ratio < 1 were factors associated with favorable visual outcomes. This study may be helpful for the treatment of TSMs.

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Author contribution Chengcheng Duan conducted statistical analysis and manuscript writing. Youjun Wang, Mingkun Wei, Junhao Fang, Tingting Zhai and Yuan An sifted and collected the data. Yan Hu, Guihong Li and Zhiyun Yu evaluated the data and results. Chengcheng Duan and Dengpan Song conceptualized the manuscript outline. Fang Wang, Yuchao Zuo and Fuyou Guo revised the manuscript. All authors read and approved the final manuscript.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

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

Conflict of interest The authors declare no competing interests.

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Comments The authors tried to investigate the possible factors for postoperative visual outcome in 208 patients with tuberculum sellae meningiomas (TSMs). They assessed their obtained data such as visual function, tumor images and treatments for visual outcomes by using the multivariate logistic regression analysis. From the huge population, it was found that the age, duration of preoperative visual symptom, tumor size, gross total removal, and tumor vertical-to-horizontal dimensional ratio were powerful positive predictors for good visual outcomes in the patients with TSMs. This study has some limitations (single-center, retrospective, without detailed ophthalmic and MRI data, etc.) and the further evaluation with MRI findings, surgical approaches including endonasal endoscopic approach and long-term follow-up is needed. However, those predictive factors from the current study with large number of patients must be valuable to decide the surgical indication for the patients with TSMs.

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