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Clinical Article

Outcome determinants of pterional surgery for tuberculum sellae meningiomas

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Summary

Background. Current literature on tuberculum sellae meningiomas is very heterogenous due to wide variation in nomenclature, diagnostic and operative techniques. The aim of this study is specifically to analyze the results of pterional craniotomy for tuberculum sellae meningiomas. A homogenous cohort of 42 consecutively operated tuberculum sellae meningioma cases are reviewed with special emphasis on the effects of pterional microsurgery on visual outcome.

Methods. This is a retrospective clinical analysis. 42 consecutive patients operated upon during the period of 15 years in a single institution using standard imaging protocols and pterional microsurgery are presented and effect of various variables on visual outcome analysed.

Findings. 81% of the patients presented with visual symptoms. The mean duration of symptoms was 12 months. Tumour volumes ranged from 7.5 to 210 mm^3. A right sided pterional microsurgery was used in all patients. Complete resection rate was 81%. Vision improved in 58%, worsened in 14%. Non-visual morbidity was 7.1% and mortality was 2.4%. The follow up period of patients ranged from 3 to 192 months (median: 30 months). The mean was 37.5 months (SD = $\pm$36.7 months) and a recurrence rate of 2.4% was observed.

Conclusions. A standard pterional craniotomy using microsurgical technique provides the necessary exposure enabling total removal while keeping the complications to a minimum. Upon analysis of our findings we found that patient age of more than 60, duration of visual symptoms longer than 1 year, severe visual symptomatology, predominantly vertical growth, presence of significant peri-tumoural oedema, absence of an intact arachnoid plane and subtotal removal were correlated with a dismal visual outcome.

Keywords: Meningioma; tuberculum sellae; pterional craniotomy; visual impairment.

Introduction

A large body of literature accompanies a great deal of confusion regarding the optimal treatment of tuberculum sellae meningiomas. Traditional nomenclature like ''suprasellar meningiomas'' or inclusion of other meningiomas with distinct outcomes like clinoidal meningiomas has complicated the interpretation of results in several surgical series. Further increasing the heterogeneity, several commonly cited publications analyzed operations in a long timeframe, where there had been a switch from macroscopic to microscopic surgery and from x-ray based diagnosis to wide utilization of MRI. A novel trend towards deliberate use of skull base approaches and inclusion of those cases to cohorts operated on conventionally made the interpretation even more difficult. All these factors make comparison among studies difficult and preclude objective selection of the best surgical approach.

This study aims specifically at analyzing the results of pterional microsurgery in treating tuberculum sellae meningiomas and reports our institutions 17 year experience. Forty-two consecutively operated on cases were reviewed to define the visual outcome for pterional surgery in this subset of meningiomas. Several clinical variables, which have been proposed as determinants of visual outcome in the literature are analyzed to define their effect in pterional microsurgery.

Patients and methods

This is a retrospective analysis. The term ''Tuberculum Sellae Meningioma'' was defined as meningiomas having their point of origin at the tuberculum sellae or the most distal sphenoid planum. Clinoidal and diaphragma sellae meningiomas were strictly excluded. In giant sized meningiomas centre of tumour base was regarded as the origin. During analysis all variables suggested by

prior reports to have an effect on visual outcome were discussed to define their impact in a cohort of tuberculum sellae meningiomas with strict treatment guidelines. These guidelines included pre-operative and immediate post-operative contrast enhanced MRI studies, pre- and post-operative formal visual testing and use of pterional micro-surgery with an aim of total microsurgical resection. The variables considered were age, gender, duration of symptoms, severity of visual impairment, laterality of eye involvement, tumour volume, vertical to horizontal dimensional ratio, peri-tumoural oedema, brain tumour interface and the extent of removal.

To facilitate an objective and systematic analysis we have used the visual symptom scoring scheme, which was first proposed by Rosenstein and Symon [25] and subsequently refined by Fahlbusch and Schott [10]. This scoring scheme uses visual acuity and visual field defects to define a quantitative score for each examination allowing interpersonal and temporal comparisons [10].

The series is homogenous with regard to the operative approach, pre- and postoperative diagnostic studies and peri-operative medications. All patients were studied preoperatively by tri-planar contrast enhanced MRI studies. Peri-tumoural edema was evaluated by both T2-weighted and proton-weighted magnetic resonance imaging according the methodology of Goldman *et al*. [13] by an experienced neuroradiologist. All patients were graded according to the following scheme: Grade 0 = absent or minimal oedema; Grade I = moderate oedema; Grade II = marked oedema. Immediate postoperative MRI examinations were done in all patients within 36 hours of the surgery. These postoperative contrast enhanced studies were evaluated by a team consisting of the operating neurosurgeon and the neuroradiologist and the extent of resection was determined along with possible complications. Tumour volume measurements were done on contrast enhanced T1 weighted images using computerized image analysis software (Imaging Research, Inc., St. Catherine's, ON, Canada). Conventional x-ray studies were done in all patients along with computerized tomography in 15 to evaluate bony involvement. In 10 patients a digital subtraction angiography was performed. Preoperative embolization was not used in any of the patients. Formal ophthalmological examinations were performed by the Ophthalmology Department at our hospital and included testing for visual acuity, visual fields and fundoscopy. A visual impairment score was calculated according to the method proposed by Fahlbusch *et al.* [10]. Presence of concomitant eye pathology was also taken into account; however the highest score calculated was taken as final. Pre and postoperative scores were compared and patients were assigned as better, worse or unchanged. A univariate analysis was performed using the Chi-square test.

Endocrinological testing was done pre and post operatively and this included blood levels for T3, T4 TSH, PRL, GH and cortisol. No suppression or stimulation tests were performed unless dictated by the clinical condition. All patients were given a standard dexamethasone regime of 4 mg four times daily and 5 mg/kg of phenytoin in three divided doses without loading.

A right sided pterional approach was used and microsurgical techniques were utilized universally for all cases. Simpson's grade [28] was recorded in the operative note for each patient. Complications were recorded for all patients. Surgical specimens were evaluated by the Pathology Department. At the time of data interpretation all results were re-analyzed according to the World Health Organization (WHO, 2000) grading criteria.

Results

From 1987 to 2004 forty-two patients were treated for tuberculum sellae meningiomas at Marmara University Department of Neurosurgery and at Marmara University Institute for Neurological Sciences. This cohort comprised 8% of our meningioma experience and 32% of our anterior fossa meningioma cases.

There were 28 females and 14 males. The male to female ratio was 1:2. The median age was 53 ranging from 24 to 79. Thirty-four (80.9%) patients presented with visual complaints, 32 patients (76.2%) with headache, 5 (11.9%) with gait imbalance and 2 (4.8%) with mental status changes. Mean duration of symptoms before presentation was 15.72 months. Median symptom duration was 12 months ranging from 4 to 60 months. Thirty four patients presented with visual symptoms and signs. Upon visual examination 2 were found to have normal visual testing. Two others had only field cuts but no decrease in visual acuity. Visual acuity was decreased unilaterally in 15 and bilaterally in 27 patients. Tumour volume as measured on MRI and calculated using an image analyzer ranged from 7.5 to 210 mm^3. Peri-tumoural oedema on preoperative MRI studies as determined by the method proposed by Goldman *et al.* [13] was read as follows. Absent in 13 (30.9%), moderate in 20 (47.6%) and marked in 9 (21.4%) patients.

Forty-two patients underwent a total of 45 operations. Of these 44 were aimed at tumour resection and one was for shunt placement. All patients were operated on by a right sided pterional approach with utilization of microsurgical techniques. Gross total tumour removal (Simpson grade II and III) was achieved in 35 (83.3%) patients. A Simpson grade II removal with coagulation of the tumour base was achieved in 29 (69%) of cases. In 6 cases (14.3%) only a Simpson grade III removal could be achieved (either with gross total tumour resection and residual hyperostotic bone or gross total tumour removal and some uncoagulated dura). Tumour pathology was reported as meningotheliomatous meningioma (WHO grade I) in 32, as transitional meningioma (WHO grade I) in 3, as psammomatous meningioma (WHO grade I) in 3, as atypical meningioma (WHO grade II) in 3 and as malignant meningioma (WHO grade III) in 1 patient. Despite the surgical aim of radical resection, in 8 patients (19%) residual tumour was present. Incomplete resection was due to tumour invasion of the internal carotid artery, anterior cerebral artery, optic canal, diaphragma sellae or adherence to hypothalamus. One patient with initial subtotal resection was re-operated on to achieve a gross total tumour resection.

Of the 7 patients with incomplete resections one died on the 30th postoperative day due to aspiration pneumonia and secondary sepsis. Gamma-Knife radiosurgery was performed in 3 of the remaining 6 patients. One patient with no adjuvant therapy had persistent tumour growth and was re-operated on at one year to achieve a complete resection. The follow-up period of patients ranged from 3 to 192 months (median: 30 months). The mean was 37.5 months (SD = ±36.7 months) None of the other 6 patients showed radiological tumour progression during their follow-up and their clinical condition remained stable.

Post-operative vision was better in 25 (59.5%), unchanged in 11 (26.2%) and worse in 6 (14.3%) patients. Effects of 10 variables on visual outcome are presented in Table 1.

Table 1. *Outcome analysis focusing on visual function*

Groups	Improved vision	p value
1. Age		
<60 years (27 patients)	in 20 of 27 patients	p = <0.05*
>60 years (15 patients)	in 5 of 15 patients	
2. Gender		
Male (14 patients)	in 8 of 14 patients	p = 0.163
Female (28 patients)	in 17 of 28 patients	
3. Duration of symptoms		
<12 months (20 patients)	in 16 of 20 patients	p < 0.001*
>12 months (22 patients)	in 9 of 22 patients	
4. Severity of visual symptoms		
Visual impairment score <20 (17 patients)	in 6 of 17 patients	p < 0.001*
Visual impairment score >20 (25 patients)	in 19 of 25 patients	
5. Laterality of eye involvement		
Binocular (27 patients)	in 14 of 27 patients	p = 0.18
Monocular (15 patients)	in 11 of 15 patients	
6. Tumour volume		
<15 mm^3 (23 patients)	in 16 of 23 patients	p = 0.42
>15 mm^3 (19 patients)	in 9 of 19 patients	
7. Vertical to horizontal dimensional ratio		
<1 (21 patients)	in 16 of 21 patients	p < 0.05*
>1 (21 patients)	in 9 of 21 patients	
8. Peri-tumoural oedema		
Grade O (13 patients)	in 11 of 13 patients	p < 0.001*
Grade II (9 patients)	in 2 of 9 patients	
9. Brain tumour interface		
Intact arachnoid plane (35 patients)	in 24 of 35 patients	p < 0.006*
Incomplete arachnoid plane (7 patients)	in 1 of 7 patients	
10. Extent of removal		
Total (35 patients)	in 24 of 35 patients	p < 0.001*
Subtotal (7 patients)	in 1 of 7 patients	

* Statistically significant

A single case of operative mortality was seen secondary to aspiration pneumonia (see above). Two further patients died during the follow-up period due to unrelated causes. Operative mortality was 2.3%. Complications were seen in 18 patients (42.8%). Of these 5 (13.8%) were visual complications. 16 (38.1%) patients had non-visual complications and 3 (7.1%) of those were permanent complications (hematoma in tumour bed and hydrocephalus). Non-visual complications consisted of CSF fistula in 4 (9.5%), transient diabetes inspidus in 3 (7.1%), worsening mental function in 3 (7.1%), aspiration pneumonia in 2 (4.8%), epidural hematoma in 1 (2.4%), hematoma in tumour bed in 1 (2.4%), hydrocephalus in 1 (2.4%) and postoperative seizures in 1 (2.4%). Rhinorrhea occurred in one patient after drilling of the clinoid process. The 3 other incidents were leaks from the incision. All leaks stopped after placement of a lumbar drain. No endocrinological complications were observed.

Discussion

Current literature on surgical treatment of tuberculum sellae meningiomas is very heterogeneous and a clear analysis of the results obtained by each approach is needed. The first successful removal of a tuberculum sellae meningioma is attributed to Cushing [7]. However he also introduced the term ''suprasellar meningioma'' [7, 8] and the nomenclature and classification of meningiomas of the region has since varied considerably [1, 2, 4, 6–12, 14, 16, 17, 19–24, 29–32, 35]. Thus although there is ample literature on anterior fossa meningiomas, variations of the studied population, treatment paradigms and method of analysis in each study precludes unbiased conclusions on tuberculum sellae meningiomas. The aim of this study is to analyze the results of pterional craniotomy for tuberculum sellae meningiomas. Several other approaches are commonly used including unilateral or bilateral subfrontal approaches with or without the addition of orbital osteotomies [23, 27]. The pterional trans-Sylvian approach using microsurgical technique is fast, safe, effective and provides adequate exposure for treatment of tuberculum sellae meningiomas (Fig. 1) [10, 23, 24, 34]. To determine its efficiency

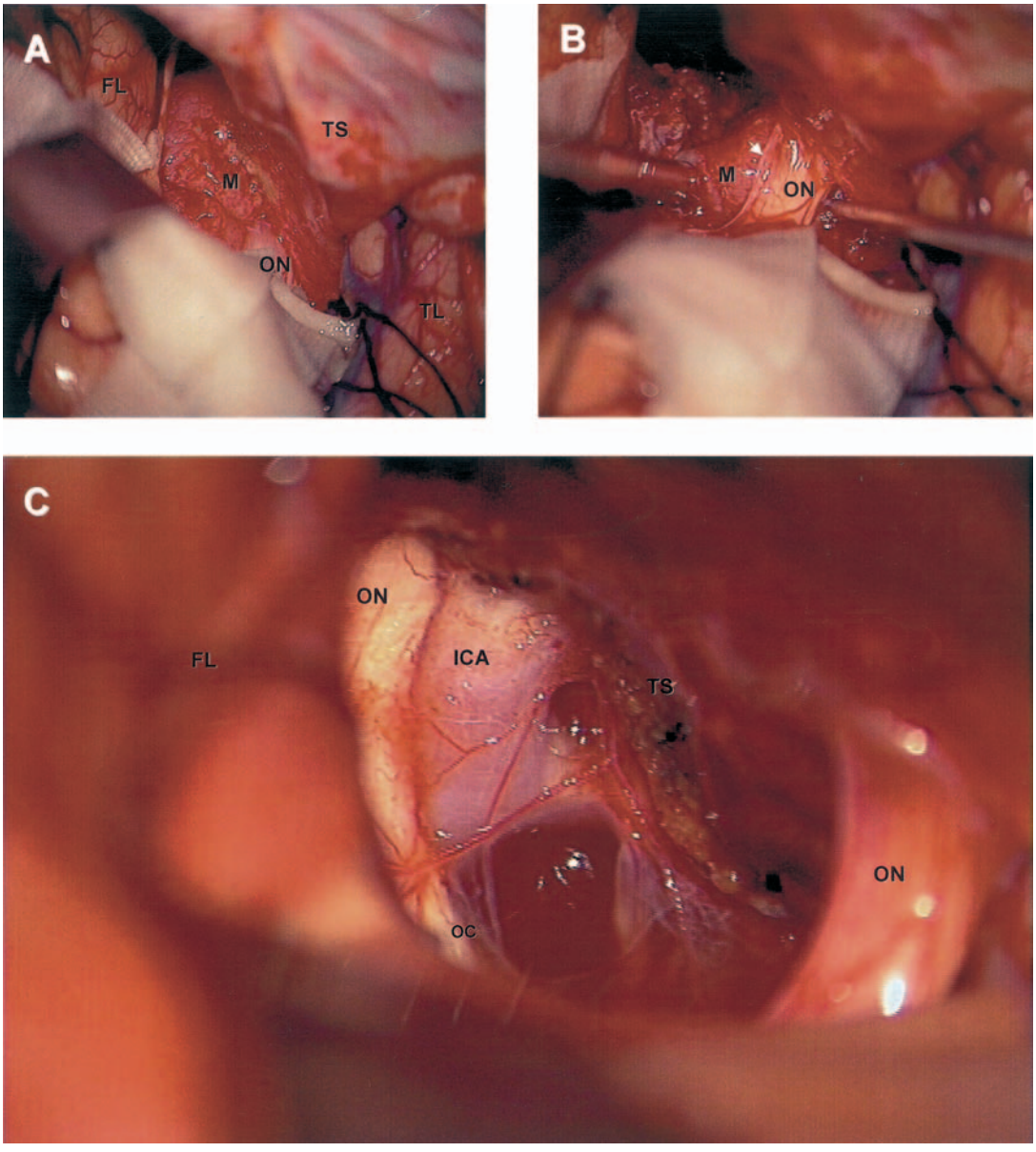

Fig. 1. (A) Operative view of a tuberculum sellae meningioma. Right sided pterional approach with the frontal lobe retracted. (B) Please note the clear arachnoid plane between the tumor and the optic nerve (arrow). (C) A wide exposure of the suprasellar area is possible with the pterional approach. Bilateral optic nerves, optic chiasm, contralateral internal carotid artery in relation to the tumor bed are visible after complete tumor resection. *FL* Frontal lobe, *ICA* Internal carotid artery, *M* Meningioma, *OC* Optic chiasm, *ON* Optic nerve, *TL* Temporal lobe, *TS* Tuberculum sellae

we used variables which, over the years, have been proved to be of prognostic significance for meningiomas of this region. This study presents a homogenous cohort of consecutively operated on tuberculum sellae meningioma cases, all of whom were treated during the course of 17 years in the MRI era, using a single operative technique without major modifications.

Eighty to ninety-six per-cent of patients with tuberculum sellae meningiomas present for clinical attention because of progressive visual deficits. As the main surgical indication in tuberculum sellae meningiomas is the presence or threat of optic compression, the surgical success should also be judged by the visual outcome [10, 25]. However so far only few studies have focused on factors influencing visual outcome [2, 10, 11, 22, 30, 34, 35]. An analysis of the available literature on tuberculum sellae meningiomas returns 13 variables suggested as determinants of the visual outcome (Tables 2 and 3). We have retrospectively analyzed our results

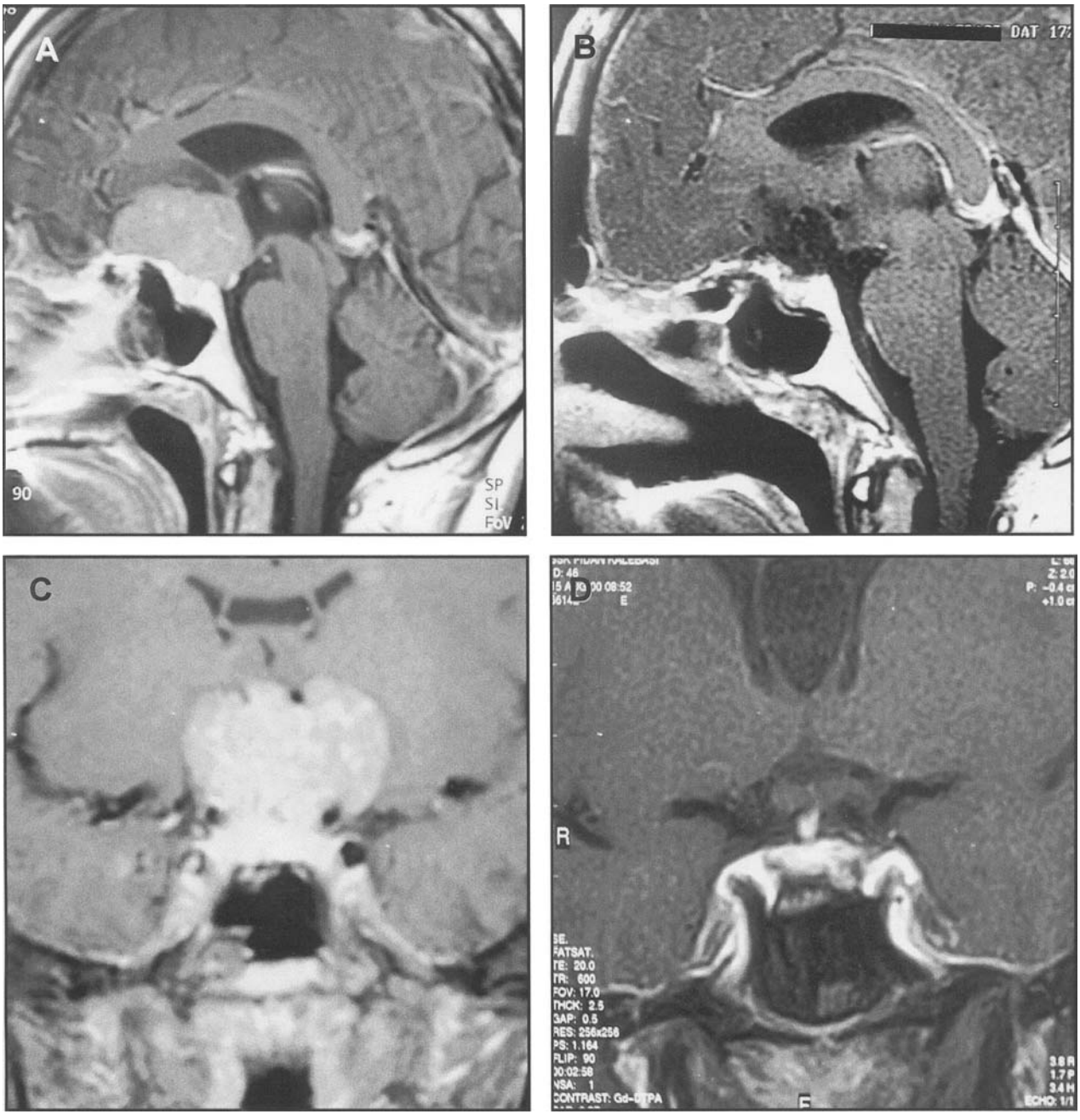

Fig. 2. Pre (A and C) and postoperative (B and D) contrast enhanced MRI examinations of a tuberculum sellae meningioma showing total tumour removal after pterional craniotomy

focussing on 10 of these variables, which are applicable to our cohort.

Age and gender

Age is one of the most commonly cited prognostic variables. In our study patients younger than 60 years had a significantly better visual outcome ($p = <0.05$). Similarly Zevgaridis *et al.* [34] have found young age to be statistically significant in both univariate and multivariate analyses. The reason for the higher risk in the elderly is not known. Animal models have demonstrated that compression of the optic nerve causes both mechanical and ischemic damage [5]. It has been hypothesized that the dismal visual outcome in the elderly may be related to poor tolerance of ischemia related to intraoperative manipulation in this group [34]. Co-morbidities such as hypertension, atherosclerosis and cardiac disease,

Table 2. *Major microsurgical tuberculum sellae meningioma series*

Author	Duration of case collection (years)	n	Duration of visual symptoms (months)	Tumour size (median–range)	Surgery	Complete resection (%)	Visual symptoms (%)	Improved vision (%)	Worsened vision (%)	Nonvisual permanent surgical morbidity (%)	Mortality (%)	Recurrence and follow-up (%/years)	Remarks
Grissoli (1986)	9	28	Mean 27.7	n/a	MI	92.9	92.9	55.4	25	n/a	3.6	3.6/?	tuberculum sellae meningiomas
Andrews and Wilson (1988)	9	38	Mean 24.5	α	MI	58	94.7	42	18	13.1	2.6	7.9–38	suprasellar meningiomas
Brihaye and Brihaye-vanGeertruyden (1988)	n/a	19	n/a	n/a	MI	n/a	n/a	n/a	n/a	n/a	21	10.5/?	suprasellar meningiomas
Al-Mefty and Smith (1991)	8	35	n/a	β	MI/SB	91	n/a	25	27	11.3	8.6	8.7/6.5	tuberculum sellae meningiomas
Conforti (1991)	n/a	39	n/a	n/a	MI	100	n/a	59	n/a	n/a	7.7	8.7/6.5	suprasellar and intraventricular meningiomas
Yaşargil (1996)	25	112	n/a	γ	MI	100	75.9	40.2	9.8	4.5	0.9	0/10	tuberculum sellae meningiomas; pterional surgery only
Zevgaritis *et al.* (2001)	6	24	Mean 10	2.5 cm (1.5–4)	MI	96	100	66.7	29.2	n/a	0	n/a	sellar meningiomas
Ohta *et al.* (2001)	20	33	n/a	n/a	MI/SB	64	n/a	42.4	12.1	n/a	0	24.2/10.7	tuberculum sellae meningiomas
Fahlbusch and Schott (2002)	15	47	2 months–18 years	δ	MI	98	96	80	20	15	0	2.1/4.3	tuberculum sellae and planum sphenoidale meningiomas, the only series with an objective visual scoring scheme; pterional surgery only
Jallo and Benjamin (2002)	19	23	Mean 16.7	n/a (2–5 cm)	MI	87	100	55	19	0	8.7	4.4/9.3	includes diaphragma sellae meningiomas
Goel *et al.* (2002)	10	70	ε	n/a	MI/SB	84.3	90	70	10	1.4	2.9	1.4/3.8	tuberculum sellae meningiomas
Present study (2004)	15	42	Mean 12	3 cm (2–7)	MI	81	80.9	58	14	7.1	2.4	2.4/3	tuberculum sellae meningiomas; pterional surgery only

Only tuberculum sellae meningioma cases were taken to analysis in each series and corresponding frequencies were re-calculated from the presented data, selectively for tuberculum sellae meningiomas. MI Microsurgery. *SB* Skull base approaches, α 15.8% <3 cm, 60.5% 3–5 cm, 18.4% >5 cm, information on tumour size not available for 5.3%, β 97% of tumours larger than 4 cm γ 2.7% <2 cm, 44.6% 2–4 cm, 52.7% >4 cm, δ 32% 1–2 cm, 49% 2–3 cm, 19% 3–4 cm, ε 21.3% 0–3 months; 55% 3 months-2 years, 3.7% 2–5 years; 7.5% >5 years.

Table 3. *Analysis of the current literature for variables influencing the postoperative visual outcome*

Author	Age	Gender	Duration of visual symptoms	Severity of visual symptoms	Laterality of eye findings	Tumour size	Tumour extension to surrounding structures	Use of microsurgery	Use of skull base approaches	Extent of removal	Brain-tumour interface	Peritumoural edema	Vertical to horizontal diameter ratio
Symon and Rosenstein (1984)	better if younger than 40, worse if older than 60 years	–	better if shorter than 2 years	worse with optic disc pallor, worse if preoperative acuity <0.5	worse when monocular	worse if larger than 3 cm	–	no difference	–	–	–	–	–
Andrews and Wilson (1988)	–	–	better if shorter than 6 months, worse if longer than 2 years	–	–	worse if larger than 6 cm	–	–	–	–	–	–	–
Yaşargil (1996)	–	–	–	postoperative blindness in cases with severly decreased visual acuity	–	–	–	–	–	–	–	–	–
Zevgaritis *et al.* (2001)	better if younger than 54 years	no difference	worse if longer than 7 months	worse if preoperative acuity below 0.2	–	no difference	no difference	–	–	no difference	better when there is an arachnoid plane	–	–
Ohta *et al.* (2001)	–	–	worse if longer than 1 year	–	–	worse if larger than 3 cm	–		no difference	no difference	–	–	–
Fahlbusch and Schott (2002)	worse if older than 50 years	–	worse if longer than 1 year	–	worse when binocular	no difference*	–	–	–	better with complete resection	–	–	–
Present study (2004)	worse if older than 60 years	no difference	worse if longer than 1 year	worse if visual symptom score is below 20	worse when binocular	no difference	–	–	–	better with complete resection	better with intact arachnoid plane	worse with significant edema	worse if the vertical diameter exceeds the horizontal

* Tumour size range 1 to 4 cm.

which are common in this age group, have all been shown to increase the risk of ischemic optic neuropathy [26].

A strong female preponderance, which is reported in other studies was also present in our series [9, 11, 30, 34]. Goel *et al*. [11] reported a higher incidence of vascular tumours with more extensive peri-tumoural oedema in patients who were diagnosed during pregnancy. Considering that hormonal effects are important in the development and growth of meningiomas one might ask if aggressive tumour characteristics might be hormonally driven [2, 3, 30, 33]. However no statistically significant effects of gender on visual outcome was noted in our series ($p = 0.163$).

Severity and duration of symptoms

Optic structures are extremely sensitive to surgical manipulation when they have been compressed by mass lesions [34]. Consistent with this fact a low preoperative visual impairment score (below 20; as calculated by the method proposed by Fahlbusch *et al.* [10]) was associated with a significantly worse visual outcome in our study ($p < 0.001$). It is notable that several authors found that vision was completely lost after surgery when visual acuity in the affected eye was very poor [34]. There is some indication that the duration of the compression is also important. Despite this fact Rosestein and Symon [25] have reported that the duration of visual symptoms did in fact affect the postoperative outcome. This finding has been confirmed by several authors using different dichotomization points (ranging from 7 months to 2 years) [10, 22, 25, 30, 35]. Our results show that patients with symptoms shorter than 12 months have a better chance of improvement in vision ($p < 0.001$). Symon and Rosenstein [25] have used the presence of optic disc pallor as an indication of chronic, severe optic compression and correlated it with a worse postoperative outcome. However we have observed optic disc pallor in all of our patients except for one, precluding its use as a practical indicator.

Symon and Rosenstein [25] reported that $2/3$ of their patients had binocular eye involvement. Interestingly the authors [25] found an insignificant trend towards a worse outcome when preoperative symptoms were confined to one eye. Fahlbusch [10] however concluded that the visual outcome was worse when both eyes were involved. There was no statistically significant difference in our study between groups with monocular or binocular findings ($p = 0.18$). None of the studies so far, however, indicated an association of the laterality of symptoms with optic canal involvement by tumour which may explain a marked difference in visual findings [10, 25]. In our study all patients who had frankly asymmetric eye findings (greater than 50 points of difference between two eyes) had optic canal involvement as documented during surgery.

Size and shape of the tumor

There are contradictory reports on the effect of tumour size on visual outcome. Several authors have shown that larger tumours had worse outcome [2, 25] while others have disputed this notion [9, 10, 33]. In our cohort the largest tumour diameter ranged from 2 to 7 cm and we took $15\,mm^3$ as a cut-off point for comparison. This roughly corresponds to the 3 cm diameter cut-off which has been found to be significant in other studies [22, 25]. A comparison between tumours smaller and larger than $15\,mm^3$ in our study was not significant ($p = 0.42$). One peculiar aspect of tuberculum sellae meningiomas is that the degree of visual impairment due to the impingement on the optic nerves and chiasm are quite variable [11, 15, 25]. Even large meningiomas may be asymptomatic for prolonged periods despite significant compression of the optic apparatus [33]. This finding shows that a large size does not preclude recovery of visual function and supports an aggressive treatment paradigm.

Tuberculum sellae meningiomas do not necessarily always grow centrifugally from their epicenter perfectly forming three-fourths of a sphere. We have observed that tumours which displayed a more prominent upward growth rather than a spherical enlargement had more severe visual symptomatology and worse postoperative visual outcomes. This led to the hypothesis that vertical growth potential is more important than pure tumour size in causing early and severe visual symptomatology. Analyzing sagittal MRI sections we found that the rate of visual improvement decreased from 76.19% to 42.86% when the horizontal dimension exceeded the vertical. This difference was statistically significant ($p < 0.05$). A superiorly oriented growth potential may result in early impingement on the optic apparatus. Yaşargil [34] reported that optic nerves and chiasma were elevated and displaced in 73.3% of cases, causing an incision of the nerve by the falciform ligament in 21.4% and by a stretched A1 segment of the anterior cerebral artery in another 21.4%. Similarly a radiological elevation of the anterior cerebral artery on cerebral

angiograms in pure tuberculum sellae meningiomas was noted in 79% of the patients [10]. As optic injury by tumour compression may be related to the impingement at the level of the optic strut, early decompression of the optic nerve during the surgery with unroofing of the optic canal may be considered to decrease the risk of iatrogenic injury due to stretch [1]. Ischemia due to compression or stretch of perforators from the anterior cerebral artery may also be important [1, 35].

Brain-tumor interface-surrounding brain parenchyma

Early identification and preservation of the arachnoid anatomy facilitates easy dissection of the tumour from its surroundings and optic and chiasmatic vessels [10, 34]. In our cohort an intact arachnoid plane could be identified in 83.33% of the patients and the visual outcome in patients with an intact arachnoid plane was significantly better than those, in whom no plane could be identified ($p < 0.006$). The importance of this plane in achieving a safe resection has been stressed by several authors [1, 10, 33, 35]. Zevgaridis *et al.* [35] were the first group to show that its presence was also correlated with a better visual outcome.

Peritumoral edema had a significantly worse visual outcome ($p < 0.001$). As we have indicated in our previous study peritumoral edema in meningiomas is correlated with a higher proliferative index and a higher angiogenetic activity [18]. Therefore it may be speculated that the dismal visual outcome might be related to a higher growth rate and accelerated course of nerve compression. However this hypothesis needs to be proved.

Extent of surgery

Several studies have stressed that complete resection should not be attempted at the cost of visual deterioration or hypothalamic dysfunction. Our results however indicate that contrary to the aforementioned hypothesis the visual outcome was better in totally resected tumours ($p < 0.05$). Similarly Fahlbusch *et al.* [10] indicated that despite total resection rates of 80% the risk of visual morbidity was not increased. An intact arachnoid plane has been reported in most tuberculum sellae meningiomas except for very large tumours and this plane allows for aggressive tumour removal with preservation of surrounding structures [10, 35].

Conclusions

- Standard pterional microsurgery is a safe and effective approach for the treatment of tuberculum sellae meningiomas.
- The following factors were found to be of significance for a better visual outcome: Patient age, duration of visual symptoms, severity of visual symptoms, predominantly vertical growth potential, presence of significant peri-tumoural oedema, presence of an intact arachnoid plane and extensive removal.

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Comment

The authors present a precisely worked out retrospective study on 42 operated tuberculum sellae meningiomas with special regard to prognostic factors for visual outcome. They do not only confirm our quoted personal experience in 47 operated cases, however they expand the well known prognostic factors such as duration of symptoms and radical removal with some new aspects: the peritumoral oedema, the vertical growth potential which influences the visual outcome in a negative way and the tongue like growth unilaterally in the optic canal occurring in 20% in their series which deteriorates the outcome. They emphasize especially the cisternal anatomy that preserved intact arachnoidal plane forming a mechanical barrier to protect adjacent vital structures, such as vessels, presents better prognosis. Different to our management is that they operated on also tumours in the stage 0 without already confirmed visual compromise – we tend to observe these cases Until further growth and visual deterioration occurs. Furthermore they have a higher amount (19%) of smaller residual tumours attaching firmly around the vital arteries and the hypothalamus, resulting convincing in excellent visual outcome and low morbidity. Tumor remnants are mainly locally irradiated.

This article underlines that the unilateral pterional or fronto-lateral approach offers excellent results to patients with tuberculum sella meningiomas based on a longer lasting experience for this entity of disease – in contrast to one or two decades before, documented by Table 2, when tumor removal was performed in the so-called macroscopically era. How to improve further? Unfortunately, our ophthalmological colleagues were not able to offer a strengthening of education within their membership, in order to diagnose tuberculum sellae meningiomas much earlier than at the time of Harvey Cushing's original publication.

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