Neurosurgical Review (2020) 43:109–117
https://doi.org/10.1007/s10143-018-1018-1

ORIGINAL ARTICLE

Long-term follow-up after surgical removal of meningioma of the inner third of the sphenoidal wing: outcome determinants and different strategies

Andrea Talacchi[1,2] · Aurel Hasanbelliu[1] · Alberto D'Amico[1] · Nicolò Regge Gianas[1] · Francesca Locatelli[3] · Alberto Pasqualin[4] · Michele Longhi[4] · Antonio Nicolato[4]

Received: 31 January 2018 / Revised: 29 June 2018 / Accepted: 2 August 2018 / Published online: 5 September 2018

Abstract

Meningioma arising in the inner third of the sphenoidal wing has been well recognized since the origin of neurosurgery, yet it still poses a formidable challenge for the surgeon. Treatment strategies can be optimized through a tailored approach to surgical timing and use of a non-surgical armamentarium. The aim of this study was to evaluate the long-term effect of different strategies on progression-free survival and overall survival. We examined the clinical records of brain tumor patients to assess determinants for surgery (extent of tumor removal, postoperative complications) and for progression-free survival and overall survival in relation to timing of surgery eventually followed by stereotactic radiosurgery (SRS). The records of 60 patients were retrospectively reviewed, from preoperative assessment to a median follow-up of 104 months. All were symptomatic with prevalently visual symptoms (42.2%), large tumors (median diameter 3.44 cm), extension into the cavernous sinus (38.3%), and severe vascular involvement of one or more encased or narrowed vessels (50%). Subtotal removal was achieved in 40% of cases, mainly determined by cavernous sinus and vascular involvement; neurological complications occurred in 18.3% (persistent in 6.7% due to oculomotor and vascular injury). The overall rate of symptom improvement was 32.3% at 3 months and 49.5% at 12 months. Radiological monitoring prevented clinical progression; tumor progression occurred in 11.7% of cases. There were significant differences in progression-free survival between patients with (median 46 months) and those without (median 104 months) recurrence ($p = 0.002$): 12.5% after total removal, 6.2% after subtotal removal and adjuvant SRS, and 28.5% after subtotal removal and observation. The related Kaplan-Meier survival curve showed no significant difference between the three strategies. Further, disease progression after recurrence was noted in 28.6% of cases, but overall survival was not influenced by either tumor recurrence or type of treatment. Treatment failure was recorded in four cases (6.7%): one perioperative death and three later on. Surgery is the mainstay for the treatment of symptomatic meningioma and to restore neurological function; however, resectability is limited by vascular and cavernous sinus involvement. Careful postoperative monitoring prevented clinical progression and adjuvant or adjunctive SRS proved effective in tumor control. A low surgical complication rate and excellent long-term outcomes were achieved with this strategy.

Keywords Meningioma · Skull base · Surgical treatment · Stereotactic radiosurgery · Long-term outcome

✉ Andrea Talacchi
andrea.talacchi@univr.it

[1] Department of Neuroscience, Biomedicine and Movement, Section of Neurosurgery, University of Verona, Verona, Italy

[2] Clinical Neurosurgery, University Hospital, Piazzale Stefani 1, 37121 Verona, Italy

[3] Department of Public Health and Community Medicine, Section of Epidemiology and Medical Statistics, University of Verona, Verona, Italy

[4] Department of Neuroscience, Neurosurgery Unit, University Hospital, Verona, Italy

Introduction

In the surgical management of meningiomas of the inner third of the sphenoidal wing, the challenge for neurosurgeons is to balance the risk of aggressive tumor surgery and potential neurovascular complications with the risk of tumor progression [1–4]. Symptoms are often related to visual impairment; their relief is the primary objective of the operation. However, surgical anatomy and tumor behavior constitute pitfalls to achieving safe removal. Infiltration of the skull base, tumor calcification, vascular encasement, cavernous sinus

involvement, contralateral, and posterior expansion are all formidable obstacles to managing these tumors [5–9].

Here, we report on long-term follow-up to retrospectively recognize outcome determinants, compare three different treatment strategies (aggressive vs. cautious removal, adjuvant stereotactic radiosurgery (SRS), or observation), and evaluate them at long term.

Material and methods

Between 2000 and 2012, a consecutive series of 60 patients were operated on at our institution for inner third sphenoidal wing meningioma with primary attachment to the anterior clinoid process (ACP) and/or cavernous sinus (CS). Meningiomas arising from the tuberculum sellae, middle and lateral portion of the sphenoidal wing, and non-exophytic mass of the cavernous sinus were excluded. Histology was reclassified according to 2007 World Health Organization (WHO) classification criteria [10]. Patient demographics, clinico-radiological features, and intraoperative findings were retrospectively reviewed and analyzed against the outcomes in the acute and delayed phase.

In the acute phase, clinical status was assessed at 7 days and again at 3 months by comparing symptoms and signs with preoperative assessment. The two perioperative end points were extent of surgical removal and complications. The extent of removal was classified according to a two-tiered classification system: total, i.e., without residual measurable mass, with or without dural replacement or dural coagulation, and subtotal, i.e., with residual mass as determined by postoperative magnetic resonance imaging (MRI). Complications were classified as local (tumor bed hemorrhage, wound infection, and epilepsy), neurological (new or worsened symptoms and signs), and systemic (respiratory and heart failure, sepsis, thromboembolic events, etc.).

In the delayed phase, clinical status was assessed at 12 months and at the last control visit by comparing symptoms, signs, and Karnofsky Performance Status (KPS) with preoperative assessment. Additional end points were **as follows**: occurrence of regrowth or recurrence, progression-free survival, and overall survival. All patients were monitored with MRI. Progression-free survival was defined as the interval between treatment and tumor regrowth or recurrence. Regrowth was defined as tumor progression as documented by follow-up MRI after subtotal removal and recurrence after total removal. Overall survival was the time interval between treatment and the last event: tumor progression or death versus tumor stabilization.

Ethical committee approval was not sought because data collection did not influence the patient management in any way.

Clinico-radiological features

Presenting symptoms and signs and length of clinical history were recorded. Multiplanar contrast-enhanced MRI and contrasted computerized tomography (CT) scans, with and without bone window, were performed before surgery. Angiography, angio-MRI, or 3D angio-CT scans were obtained to better evaluate the relation between the lesion and the arteries of the anterior circle of Willis, i.e., internal carotid artery (ICA), middle cerebral artery (MCA), and anterior cerebral artery (ACA, A1-A2). Preoperative embolization of the tumor feeding arteries was not performed in this series. The relation between meningioma and vessels was classified as no contact, contact, displacement, encasement, and narrowing. Vessel names and number and type of involvement were recorded. As the lesions presented a spherical shape, the volumes were measured according to modified MacDonald ellipsoid criteria [11]. The mean diameter was calculated as the sum of the three largest diameters divided by three, and the direction of tumor extension was described. Edema was classified as absent, perilesional (< 2 cm), or massive.

Treatment strategies

Treatment included surgical resection as first-line treatment and stereotactic radiosurgery (SRS) with Leksell instrumentation. The standard surgical approach consisted of pterional craniotomy and transsylvian approach to the tumor in all cases, with additional steps on a case-by-case basis (optic canal unroofing, clinoidectomy, and apical orbitectomy). Particular attention was paid to decompressing the optic nerve in patients with visual impairment. Type of vascular involvement, arachnoidal cleavage plane with regard to the brain and the vessels, tumor consistency, and bleeding were recorded and evaluated.

SRS procedures were performed with a model C 201-source Co60 Leksell Gamma Unit and, since June 2008, with Gamma Knife (GK) Perfexion (both from Elekta Instruments). Three-dimensional treatment planning was developed using Leksell Gamma Plan (versions 4.12, 5.34, and 8.3; Elekta Instruments). Neuroradiological localization was routinely performed using stereotactic MRI with specific algorithms and sequences: 1-mm-isovoxel volumetric, T1 fat saturated, and steady-state gadolinium-enhanced images. Mean and range dose planning parameters were as follows: gross target volume (GTV 9.4 cc, 1.22–29.6), prescription dose (PD 12.01 Gy, 10–15), prescription isodose (PI 47.6%, 30–60), maximum dose (MD 23.8 Gy, 20–28), and shot number (11.5, 1–31). SRS was characterized by PD and MD intensity delivered in compliance with the optic

Table 1 Time course of symptoms and signs

	Preoperative	Postoperative course compared with preop									
		7 days				3 months		12 months[†]		Total	
	n, %	New	↓	↑	=	↑	=	↑	=	↑, %	=, %
Headache	19, 21.1	–	–	6	13	1	12	2	10	9, 9.1	10, 10.1
Monocular visual impairment (> 3/10)	13, 14.4	–	–	4	9	2	7	–	7	6, 6.1	7, 7.1
Monocular severe visual impairment (< 3/10)	9, 10	–	–	1	8	1	7	3	4	5, 5.1	4, 4
Binocular mild visual impairment (> 3/10 in both eyes)	1, 1.1	–	–	1	–	–	–	–	–	1 1	–, 0
Binocular severe visual impairment (at least < 3/10 in one eye)	4, 4.4	–	–	2	2	–	2	–	2	2, 2	2, 2
Visual field deficit	11, 12.2	1	–	–	11	–	12	3	9	3, 3	9, 9.1
Diplopia	3, 3.3	3	–	–	3	–	6	2	4	2, 2	4, 4
Epilepsy	15, 16.7	1	1	1	13	4	11	3	8	8, 8.1	8, 8.1
Cognitive problems	5, 5.6	1	1	3	1	1	2	2	–	6, 6.1	–, 0
Motor impairment	5, 5.6	2	–	1	4	–	6	1	5	2, 2	5, 5.1
Other*	5, 5.6	1	–	3	2	1	3	1	1	5, 5.1	1, 1
Total	90, 100									49/99♦, 49.5	50/99, 50.5
< 70	1								3		
KPS = 70	10								4		
> 70	49								48		

New number of patients with new symptoms registered after surgery, ↓ number of patients that worsened after surgery, ↑ number of patients that improved or returned to normal status, = number of patients that remained stable

*Other: facial hypesthesia, retrobulbar pain

[†] Four patients were lost at 12-month follow-up; one other patient died after first operations

♦ At 3- and 12-month evaluation, patients were compared with preoperative symptoms/sign and postoperative new symptoms and signs (total $n = 99$)

nerve, the chiasm, and the pituitary peduncle. SRS was offered as adjuvant treatment in patients with postoperative remnants or as adjunctive treatment at tumor progression.

Statistical analysis

Significance of differences between patients for the three end points, extent of surgical removal (total/subtotal),

Table 2 Radiological findings

		Mean	Range
Size			
	Tumor diameter ($[x + y + z]/3$; cm)	3.44 ± 1.09	1–5.33
	Tumor volume $1/6 \times \pi \times x \times y \times z$ (cm^3)	27.092	0.524–77.754
		No.	%
Primary location			
	Clinoidal	55	91.7
	Cavernous	5	8.3
Extension			
	Cavernous	18	30
	Sella	8	13.3
	Parasellar	14	23.3
	Orbit	6	10
	Petrous apex - posterior fossa	6	10
	Across the midline	4	6.7
	2 or more locations	29	48.3
Edema			
	Absent	13	21.7
	Perilesional (< 2 cm)	23	38.3
	Massive (> 2 cm)	24	40

complications (present/absent), and tumor regrowth or recurrence (present/absent) were evaluated using Fisher's exact test for categorical variables and by the Wilcoxon–Mann–Whitney non-parametric test for continuous variables. Variables were as follows: age, sex, KPS, symptoms/signs, tumor volume, tumor extension, edema, main vessel involvement (ICA, MCA, ACA), degree of vascular involvement, arachnoidal plane around both vessels and brain, tumor consistency, and tumor bleeding. Additional variables related to treatment were extent of surgical removal and eventual adjuvant SRS for determinants of regrowth/recurrence.

Progression-free survival curves were generated using the Kaplan–Meier method, and statistical significance was determined using the log-rank test according to treatment strategies: total removal, subtotal removal, and subtotal removal with adjuvant SRS. All p values were two-sided, and a p value of < 0.05 was considered statistically significant. Statistical analyses were performed using Stata 14.0 (StataCorp, College Station, TX, USA).

Results

A total of 39 women and 19 men (ratio 2.05:1; mean age 57 ± 15 years, range 22–87) were operated on for the first time for meningioma arising from the inner portion of the sphenoid wing.

Clinico-radiological features

Preoperatively, visual acuity and visual field deficits accounted for 42.2% ($n = 38$) of signs and symptoms in 31 patients (51.7%). Headache and epilepsy were present in 19 (31.7%) and 15 (25%), respectively. Overall, the number of patients with KPS > 70 was 49 (81.7%) (Table 1).

Radiological findings are reported in Tables 2, 3, and 4 (Figs. 1, 2, and 3). The primary location of meningioma was the ACP in 55 (91.7%) cases and the CS in the remaining 5 (8.3%). The most frequently occupied secondary sites were the CS in 18 (30%), the parasellar area in 14 (23.3%), and the sellae in 8 (13.3%). Two or more sites were found in 29 (48.3%) cases. The preoperative mean tumor volume was 27.1 cm^3 (range 0.52–77.75) and the mean diameter was 3.44 ± 1.09 cm (range 1–5.33). Tumor volume and extension accounted for a large tumor series. Edema was present in 78.3% of cases (Table 2). Integration of radiographic findings and operating notes made it easier to understand the involvement of the adjacent vascular structures: the ICA was the most severely affected vessel (encasement) ($n = 26$, 43.3%); the MCA was the most often displaced vessel ($n = 30$, 50%), and the ACA, A1-A2 had no contact with the tumor in the majority of cases ($n = 40$, 66.7%) (Table 3). In addition, a new parameter was added to the analysis: degree of vascular involvement.

Table 3 Vascular involvement

		No.	%
ICA			
	No contact	13	21.7
	Contact	4	6.7
	Displacement	14	23.3
	Encasement	26	43.3
	Narrowing	3	5
MCA			
	No contact	13	21.7
	Contact	1	1.7
	Displacement	30	50
	Encasement	13	21.7
	Narrowing	3	5
ACA, A1-A2			
	No contact	40	66.7
	Contact	2	3.3
	Displacement	11	18.3
	Encasement	6	10
	Narrowing	1	1.7

ICA denotes internal cerebral artery, *MCA* middle cerebral artery, *ACA* anterior cerebral artery

Three groups were recognized with a higher degree of vascular involvement (encasement and narrowing) based on the number of vessels entrapped in the tumor ($n = 30$, 50%): one group ($n = 14$, 46.7%) with only ICA involvement in 92.9% of cases, a second group ($n = 10$, 33.3%) with ICA-MCA involvement in 90%, and a third group ($n = 6$ 20%) with ICA-MCA-ACA (A1-A2) involvement in all 6 cases (Table 4).

Surgical treatment

Surgery was performed at 13 months after the onset of symptoms (ranging from a few weeks to 94 months). Total removal was obtained in 36 (60%) cases. In the remaining 24 (40%), the residual mass measured less than 2 cm in 16 cases (26.7%) and less than 3 cm in 8 (13.3%). The factors limiting achievement of total removal were infiltration of the CS in 75% ($n = 18$) of cases, encasement/invasion of adjacent neurovascular structures in 41.7% ($n = 10$), tumor consistency in 12.5% ($n = 3$), and bleeding in 8.3% ($n = 2$) (Figs. 2 and 3). Atypical meningiomas were observed in 3 patients, with total removal achieved in two of them.

Significant predictors of incomplete removal in order of importance were as follows: degree of vascular involvement ($p < 0.001$), ICA involvement ($p < 0.001$), CS invasion ($p < 0.001$), tumor volume ($p < 0.01$), cleavage plane around vessels ($p < 0.01$), and tumor consistency ($p < 0.01$).

Table 4 Degree of vascular involvement

	Group I			Group II			Group III
	ICA	MCA	ACA	ACA-ICA	ACA-MCA	ICA-MCA	ACA-ICA-MCA
No. of cases	13	1	–	1	–	9	6

Vessel encasement and/or narrowing was present in 30 patients (50%)

ICA denotes internal cerebral artery, *MCA* middle cerebral artery, *ACA* anterior cerebral artery

Perioperative outcome

Recovery of presenting deficits was observed within the first 7 days after surgery in 21 (35%) patients, then much slower in the following months. An example is the effect of decompression on optic function, since visual acuity was improved in 29.6% of patients ($n = 8$) (Table 1).

Local complications occurred in 4 patients (6.7%), systemic in 5 (8.3%), and neurologic in 11 (18.3%), due to new disturbances that later improved at 3 months in 7 cases but persisted in 4 (6.7%) (hemiparesis due to vascular injury and diplopia in 2 cases each) (Table 5). The only significant predictor for complications of any type was KPS ≤ 70 ($p < 0.01$). One patient died (1.7% of perioperative mortality) a few days after the operation because of malignant endocranial hypertension due to severe cerebellar "zebra sign" hemorrhage and hydrocephalus.

Follow-up and final outcome

Four patients were lost to follow-up at 5–12 months after surgery, and 55 patients could be traced in a timeframe between 12 and 290 months. Improvement was noted for visual disturbances (acuity and field disturbances) in 16 patients (51.6%), headache in 9 (47.4%), and epilepsy in 8 (50%) (patients without epileptic fits without antiepileptic therapy). Forty-eight (87.3%) patients were independent (Table 1).

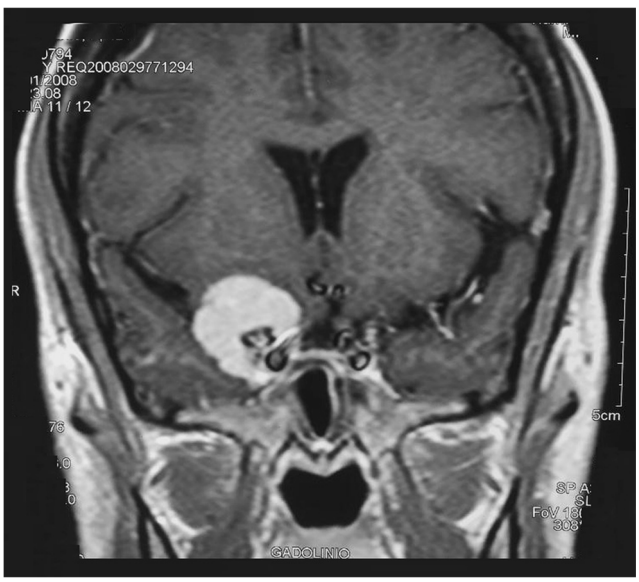

Fig. 1 MR enhanced T1-weighted images on coronal view showing clinoidal hyperostosis, site of attachment, distortion of the chiasm, and vicinity of the carotid artery. Note that the cavernous sinus is not occupied by the tumor

Sixteen out of 23 patients with subtotal removal underwent subsequent adjuvant SRS between 2 and 12 months after surgery. The mean PD was 12.01 Gy (range 10 to 15) and the MD was 23.8 Gy (range 20 to 28); 7 patients underwent observation, as done for all the patients in the total removal group ($n = 32$). Of the 39 patients who were followed by observation, 6 experienced recurrence: 4 (12.5%) in the total removal group at a mean 58 months, 2 of which progressed to atypical meningioma at recurrence 48 and 160 months after initial surgery, and 2 in the subtotal removal group (28.6%) at a mean 22 months. Another recurrence occurred at 46 months in a patient who had received subtotal removal with adjuvant SRS (6.2%).

Five patients underwent SRS for disease recurrence, one of which had tumor progression at the most recent follow-up visit, and two underwent more than one operation followed by SRS. The median progression-free survival was 46 months (range 14–160) and differed significantly from the 104 months (range 12–211) noted for the patients without relapse ($p = 0.02$).

Preoperative volume was found to be the only factor associated with tumor regrowth/recurrence ($p = 0.01$). Progression-free survival was estimated with the Kaplan–Meier method after recording the type of treatment as a three-level variable (total removal vs. subtotal removal vs. subtotal removal with adjuvant SRS). No significant differences were observed between the three treatment strategies (Fig. 4).

In addition, tumor recurrence was noted in two of the three patients with atypical meningioma: total removal was performed in one and adjuvant SRS in another case at 66 and 22 months, respectively, for a total of nine relapses (16.4%). Three out of five patients with atypical meningioma at recurrence died after reoperation and/or SRS a mean 83 months after initial surgery. The median overall survival was 104 months (range 0–290), 104 months (range 12–211) without relapse, and 114 months (range 81–290) with relapse.

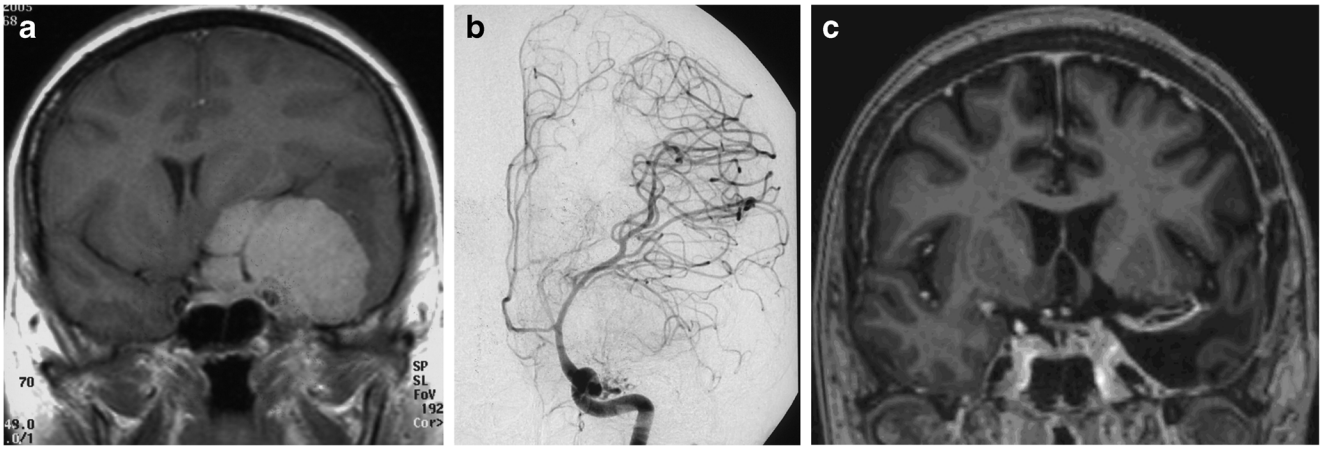

Fig. 2 MR enhanced T1-weighted images on coronal view and angiography showing the ICA and its branches (A1 and MCA) encased in the tumor (**a**, **b**). Postoperative coronal view showing complete removal of the intradural part with some remnants in the cavernous sinus (**c**). This patient did not undergo adjuvant SRS and the tumor is stable so far (58 months after surgery)

Discussion

Since 1990, medial sphenoid wing meningiomas have been extensively studied, thanks to a work by Al-Mefty [5] who identified clinoidal meningiomas and its subgroups including cavernous sinus involvement. Medial sphenoid wing meningiomas can occupy both areas (clinoidal and cavernous) and extend beyond them [12]. The distinctive features are primary attachment (either of the two, keeping in mind that clinoidal meningiomas may extend to the cavernous sinus rather than the contrary) and type of cavernous sinus involvement, since the lateral wall may be peeled away from the tumor, while medial occupation with carotid encasement is a surgical limitation [13–16]. Our observation of primary invasion in 8.3% of cases and secondary invasion in 30% is shared by Russell et al. (31.4%) [8] but not by Nakamura et al. (63.9%) [12]. The growing experience with this type of tumor makes Al Mefty's inference about the arachnoidal plane around the ICA and its main trunks unlikely, invaliding the same classification. As a consequence, both tumors are surgical targets for debulking and functional improvement, with the arachnoidal plane being difficult to predict yet often present [6, 8, 17]. Further detailed description of tumor site is feasible only in small or middle-sized tumor. Bassioumi et al. [17] and Pamir et al. [18] described a tumor subgroup with better prognosis, i.e., tumors extending only into the anterior cranial fossa, above the clinoid, because of improbable vascular adhesions. Nakamura described a medial and a lateral group of tumors of the inner sphenoidal wing, with the medial involving the cavernous sinus and the lateral lying outside with less vascular involvement [12].

Clinico-radiological features

Clinical and radiological features are often closely linked. Tumor size typically affects the visual apparatus, by far the most frequently involved nervous structure. In this series of large tumors (mean diameter 3.44 cm and 48.3% of cases with

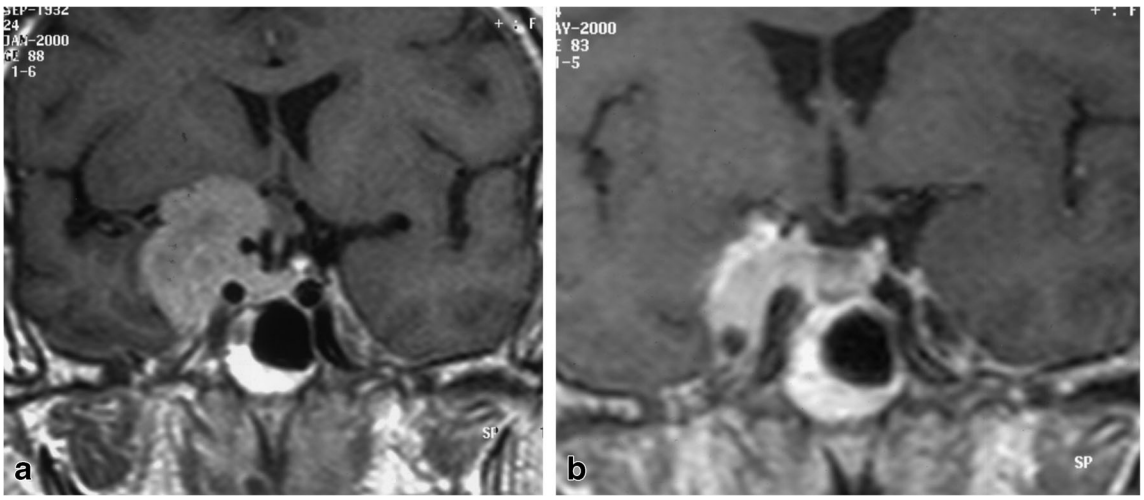

Fig. 3 Preoperative coronal view on MR enhanced T1-weighted images showing primary exophytic cavernous sinus meningioma (**a**). Postoperative scans showing cytoreduction (**b**). This patient underwent adjuvant SRS

Table 5 Perioperative complications

Complication	Cases	%
None	44	73.3
Local	2	3.3
Systemic	3	5
Neurological	7	11.7
Neurological + local	2	3.3
Neurological + systemic	2	3.3
Total local	4	6.7
Total systemic	5	8.3
Total neurological	11	18.3

extension into neighboring areas), visual symptoms were present in 51.7% of cases, followed by headache and epilepsy [5, 19–21].

The relation of the carotid artery with the tumor was classified by Hirsh et al. [22] and Behari et al. [23]. However, depending on site of tumor attachment, size, and extension, it is not the only vessel involved. We found a different pattern of severe vascular involvement whose extent was seen to increase surgical risk and therefore merits special attention. Calcifications were noted in 23.3% of cases, often limited to the clinoid rather than to the majority of the tumor mass [20, 22]. Pneumatized clinoid should be investigated for the risk of rhinorrhea (Fig. 1) [24]. Massive edema may have several different pathological meanings: effect of angiogenetic factors, expression of malignancy, compression of the sylvian veins, which is merely a mechanical obstacle of low prognostic importance [10, 24].

Extent of surgical removal

Surgical features are not consistent across clinical series; total removal varies from 30 to 77% probably due to the intrinsic heterogeneity of this group of meningiomas in which the main determinants of surgical outcome are clear [9, 12, 17, 25, 26]. Tumor extension into the cavernous sinus or controlaterally, encasement of the ICA and its main trunks, tumor size, arachnoid cleavage, and tumor consistency remain, in order of importance, the main predictors for subtotal removal in most series published to date including ours. This is borne out by the relative number of classification systems [4, 8, 18, 20, 23, 27]. We found that the extent of vessel encasement and narrowing is a major limitation, more so than the involvement of a single portion (carotid vs. middle cerebral artery vs. anterior cerebral artery). In addition, the anfractuosity of the dural folds in this small area makes it highly probable that nests of cells will be left in site, providing an opportunity for the tumor to recur even after total removal (12.5% in our series, similar to others) [5, 12, 17, 26, 28].

Functional outcome

Refining technical steps like early unroofing of the optic canal, clinoidectomy, and apical orbitectomy have led to safer management of the optic nerve and precocious identification of the carotid artery, which are key elements for enhancing visual improvement and safety [6, 7, 9, 18, 29–31]. In larger tumors, if the tumor burden cannot be managed, the site of attachment at the distal course of the middle cerebral artery can be followed backwards to the carotid bifurcation, using the vessels as a guide to split the tumor before further debulking [17, 32]. We fully share this surgical strategy, having often identified an arachnoidal plane around the vessels even in those that were encased and narrowed [8, 19].

Surgical technique has dramatically improved functional outcome and lowered the rate of vascular complications from 45 to 4%. This has drawn attention to a critical factor limiting surgical removal, i.e., the firm adhesion between tumor and vascular adventitia [12, 18, 33]. In the present study, taking together local, neurological (including vascular), and systemic complications, the overall neurological complication rate was 18%, of which only 6% persisted at 3 months (50% ocular

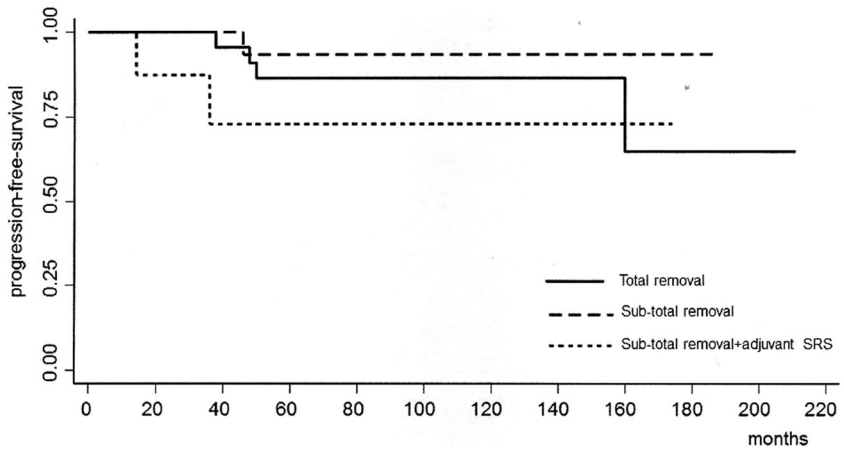

Fig. 4 Kaplan–Meier curve. Progression-free survival was estimated based on the type of treatment as a three-level variable (total removal vs. subtotal removal vs. subtotal removal with adjuvant SRS). There were no significant differences between the three treatment modalities

cranial nerves and 50% vascular complications, respectively). The type of long-term consequences was similar to previous studies [12, 17, 23, 34]. Oculomotor impairment was also reported as the most frequent persistent deficit (range 8 to 41%) possibly due to aggressive clinoid drilling [5, 24, 25, 35].

Long-term visual improvement ranged between 40 and 77% [5, 9, 12, 17, 36], while impairment remained stable between 14 and 22% [17, 25]. Predictors of visual outcome have been assessed by Margalit et al. [35] who reported on preoperative degree of visual impairment, tumor size, and optic nerve encasement, while Chaichana et al. [37] reported on preoperative visual acuity, subtotal removal, and recurrent tumor. In the past, less attention was given to other symptoms/signs. All patients in the present series were symptomatic before surgery and improved at 12 months after surgery with a KPS > 70 in 87.3% of cases.

Recurrence and survival

In medial sphenoidal wing meningioma, especially in CS meningioma, SRS has been demonstrated effective on residual tumor to prevent tumor progression [14, 37–41]. The present study may provide some answers for clinical management based on validated treatments with different strategies (total vs. subtotal removal and adjuvant vs. adjunctive SRS), the longest follow-up published in the literature (median 104 months), and the median progression-free survival consistently observed within 60 months [17].

The type of surgical removal did not influence malignant transformation into atypical meningiomas, even though the number is limited, which per se is a major determinant for recurrence and survival. Early SRS was noted to prevent regrowth as compared with observation (regrowth rate 6.2% vs. 28.6%), whereas delayed treatment, at recurrence/regrowth, seemed to be less effective (regrowth rate 20%, albeit with a limited number). These clinically meaningful differences were not statistically significant for progression-free survival or survival.

Two main reasons to delay SRS are as follows: the risk of scarring caused by SRS, which is an adverse factor for both safety and extent of surgical removal in case of need for reoperation, and the indolent biological behavior of CS meningiomas [5, 8, 13, 16, 17]. In any case, convergent results indicate that the main objectives of surgery are to reduce the mass to improve the patient's quality of life, reduce the risk of regrowth, and facilitate further treatment [4, 28, 38, 39, 41, 42].

Conclusions

Surgery remains the gold standard for the treatment of symptomatic meningioma of the inner sphenoidal wing. Based on clinical and radiological findings, the surgical risk can be estimated with fairly good precision—but not completely because arachnoidal cleavage around vessels is an (often favorable) intraoperative determinant. The major determinants for extent of surgical removal are tumor extension in the CS and degree of vascular involvement. The mortality rate in this series was 1.7%. Because they can be persistent, vascular and oculomotor complications increase the risk of diminished quality of life (6.7%). Although the Kaplan–Meier curve did not show a significant difference in progression-free survival between the three strategies (observation after total removal, observation after subtotal removal, and adjuvant SRS after subtotal removal), we noted that early SRS was associated with lower regrowth rate (6.2% vs. 28.6%). Our cautious approach to dealing with tumor adherent to vessels or invading the CS has yielded very good results with low mortality, low rate of persistent complications, and excellent long-term tumor control.

Compliance with ethical standards

- The authors declare that they have no conflict of interest.
- 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.
- For this type of study, formal consent is not required.

References

1. Al-Mefty O (1990) Clinoidal meningiomas. J Neurosurg 73:840–849
2. Mathiesen T, Lindquist C, Kihlstrom L, Karlsson B (1996) Recurrence of cranial base meningiomas. Neurosurgery 39:2–7; discussion 8–9
3. Metellus P KS, Kapoor S, Weiss S, Rigamonti D.(2007) Cavernous sinus meningiomas: treatment strategy in the stereotactic irradiation era. A review. Neurosurg Q.226–234
4. Nanda A, Konar SK, Maiti TK, Bir SC, Guthikonda B (2016) Stratification of predictive factors to assess resectability and surgical outcome in clinoidal meningioma. Clin Neurol Neurosurg 142:31–37
5. Abdel-Aziz KM, Froelich SC, Dagnew E, Jean W, Breneman JC, Zuccarello M et al (2004) Large sphenoid wing meningiomas involving the cavernous sinus: conservative surgical strategies for better functional outcomes. Neurosurgery 54:1375–1383; discussion 1383–1374
6. Lee JH, Jeun SS, Evans J, Kosmorsky G (2001) Surgical management of clinoidal meningiomas. Neurosurgery 48:1012–1019; discussion 1019–1021
7. Lee JH, Sade B, Park BJ (2006) A surgical technique for the removal of clinoidal meningiomas. Neurosurgery 59:ONS108–ONS114; discussion ONS108–114
8. Russell SM, Benjamin V (2008) Medial sphenoid ridge meningiomas: classification, microsurgical anatomy, operative nuances, and long-term surgical outcome in 35 consecutive patients. Neurosurgery 62:1169–1181
9. Tobias S, Kim CH, Kosmorsky G, Lee JH (2003) Management of surgical clinoidal meningiomas. Neurosurg Focus 14:e5

10. Louis DN, Ohgaki H, Wiestler OD, Cavenee WK, Burger PC, Jouvet A, Scheithauer BW, Kleihues P (2007) The 2007 WHO classification of tumours of the central nervous system. Acta Neuropathol 114:97–109
11. Therasse P, Arbuck SG, Eisenhauer EA, Wanders J, Kaplan RS, Rubinstein L, Verweij J, van Glabbeke M, van Oosterom AT, Christian MC, Gwyther SG (2000) New guidelines to evaluate the response to treatment in solid tumors. European Organization for Research and Treatment of Cancer, National Cancer Institute of the United States, National Cancer Institute of Canada. J Natl Cancer Inst 92:205–216
12. Nakamura M, Roser F, Jacobs C, Vorkapic P, Samii M (2006) Medial sphenoid wing meningiomas: clinical outcome and recurrence rate. Neurosurgery 58:626–639, discussion 626–639
13. De Jesus O, Sekhar LN, Parikh HK, Wright DC, Wagner DP (1996) Long-term follow-up of patients with meningiomas involving the cavernous sinus: recurrence, progression, and quality of life. Neurosurgery 39:915–919; discussion 919–920
14. Hasegawa T, Kida Y, Yoshimoto M, Koike J, Iizuka H, Ishii D (2007) Long-term outcomes of Gamma Knife surgery for cavernous sinus meningioma. J Neurosurg 107:745–751
15. Klinger DR, Flores BC, Lewis JJ, Barnett SL (2013) The treatment of cavernous sinus meningiomas: evolution of a modern approach. Neurosurg Focus 35:E8
16. Sindou M, Wydh E, Jouanneau E, Nebbal M, Lieutaud T (2007) Long-term follow-up of meningiomas of the cavernous sinus after surgical treatment alone. J Neurosurg 107:937–944
17. Bassiouni H, Asgari S, Sandalcioglu IE, Seifert V, Stolke D, Marquardt G (2009) Anterior clinoidal meningiomas: functional outcome after microsurgical resection in a consecutive series of 106 patients. Clinical article. J Neurosurg 111:1078–1090
18. Pamir MN, Belirgen M, Ozduman K, Kilic T, Ozek M (2008) Anterior clinoidal meningiomas: analysis of 43 consecutive surgically treated cases. Acta Neurochir (Wien) 150:625–635; discussion 635–626
19. Cui H, Wang Y, Yin YH, Fei ZM, Luo QZ, Jiang JY (2007) Surgical management of anterior clinoidal meningiomas: a 26-case report. Surg Neurol 68(Suppl 2):S6–S10; discussion S10
20. Goel A, Gupta S, Desai K (2000) New grading system to predict resectability of anterior clinoid meningiomas. Neurol Med Chir (Tokyo) 40:610–616; discussion 616–617
21. Puzzilli F RA, Mastronardi L, Agrillo A, Ferrante L. (1999) Anterior clinoidal meningiomas: report of a series of 33 patients operated on through the pterional approach. Neuro Oncol. :188–195
22. Hirsch WL, Sekhar LN, Lanzino G, Pomonis S, Sen CN (1993) Meningiomas involving the cavernous sinus: value of imaging for predicting surgical complications. AJR Am J Roentgenol 160: 1083–1088
23. Behari S, Giri PJ, Shukla D, Jain VK, Banerji D (2008) Surgical strategies for giant medial sphenoid wing meningiomas: a new scoring system for predicting extent of resection. Acta Neurochir (Wien) 150:865–877; discussion 877
24. Spektor S, Dotan S, Mizrahi CJ (2013) Safety of drilling for clinoidectomy and optic canal unroofing in anterior skull base surgery. Acta Neurochir 155:1017–1024
25. Attia M, Umansky F, Paldor I, Dotan S, Shoshan Y, Spektor S (2012) Giant anterior clinoidal meningiomas: surgical technique and outcomes. J Neurosurg 117:654–665
26. Liu DY, Yuan XR, Liu Q, Jiang XJ, Jiang WX, Peng ZF, Ding XP, Luo DW, Yuan J (2012) Large medial sphenoid wing meningiomas: long-term outcome and correlation with tumor size after microsurgical treatment in 127 consecutive cases. Turk Neurosurg 22:547–557
27. Risi P, Uske A, de Tribolet N (1994) Meningiomas involving the anterior clinoid process. Br J Neurosurg 8:295–305
28. Czernicki T KP, Nowak A, Marchel A. (2015) Results of surgical treatment of anterior clinoidal meningiomas – our experiences. . Neurol Neurochir Pol.:29–35
29. Lehmberg J, Krieg SM, Mueller B, Meyer B (2013) Impact of anterior clinoidectomy on visual function after resection of meningiomas in and around the optic canal. Acta Neurochir 155:1293–1299
30. Mariniello G, de Divitiis O, Seneca V, Maiuri F (2012) Classical pterional compared to the extended skull base approach for the removal of clinoidal meningiomas. J Clin Neurosci 19:1646–1650
31. Taha AN, Erkmen K, Dunn IF, Pravdenkova S, Al-Mefty O (2011) Meningiomas involving the optic canal: pattern of involvement and implications for surgical technique. Neurosurg Focus 30:E12
32. Yoshimoto K, Nakamizo A, Sasaki T (2013) Surgical techniques for the dissection of encased perforators in giant clinoidal meningiomas. Acta Neurochir 155:1409–1412
33. Yang J, Ma SC, Liu YH, Wei L, Zhang CY, Qi JF, Yu CJ (2013) Large and giant medial sphenoid wing meningiomas involving vascular structures: clinical features and management experience in 53 patients. Chin Med J 126:4470–4476
34. O'Sullivan MG, van Loveren HR, Tew JM Jr (1997) The surgical resectability of meningiomas of the cavernous sinus. Neurosurgery 40:238–244; discussion 245–237
35. Margalit NS, Lesser JB, Moche J, Sen C (2003) Meningiomas involving the optic nerve: technical aspects and outcomes for a series of 50 patients. Neurosurgery 53:523–532; discussion 532–523
36. Yonekawa Y, Ogata N, Imhof HG, Olivecrona M, Strommer K, Kwak TE, Roth P, Groscurth P (1997) Selective extradural anterior clinoidectomy for supra- and parasellar processes. Technical note J Neurosurg 87:636–642
37. Chaichana KL, Jackson C, Patel A, Miller NR, Subramanian P, Lim M, Gallia G, Olivi A, Weingart J, Brem H, Quiñones-Hinojosa A (2012) Predictors of visual outcome following surgical resection of medial sphenoid wing meningiomas. J Neurol Surg B Skull Base 73:321–326
38. Dufour H MX, Métellus P, Régis J, Chinot O, Grisoli F. (2001) Long-term tumor control and functional outcome in patients with cavernous sinus meningiomas treated by radiotherapy with or without previous surgery: is there an alternative to aggressive tumor removal? Neurosurgery:285–296,
39. Duma CM LL, Kondziolka D, Harsh GR, Flickinger JC : (1993) Stereotactic radiosurgery of cavernous sinus meningiomas as an addition or alternative to microsurgery. Neurosurgery :699–704–695
40. Liscak R, Simonova G, Vymazal J, Janouskova L, Vladyka V (1999) Gamma knife radiosurgery of meningiomas in the cavernous sinus region. Acta Neurochir 141:473–480
41. Nicolato A, Foroni R, Alessandrini F, Bricolo A, Gerosa M (2002) Radiosurgical treatment of cavernous sinus meningiomas: experience with 122 treated patients. Neurosurgery 51:1153–1159; discussion 1159–1161
42. Brell M, Villa S, Teixidor P, Lucas A, Ferran E, Marin S et al (2006) Fractionated stereotactic radiotherapy in the treatment of exclusive cavernous sinus meningioma: functional outcome, local control, and tolerance. Surg Neurol 65:28–33; discussion 33–24