Cytology & Histology

Ouyang T, et al., J Cytol Histol 2014, 5:4
http://dx.doi.org/10.4172/2157-7099.1000237

Research Article Open Access

Sphenoid Wing Meningiomas: Surgical Strategies and Evaluation of Prognostic Factors Influencing Clinical Outcomes

Ouyang T[1], Zhang N[2], Wang L[1], Jiao J[1], Wang Y[1], Zhao Y[1], Li Z[1] and Chen J[1*]

[1]*Department of Neurosurgery, Tongji Hospital, Huazhong University of Science and Technology, Wuhan, PR China*

[2]*Department of Neurology, Tongji Hospital, Huazhong University of Science and Technology, Wuhan, PR China*

[*]**Corresponding author:** Jian Chen, Department of Neurosurgery, Tongji Hospital, Huazhong University of Science and Technology, Wuhan, 430030, PR China, Tel: 8602783665382; E-mail: husttjouyang110@163.com

Rec date: Feb 25, 2014, **Acc date:** May 23, 2014, **Pub date:** May 25, 2014

Abstract

Objective: To study microsurgical technique and prognostic factors influencing clinical outcomes in a series of 53 patients with sphenoid wing meningiomas.

Materials and Methods: The clinical materials of 53 patients with sphenoid wing meningiomas treated microsurgically between January 2008 and January 2012 were analyzed retrospectively. Postoperative follow-up ranged from 6 to 62 months (mean, 34 months). Clinical outcomes including postoperative quality of life and recurrence rate were evaluated. Univariate and multivariate statistical analysis were performed among the factors that might influence postoperative quality of life.

Results: In our group, the mean age of patients was 49 years. Mean tumor size was 3.9 cm. Total tumor resection were achieved in 38 cases (71.7%), subtotal in 10 cases (18.9%) and partial resection in 5 cases (9.4%). Within the follow-up period, 10 patients (18.9%) recurred and 3 patients (5.7%) died. Through univariate analysis, we found the postoperative Karnofsky Score (KPS) improvement was determined by various factors, including extent of tumor resection, peritumoral edema, tumor blood supply, size of the tumor, adhesion to the surrounding structures, encasement of major vessels and preoperative Karnofsky score .However, multivariate analysis showed that extent of tumor removal, tumor blood supply, adhesion to the surrounding structures, and encasement of the neurovascular structures were the most influential factors.

Conclusions: The extent of tumor removal and intraoperatively defined tumor characteristics played an important role in identifying postoperative functional status. An individual treatment strategy after careful preoperative evaluation could improve quality of life.

Keywords: Meningioma; Microsurgery; Multivariate analysis; Quality of life; Sphenoid wing

Abbreviations:

SWMs: Sphenoid Wing Meningiomas; KPS: Karnofsky Score; EBL: Estimated Blood Loss; STR: Subtotal Resection; PR: Partial Resection; POEZ: Pteriono-orbital Approach Extended to the Zygoma

Introduction

Sphenoid wing meningiomas (SWMs) account for approximately 15-20% of intracranial meningiomas [1]. The surgery of SWMs is complicated and difficult due to their invasion of bone and their proximity to main arteries and cranial nerves. Compared with other meningiomas, sphenoid swing meningiomas possess higher mortality, disability rate, and recurrence rate [2]. The symptoms of SWMs include headache, impaired vision, proptosis and limb weakness. Although there are plenty of studies on microsurgical management of SWMs [2,3], there have been few reports of univariate and multivariate statistical analysis of the factors influencing postoperative quality of life. This study focuses on a group of SWMs patients with surgical treatment. Many clinical variables were analyzed through statistical methods.

Materials and Methods

Between January 2008 and January 2012, a total 67 of patients with SWMs were treated in Wuhan TongJi hospital, China. But 14 patients were lost to follow up and were thus excluded from the statistical analysis for the sake of sample homogeneity. 22 males (41.5%) and 31 (58.5%) females patients were included in our study, with an age range of 35–72 years (mean, 49 years). 25 patients (47.2%) had impaired vision and 20 patients (37.7%) had headache. In our group, the preoperative $90 \leq KPS \leq 100$ was in 7 patients (13.2%), KPS=80 in 24 patients (45.2%), KPS=70 in 14 patients (26.4%), $50 \leq KPS \leq 60$ in 6 patients (11.3%) and $KPS \leq 40$ in 2 patients (3.7%). We enrolled patients with complete clinical data regarding patients demographics, clinical history, radiographic findings, operative details, anesthetic record and tumor characteristics, and pathological records. Each patient's preoperative and postoperative quality of life was assessed using Karnofsky Score (KPS). The clinical data of the 53 patients were retrospectively reviewed.

Radiologic examination and follow-up

All patients were given computed tomography (CT) and magnetic resonance imaging (MRI) scans preoperatively. Thirty six patients had three–dimensional CT and 46 patients received CTA examination preoperatively. After the discharge from hospital, patients were followed up from 6 to 62 months (mean, 34 months). 43 patients received MRI during follow-up. The follow-up information about postoperative quality of life and recurrence was collected by telephone interviews or during clinic visits. The patients were questioned with regard to their ability to work, how they coped with any existing disabilities, and their caregiver burden according to the KPS, but our classification of the KPS were a little different. In our classification the patients that could carry normal work with or without slight symptoms were classified to 90-100. The patients who could grudgingly carry normal work but with some symptoms or signs were classified to 80 and who were unable to carry normal work but could care for themselves were 70. The score 50-60 was given to patients that sometimes could care for themselves but often need help. The score ≤ 40 was given to patients who could not care for themselves.

Surgical techniques

The surgical approaches included a conventional pterional approach in 36 patients, extensive pterional approach in 12 patients andorbito-pterional approach extended to the zygoma in 5 patients. After the tumor was exposed, internal carotid artery should be identified. Generally, the base and feeding artery of the tumor were coagulated with bipolar coagulation first. After the tumor feeding artery was blocked, the tumor could be dealt with under clear operative field, and en bloc resection of tumor could be achieved. However, sometimes the tumor was too large and difficult to get its real base confirmed and the major feeding arteries could not be interrupted immediately. In this situation, we preferred to first coagulate the tumor capsule and abnormal arteries creeping on it, simultaneously dissecting tumor tissue nearby the base progressively. After tumor debulking was managed in piecemeal removal, the base of tumor could be determined and the major feeding artery be blocked. The basal dura was coagulated or incision in our cases. If the tumor involved the cavernous sinus, extra-cavernous portion of the tumor was removed while preserving anatomical continuity of neurovascular structures of cavernous sinus. If the tumor invaded into cavernous sinus, the part of tumor inside cavernous sinus was left behind because complete resection was not possible without a significant risk of further neurological deficits. The bulk of the intradural extra-cavernous part of the tumor was removed. If optic canal was involved, fibrous ligament would be opened and bone canal be drilled with continuous irrigation to avoid heat damage to optic apparatus.

Pathologic studies

According to WHO classification (2007) of tumors of the central nervous system [4], endothelial type were confirmed in 29 cases (54.7%), fibrous (fibroblastic) in 5 cases, transitional in 14 cases, angiomatous in 3 cases, atypical type in 2 cases. The first four groups corresponded to WHO grade 1 and the last group corresponded to WHO grade 2.

Statistical analysis

Univariate and multivariate statistical analysis were done among factors that might influence postoperative KPS improvement. Statistical analysis was performed with the use of X^2 test, Fisher's exact test and Logistic regression. SPSS 16.0 statistical software was used to deal with data and make 0.05 the boundary of statistical significance. For logistic statistical analysis, entry and removal probability values for stepwise were 0.10 and 0.10.

Results

Symptoms and signs

The clinical symptoms and signs included visual impairment, headache, limb weakness, proptosis, epilepsia, hemiplegia, psychological disturbances, dizziness, and hearing impairment. Of these symptoms and signs, visual impairment and headache were the main manifestations.

Surgical outcome and complications

Two patients died during perioperative period and three patients died at the time of follow-up. Gross total resection (Simpson grade I-II) was achieved in 38 of 53 cases (71.7%) and subtotal resection (Simpson grade III) in 10 cases (18.9%) and partial resection (Simpson grade IV) in 3 cases (9.4%). The vision improved in 60% of patients and headache improved in 65%. The mean operative time was 4.85 hours (range 2.5–12 hours). The estimated blood loss (EBL) was 1439 ml (range from 200 to 2800 ml). The comparison between preoperative and postoperative examination images of SWMs is shown in Figure 1, and the complications are shown in Table 1.

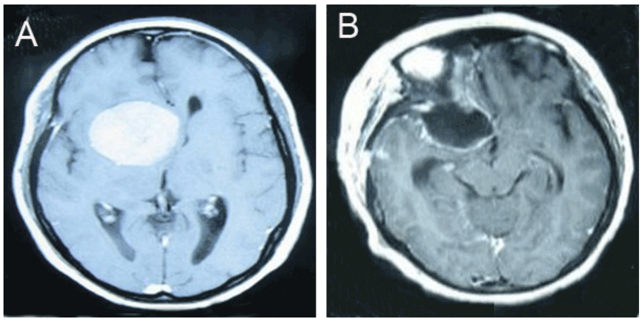

Figure 1: Contrast enhanced MRI (axial) revealed medial Sphenoid Wing Meningioma preoperatively (A). Contrast enhanced MRI (axial) revealed total removal (B)

Univariate analysis on postoperative quality of life

Postoperative quality of life was the most important index in assessing prognosis. The KPS was adopted in every patient preoperatively and at follow-up. Univariate analyses of different variables were made to search influential factors (Table 2). In general variables, age and gender were not significant factors influencing postoperative KPS improvement. The preoperative headache and impaired vision were also not significant factors. The tumor location and surgical approach were not significant factors influencing the postoperative quality of life. There was statistically significant relationship between tumor size and postoperative KPS improvement (P=0.034). Statistical significance was found between postoperative KPS improvement and extent of tumor resection, peri-tumoral edema (P=0.022; P=0.044). The improved KPS percentage of total resection

Citation: Ouyang T, Zhang N, Wang L, Jiao J, Wang Y, et al. (2014) Sphenoid Wing Meningiomas: Surgical Strategies and Evaluation of Prognostic Factors Influencing Clinical Outcomes. J Cytol Histol 5: 237. doi:10.4172/2157-7099.1000237

group (52.6%) was lower than that in subtotal resection group (90%) and partial resection group (100%). The intraoperatively defined tumor characteristics including the tumor blood supply, tumor adherence to adjacent structures and tumor encasement of neurovascular structures were significant factors (P=0.003; P=0.004; P=0.002). The preoperative KPS was also a significant factor (P=0.006). However, we did not find statistically significant factors among duration, estimated blood loss and operative time.

Complications	**Numbers**	**Percentages (%)**	**outcomes at Discharge**
CSF leakage	2	3.77	All cured
Incomplete aphasia	3	5.66	All improved but uncured
Subcutaneous collection	1	1.88	Cured
Oculomotor nerve palsy	3	5.66	1 cured ,2 improved
Epilepsy	3	5.66	Uncured
Ptosis	2	3.77	Uncured but improved
Epidural hematoma	2	3.77	All cured
Hemiplegia	5	9.43	3 improved ,2 unimproved
Cerebral infarction	1	1.88	Uncured
Tumor bed bleeding	2	3.77	All cured

Table 1: Postoperative Complications of Sphenoid Wing Meningiomas

Variables	**Improved/Unimproved**	**Improved Percentage (%)**	**P Value**
Gender			1.000
Male	15/7	68.1	
Female	20/11	64.5	
Age (years)			0.397
＜ 40	4/3	57.1	
40-50	18/6	75	
50-60	10/7	58.8	
＞ 60	2/3	40	
Headache			1.000
Yes	13/7	65	
No	22/11	66.7	
Impaired vision			0.402
Yes	15/10	60	
No	20/8	71.4	
Location			1.000
medial	13/7	65	
middle and lateral	22/11	66.7	
Tumor size (cm)			0.034
size ≤3	23/6	79.3	

3 < size ≤5	10/11	47.6	
size > 5	1/2	33.3	
Peritumoral edema			0.044
Yes	5/8	38.5	
No	29/11	72.5	
Encasement			0.002
Yes	2/8	20	
No	32/11	74.4	
Extent of resection			0.022
Simpson I-II	20/18	52.6	
Simpson III	9/1	90	
Simpson IV	5/0	100	
Approach			0.353
Conventional pterional	25/11	69.4	
Extended pterional	7/5	58.3	
POEZ*	2/3	40	
Blood supply			0.003
Rich	16/17	48.5	
Poor	18/2	90	
Adhesion			0.004
Yes	14/16	46.7	
No	20/3	87.0	
Pathological category			0.811
Endothelial	21/8	72.4	
Transitional	8/6	57.1	
Fibrous	3/2	60	
Angiomatous	2/1	66.7	
Atypical type	1/1	50	
Duration(months)			0.773
≤3	15/5	75	
3 < duration ≤ 6	5/3	62.5	
6 < duration ≤ 12	4/3	57.1	
12 < duration ≤ 24	4/3	57.1	
duration > 24	6/5	54.5	
Preoperative KPS			0.006
90 ≤ KPS ≤ 100	1/6	14.3	

KPS=80	19/5	79.2	
KPS=70	10/4	71.4	
50 ≤ KPS ≤ 60	4/2	66.7	
KPS ≤ 40	0/2	0	
Estimated blood loss (ml)			0.967
> 1600	6/3	66.7	
1200-1600	14/7	66.7	
900-1200	8/6	57.1	
600-900	3/1	75	
≤ 600	4/1	80	
Operative time (hour)			0.219
< 3	5/4	55.6	
4 ≤ time < 5	16/8	66.7	
5 ≤ time < 6	5/5	50	
6 ≤ time < 7	7/0	100	
≥ 7	2/1	66.7	
POEZ *: Orbito-petrional approach extended to the zygoma			

Table 2: Univariate analysis on KPS improvement

Multivariate analysis on postoperative KPS improvement

The univariate analysis showed some potential factors influencing KPS improvement, but that was not enough. We found that degree of tumor removal, tumor blood supply, tumor adhesion and tumor encasement were the most influential factors by multivariate logistic analysis (Table 3). However, other factors that had statistical significance in the univariate analysis including tumor size, peri-tumoral edema and preoperative KPS were eliminated through selection by the multivariate logistic analysis.

						95% C.I. for EXP(B)	
	B	SE	Wald	Sig.	EXP(B)	Lower Upper	
EOR	-2.240	1.168	3.675	0.055	0.107	0.011	1.051
Bloodsupply	-2.709	1.199	5.105	0.024	0.067	0.006	0.698
Adhesion	-1.827	0.912	4.012	0.045	0.161	0.027	0.962
Encasement	-2.286	1.261	3.289	0.070	0.102	0.009 1.203	
Constant	12.250	3.683	11.061	0.001	2.090E5		
EOR: Extent of Resection; B: Standard Partial Regression Coefficient; SE: Standard Error; Wald: value of Wald test C.I: Confidence Interval; Sig: Significance							

Table 3: Variables in the Equation of Mutlivariate Analysis

Recurrence

The 10 patients with STR (subtotal resection) and 5 patients with PR (partial resection) received postoperative radiosurgery. Of the 53 patients, there were ten patients with recurrence at the time of follow-up. The ten recurrent cases included three cases with total resection, four cases with subtotal resection and three cases with partial resection. The time of tumor recurrence was the shortest among in three partial resection (mean, 29 months), and was the longest among three total resection (mean, 52 months). Seven patients of the 15 patients (46.7%) with incomplete resection recurred after postoperative radiosurgery. From the view of pathological type, the ten recurrent cases included four of the 30 patients with endothelial type, three of the 14 patients with transitional type, one of the 5 cases with fibrous type, one of the 2 cases with angiomatous type and one of the 2 cases with atypical pathological type. Eight of the ten patients with recurrence received a secondary surgery and radiosurgery and the remaining two patients only received radiosurgery with regard to their age, physical condition and their own wish.

Discussion

General variables

For gender factor, in our group female were more than male and the female / male ratio was 1.4:1 compared with 2:1 in previous literatures [5]. No statistically significant effect of gender on postoperative quality of life was found in our data (P=1.000). The improved percentage of postoperative quality of life in patients aged < 60 years was higher than that in patients aged ≥ 60, but their difference was also not statistically significant. To the contrary of other studies impairment of vision was the most common symptom followed by headache of SWMs in our data [6,7]. After operation, the two symptoms improved some patients. The two symptoms could influence the pre-and postoperative KPS, but there was no statistically significant effect on the KPS improvement. The duration of symptoms ranged from several days to several years, but the improved percentage was not obviously different except that the duration ≤ 3 months could achieve better outcome. The preoperative KPS was a significant factor influencing postoperative quality of life in our data. We found that the improved percentage in patients with KPS of 90-100 was lower than that in patients with KPS of 80,70,50-60, which might be explained that there was hardly space for improving for those with KPS of 90-100. But except the highest preoperative KPS, other subgroups showed the better preoperative status was, the higher the improved percentage would be.

Tumor variables

In our data, we found that improvement of postoperative functional status was favourable (79.3%) when tumor size was less than 3 cm in diameter. Large SWMs frequently encase the major neurovascular, and invade cavernous sinus, and recruit abundant blood supply [8]. We also found that rich blood supply was a risk factor leading to worse quality of life post-operatively. For the SWM, the tumor may be supplied by either branches of internal or external carotid system, or both [9]. A careful analysis of CTA or MRA sequences is recommended to assess extent and origin of the feeding meningeal arterial branches of these meningiomas, particularly the branches that could come from internal carotid artery to feed the Tumor [10,11]. Vascular changes associated with meningiomas have been noticed as a sign of its direct involvement. The anterior basal meningiomas, particularly sphenoid wing meningiomas always bring vascular deformation, such as narrowing and occlusion of vessels [12]. Such vascular alteration adding rich blood supply indicates tremendous difficulties when dissecting and interrupting basal blood supply, which is the crucial step in resecting tumors. In our data, patients with tumors that were adherent to adjacent structures such as optic nerves and tract, cerebral vessel and bone showed a tendency to be associated with lower rates of KPS improvement compared with those with non-adherent tumors and the difference was statistically significant (P=0.01), which might be due to adhesion to optic nerve and optic tract resulting in lower resection rates and higher recurrence [13]. Of the 53 patients, only 38.5% of patients who had clear peri-tumoral edema by CT or MRI examination had KPS improvement compared with the non-edema group of 72.5% and the difference reached statistical significance. A positive correlation has been found between the extent of peri-tumoral edema and tumor size, cortical penetration, and consequentially tumor recurrence [14,15]. Peri-tumoral edema may limit operative exposure and increase difficulty of surgical resection by restricting of the amount of brain retraction possible and risk of postoperative intracranial hematoma and hypertension [13,16,17]. This might be due to the fact that peri-tumoral edema had highly significant lower cerebral blood flow and volume in neural tissue adjacent to the tumor [17]. In our series, the KPS improvement of group with neurovascular encasement was obviously lower than that in the other group without tumor encasement and reached statistical significance. When the tumor encases optic nerve, vision is difficult to improve. When tumors encase internal carotid artery trunk and its branches, it is often possible to dissect the vascular structures out of tumors, but this procedure increases risk of inducing vasospasm of the vessels with subsequently delayed neurological complications [18]. It is a really surgical challenge for surgeons when tumors invade cavernous sinus [2,19-21]. Total resection of the tumor invading cavernous sinus is difficult and often causes complications [22-25]. In the past three decades, controversies existed whether the tumor should be totally removed or not. Some authors have recommended a total removal of cavernous portion of tumor with the purpose of lessening tumor recurrence [26]. However, Sephernia et al. [27] emphasized the characteristic adhesion between tumor and surrounding tissue in meningioma in comparison to neurinoma or pituitary adenoma and rejected radical surgery in the first operation to avoid additional neurologic deficits. In our experience, the extra-cavernous portion of tumor is removed while preserving anatomical continuity of neurovascular structures of cavernous sinus, but the part of tumor inside cavernous sinus is left alone to avoid the risk of further neurological deficits. This is followed by postoperative radiotherapy. In the pathological classification, endothelial type was the most common (54.7%) but there was not statistical significance on postoperative KPS improvement in our series. Tumor location had no statistical significance on KPS although it has been acknowledged that operative difficulty of medial SWMs is more than middle and lateral SWMs.

Surgical variables

Whether total resection should be the final goal in management of SWMs or not is controversial. As a rule, gross total resection should not be at the expense of quality of life. For patients in whom total removal of tumor carries significant risk of morbidity, it is better to leave some tumor and plan to observe the patient because reoperation and or radiosurgery can be always considered. In our group, three kinds of approaches including conventional pterional approach, extended pterional approach and orbito-pterioanl approach extended to the zygoma [28,29] were adopted with first approach being the most common (67.9%). Utilizing any of the above approaches did not reach any statistical significance (P=0.353). After the univariate analysis, the estimated blood loss and operative time were not found with statistical significance on the postoperative KPS improvement.

Multivariate analysis

The result of multivariate analysis showed that extent of resection, tumor adhesion, tumor blood supply and encasement of neurovascular structures were the main factors influencing postoperative quality of life. Recent researches have shown that it is appropriate to leave parts of tumor invading into cavernous Sinus [22,24,29]. The policy for management of cavernous sinus involvement of these tumors has changed considerably over the years because of good result of radiation therapy for residual tumor in the cavernous sinus [27]. When tumors adhere to the optic nerve and tract, it is of great benefit to know their relationship before surgery to avoid postoperative visual deficit. When tumors adhere to adjacent bone, it can induce hyperostosis that is stimulated by meningioma cells [30]. Often, it is difficult to drill hyperostotic bone and completely excise dural attachment [13]. Despite extensive coagulation, the hyperostotic bone as well as its dural covering may provide a nidus for regrowth of the tumor [30,31]. Encasement of optic nerve or internal carotid artery influences total resection rate and increases risks of further neurologic deficits [32]. Resection of tumors with rich blood supply and adherence to optic nerve and tract, cerebral vessel and osseous requires better exposure, more exercises to cranial nerve and vascular structures, which might increase the risk of surgical complications, prolong the recovery time and even induce permanent neurological deficit.

Recurrence and postoperative therapy

Many studies have shown that extent of resection is the most important factor influencing recurrence rate [26]. Incomplete resection of meningiomas frequently results in recurrence, but even total resection is associated with a significantly high incidence of recurrence, ranging from 3 to 32% in different series [33]. The present study agrees with previous works in the importance of extent of resection to recurrence. In our group, seven of the 15 patients (46.7%) with incomplete removal of SWMs had recurrence compared with three of 38 patients (7.9%) suffering recurrence with total resection and the difference reached statistical significance (P=0.004). The relationship between histopathology and recurrence is still uncertain. One study with a single series of 1799 meningiomas from 1582 patients followed for an average of 13 years showed that the recurrence rate was 7% of WHO I tumors, 35% of WHO II, and 72.7% of WHO III [19]. In our group, no apparent relationship was found. As to the relationship between histopathology and recurrence, more studies may be required. In the recurrent cases, alternative treatments including a second –stage operation, radiotherapy, radiosurgery and chemotherapy have been considered according to the each case [20]. Radiotherapy has proven beneficial about one month after operation for patients with incompletely resected meningiomas, and may be beneficial in the recurrent cases [34]. Radiosurgery, can be considered as a safe and effective modality for tumor control [22].

Conclusion

To achieve a good postoperative quality of life in patients with SWM, intentionally, incomplete resection may be considered as an acceptable treatment option. Multivariate analysis confirmed that tumor blood supply, tumor adhesion to adjacent structure and degree of resection were the most important factors. However, this does not means that other factors are less important. The extent of resection and intraoperatively defined tumor characteristics play an important role in identifying postoperative functional status. An individual treatment strategy could improve quality of life.

References

1. Al-Mefty O (1991) Meningiomas. New York: Raven Press Ltd.
2. Kreppel D, Antoniadis G, Seeling W (2003) Spinal hematoma: a literature survey with meta-analysis of 613 patients. Neurosurg Rev 26: 1-49.
3. 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 626-39.
4. Perry A, Louis DN, Scheithauer BW, Budka H, Von D, et al. (2007) World Health Organization Classification of Tumours of the Central Nervous System, (4thedn), IARC Press, Lyon, 164-172.
5. Whittle I, Smith C, Navoo P, Collie D (2004) Meningiomas. Lancet 363: 1535-1543.
6. Behari, 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.
7. Honig S, Trantakis C, Frerich B, Sterker I, Kortmann RD, et al. (2010) Meningiomas involving the sphenoid wing outcome after microsurgical treatment--a clinical review of 73 cases. Cent Eur Neurosurg 71: 189-198.
8. Oi S, Saito K, Ichikawa M, Aimi Y, Okada T, et al. (2008) [Case of large sphenoid ridge meningioma treated by 2-stage surgery]. No Shinkei Geka 36: 885-890.
9. Yamaki T, Tanabe S, Sohma T, Uede T, Shinya T, et al. (1988) Feeding arteries of parasellar meningiomas--angiographic study of medial sphenoid ridge and tuberculum sellae meningiomas. Neurol Med Chir (Tokyo) 28: 553-558.
10. Bozzao A, Finocchi V, Romano A, Ferrante M, Fasoli F, et al. (2005) Role of contrast-enhanced MR venography in the preoperative evaluation of parasagittal meningiomas. Eur Radiol 15: 1790-1796.
11. Engelhard HH (2001) Progress in the diagnosis and treatment of patients with meningiomas. Part I: diagnostic imaging, preoperative embolization. Surg Neurol 55: 89-101.
12. Sansregret A, Ledoux R (1971) Lesser wing meningiomas: a few unfamiliar differential diagnoses. Neuroradiology 2: 9-14.
13. Roser F, Nakamura M, Jacobs C, Vorkapic P, Samii M (2005) Sphenoid wing meningiomas with osseous involvement. Surgical Neurology 64: 37-43.
14. Tomasello F, de Divitiis O, Angileri F, Salpietro M, d'Avella D (2003) Large sphenocavernous meningiomas: is there still a role for the intradural approach via the pterional-transsylvian route? Acta Neurochir (Wein) 145: 273-282.
15. 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.
16. Bitzer M, Klose U, Geist-Barth B, Nägele T, Schick F, et al. (2002) Alterations in diffusion and perfusion in the pathogenesis of peritumoral brain edema in meningiomas. Eur Radiol 12: 2062-2076.
17. Vignes JR, Sesay M, Rezajooi K, Gimbert E, Liguoro D (2008) Peritumoral edema and prognosis in intracranial meningioma surgery. J Clin Neurosci 15: 764-768.
18. Bassiouni H, Asgari S, Sandalcioglu E, Seifert V, Stolke D, et al. (2009) Anterior clinoidal meningiomas: functional outcome after microsurgical resection in a consecutive series of 106 patients Clinical article. J Neurosurg 111: 1078–1090.
19. Maier H, Ofner D, Hittmair A, Kitz K, Budka H (1992) Classic, atypical, and anaplastic meningioma: three histopathological subtypes of clinical relevance. J Neurosurg 77: 616-623.
20. Morita A, Coffey RJ, Foote RL, Schiff D, Gorman D (1999) Risk of injury to cranial nerves after gamma knife radiosurgery for skull base meningiomas: experience in 88 patients. J Neurosurg 90: 42-49.
21. Metellus P, Regis J, Muracciole X, Fuentes S, Dufour H, et al. (2005) Evaluation of fractionated radiotherapy and gamma knife radiosurgery in cavernous sinus meningiomas: treatment strategy. Neurosurgery 57: 873-886.
22. Eisenberg MB, Al-Mefty O, DeMonte F, Burson GT (1999) Benign nonmeningeal tumors of the cavernous sinus. Neurosurgery 44: 949-954.
23. Goel A, Muzumdar DP, Nitta J (2001) Surgery on lesions involving cavernous sinus. J Clin Neurosci 8 Suppl 1: 71-77.

24. Peker S, Kiliç T, Sengöz M, Pamir MN (2004) Radiosurgical treatment of cavernous sinus cavernous haemangiomas. Acta Neurochir (Wien) 146: 337-341.
25. Sughrue ME, Rutkowski MJ, Aranda D, Barani IJ, McDermott MW, et al. (2010) Factors affecting outcome following treatment of patients with cavernous sinus meningiomas. J Neurosurg 113: 1087-1092.
26. Puzzilli F, Ruggeri A, 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 1: 188-195.
27. Sepehrnia A, Samii M, Tatagiba M (1991) Management of intracavernous tumours: an 11-year experience. Acta Neurochir Suppl (Wien) 53: 122-126.
28. Newton HB, Scott SR, Volpi C (2004) Hydroxyurea chemotherapy for meningiomas: enlarged cohort with extended follow-up. Br J Neurosurg 18: 495-499.
29. Day JD (2000) Cranial base surgical techniques for large sphenocavernous meningiomas: technical note. Neurosurgery 46: 754-759.
30. Pieper DR, Al-Mefty O, Hanada Y, Buechner D (1999) Hyperostosis associated with meningioma of the cranial base: secondary changes or tumor invasion. Neurosurgery 44: 742-746.
31. Aziz KM, Froelich SC, Cohen PL, Sanan A, Keller JT, et al. (2002) The one-piece orbitozygomatic approach: the MacCarty burr hole and the inferior orbital fissure as keys to technique and application. Acta Neurochir (Wien) 144: 15-24.
32. 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.
33. Mirimanoff RO, Dosoretz DE, Linggood RM, Ojemann RG, Martuza RL (1985) Meningioma: analysis of recurrence and progression following neurosurgical resection. J Neurosurg 62: 18-24.
34. Aghi MK, Carter BS, Cosgrove GR, Ojemann RG, Amin-Hanjani S, et al. (2009) Long-term recurrence rates of atypical meningiomas after gross total resection with or without postoperative adjuvant radiation. Neurosurgery 64: 56-60.