Sphenoid Wing Meningiomas: Factors Affecting the Degree of Resectability and Outcome in 34 cases

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ABSTRACT

Objectives: *Sphenoid wing meningiomas are a formidable surgical challenge when they extend into the cavernous sinus. The goal of the present study is to evaluate the results of surgical management of sphenoid wing meningioma stressing on the factors determining the degree of tumor respectability and recurrence on the basis of experience with 34 cases.* ***Methods:*** *Thirty four patients with sphenoid meningiomas underwent surgery. Surgery was performed via fronto-temporal approach, and fronto-temporal with orbito-zygomatic (O-Z) osteotomy (23 cases and 11 cases respectively). A retrospective study was conducted by analyzing clinical data, neuro-imaging studies, operative findings, and histopathological reports. The degree of tumor removal, clinical outcome, post operative complications, and recurrence are described. The patients were classified into four subtypes, lateral, middle, medial (Clinoidal without CS invasion), and spheno-cavernous (with CS invasion) subtypes. The extent of tumor resection was graded according to the Simpson classification.* ***Results:*** *Encasement of the ICA and its branches was observed in ten (29.4 %) cases, while hyperostosis was present in four (11.8%) cases. Postoperative infarction from injury of middle cerebral artery territory occurred in four patients (11. 8%), two with medial (clinoidal) meningioma with encasement of MCA, and another two with middle sphenoid meningioma. Four patients died (11.8%). Three died from cerebral infarction after MCA injury during dissection (two clinoidal meningioma- one middle sphenoidal meningioma). Another patient died after evacuation of post operative ICH (spheno-cavernous). Total resection (Simpson Grade 2) was achieved in 14 patients (41.2%), subtotal resection (Simpson Grade 3) was achieved in nine patients (26. 5%), while Subtotal removal (Simpson Grade 4) was obtained in 11 patients (32.6%).* ***Conclusions:*** *The surgical treatment of medial sphenoid wing meningiomas still represents a difficult task for neurosurgeons. Location of the meningioma is an important factor determining the degree of tumor resectability. Encasement of ICA and/or MCA and their branches together with CS invasion and extension into superior orbital fissure are limiting factors for radical removal. Presence of hyperostosis, incomplete tumor removal, and atypical histopathological variant are factors responsible for recurrence. Conservative surgical strategy for clinoidal and spheno-cavernous meningiomas for better functional outcome should be taken in mind particularly with the advent of radiosurgery.*

Keywords; *clinoidal meningiomas; hyperostosis; meningiomas; spheno-cavernous meningiomas; recurrence.*

INTRODUCTION

Meningiomas are common tumors, accounting for 14 to 18% of intracranial neoplasms. Sphenoid ridge meningiomas represent approximately 20% of supratentorial meningiomas, among which less than half arise from the medial ridge[18]. Cushing and Eisenhardt were the first to describe sphenoid ridge meningiomas in detail. They distinguished between globoid tumors with nodular shape and en plaque tumors, which are flat and

spread along the entire ridge[8]. Nakamura et al.[18] classified medial sphenoid wing meningiomas into two different groups on the basis of preoperative radiological findings. Group 1 comprised tumors without cavernous sinus involvement. Group 2 included tumors with cavernous sinus involvement. Aziz et al.[1] classified medial (Clinoidal) meningiomas into 3 subgroups, clinoido-cavernous, spheno- cavernous, and spheno-clinoidocavernous meningiomas. Inner sphenoid wing and clinoidal meningiomas are a formidable surgical challenge when they extend into the cavernous sinus and become clinoido-cavernous, spheno- cavernous, or sphen-clinoidocavernous. Medial sphenoid wing meningiomas are challenging lesions to be resected completely and safely because they often involve the anterior visual pathways, arteries of the anterior circulation, and sometimes invade the cavernous sinus[18].

In this study, we report on a surgical series of 34 sphenoid wing meningiomas presenting the clinical outcome, with special focus on the factors determining the degree of tumor respectability and recurrence.

PATIENTS & METHODS

Between 1999 and 2007, 34 cases of sphenoid meningiomas were operated on at the Department of Neurosurgery, Ain Shams University Hospitals. There were 26 females, and eight males ranging in age from 12 to 69 years (mean 50.2 years). Computed tomographic (CT) scans were performed for all patients; osseous involvement was studied using multislice spiral CT. Magnetic resonance imaging (MRI) was performed for all cases.

Surgery was performed via fronto-temporal approach, and fronto-temporal with orbito-zygomatic (OZ) osteotomy (23 cases and 11 cases respectively). Clinical data, neuro-imaging studies, operative findings, post operative morbidity and mortality, and histopathological reports were analyzed retrospectively. The extent of tumor resection was graded according to the Simpson classification[25]. Grade 1 indicated total tumor resection with excision of infiltrated dura; Grade 2 indicated total tumor resection and coagulation of dural attachments; Grade 3 indicated gross total tumor resection without excising dural attachments or extradural extensions (e.g., infiltrated sinus or bone); and Grade 4 indicated subtotal tumor resection. Immediate 1st day post operative CT scan was performed routinely. Post operative follow up MRI in first 3 months was also done routinely. Periodic post operative clinical and radiological follow up period ranged from three to 90 months (mean 40 months).

Tumor classification, and approach selection

On the basis of preoperative imaging studies and after intra-operative inspection and exploration, the patients were classified into four subtypes, lateral, middle, medial (Clinoidal without CS invasion), and spheno-cavernous (with CS invasion) subtypes. In large tumors involving the medial sphenoid and cavernous sinus, the exact site of origin (medial sphenoid compared with cavernous sinus) is often difficult to determine. Therefore, the term spheno-cavernous meningioma involved tumor that extend on both medial sphenoid and cavernous sinus[18].

Surgical approach was selected according the location of the tumor its basal attachment and the aim of surgery either radical or conservative surgery depending on the preoperative imaging study. Fronto-temporal approach was used in 23 patients (67.7%) (Five having lateral meningiomas, eight cases with middle sphenoid meningiomas, and ten cases with medial sphenoid meningioma). The remaining 11 patients (32.3%) were approached by fronto- temporal approach with O-Z osteotomy (spheno-cavernous variant) [Table 1].

In order to preserve the frontal branch of facial nerve, the skin incision is initiated 1 cm anterior to the tragus at the level of the zygomatic arch and extended behind the hairline toward the contralateral superior temporal line. The scalp flap is reflected anteriorly, leaving thick areolar tissue with the pericranial layer adhering to the calvaria. Both the superficial and the deep layers of the temporal fascia are incised 1 cm posterior and parallel to the course of the frontal branches of the facial nerve, along the zygomatic arch. The deep and superficial layers with their intervening fat pad, which contain the facial branches, are then reflected with the skin flap.

Fashioning of fronto- temporal craniotomy is performed as mentioned previously in literature[1,11,18]. The orbito- zygomatic osteotomy was tailored in two pieces.

After adequate exposure, good drilling of the lateral sphenoid ridge is performed to increase angle of exposure. Cutting of the basal blood supply is done mainly by cauterization of the middle meningeal artery to aid in tumor resection and minimized blood loss.

The dura is opened in a semicircular fashion from the frontal to temporal regions. Central debulking was started by using CUSA or piecemeal removal of the central part of the tumor by microsurgical technique. There is usually an arachnoid plane preserved between the tumor and the surrounding critical neuro vasculature such as the optic nerve, ICA and its branches (Fig 1-B.). The remainder of the tumor circumscribing or displacing the optic nerve, ICA, and their branches, and the oculomotor nerve were removed through the inter optic, optico-carotid, and carotico-oculomotor triangles. The cavernous sinus might be explored if the tumor is soft and amenable to extirpation. After exposing normal vessels proximal and distal to the tumor, the dissection should be through the arachnoidal planes around blood vessels and split the tumor along the distal ICA and the proximal middle cerebral artery. This results in two tumor pieces on both sides of the vascular tree, which were subsequently easily resected. In cases with extensive cavernous sinus involvement by fibrous and tough tumor, surgery was stopped after confirmation of the following: 1) gross-total resection of the intradural extracavernous portion of the tumor and removal of any accessible tumor-involved dura; 2) decompression of the optic nerve; and 3) decompression of the oculomotor nerve. The dura was closed using interrupted sutures and the dural defect repaired using pericranial flap as a dural graft.

RESULTS

Clinical Presentation

Headache was the first most common presenting symptom occurring in 31 (91.2%) of patients,

and it was the only presenting symptom in two patients (5.9%). The second common presenting symptoms was seizure in 26 (76.5%) of patients. Visual deterioration was observed in 17 (50%) of patients, facial pain in 11 (32.3%), diplopia in 10 (29.4%) [All have spheno-cavernous subtype], and motor weakness in seven patients (20.6%).

Neuro-imaging features

Peritumoral edema was observed in 11 (32. 3%) cases, three in lateral sphenoid [Fig. 1 B], three in middle sphenoid, three in medial sphenoid, and two in spheno- cavernous. Encasement of the ICA and its branches was observed in ten (29. 4 %) cases, five spheno-cavernous (cavernous carotid) [Fig. 6 A- B], three medial sphenoid (Supaclinoid segment) [Fig. 5 A- B] and two middle sphenoid meningioma (MCA) [Fig. 4 A- B]. Tumor calcification was found in six (17. 7%) cases (Fig. 1 A), three middle sphenoid, two medial sphenoid meningioma, and one lateral sphenoid meningioma. Hyperostosis (Fig. 2 A) was present in four (11. 8%) cases, three laterals sphenoid and one patient with medial sphenoid meningioma. [Table 2].

Clinical outcome

Motor power improved in four (11.8%) patients who have motor deficit before surgery. Vision improved in three (8.8%) patients after optic nerve decompression but still there is another three patients have more deterioration of vision than preoperative condition.

Morbidity

The most common surgical complication encountered was postoperative subcutaneous cerebrospinal fluid (CSF) collection in eight (23. 5 %) patients. One of them developed wound infection. No meningitis occurred. CSF collection was controlled via repeated lumber puncture.

Postoperative infarction from injury of middle cerebral artery territory occurred in four patients (11. 8%), two with medial (Clinoidal) meningioma with encasement of MCA, and another two with middle sphenoid meningioma. Three of them died (two clinoidal, and one middle sphenoid) from massive cerebral infarction, and another patient developed new motor deficit than preoperative, and then improved by medical treatment and rehabilitation after four months (middle sphenoidal meningioma-Fig. 4 A- B- C- D). Postoperative hemorrhage occurred in one (2.9%) patient (spheno-cavernous meningioma) which required surgical evacuation. The patient died in the first two weeks. Postoperative facial pain and numbness as new deficit occurred in four patients (11. 8 %). Postoperative visual deterioration observed in three patients (8. 8 %), one of them improved by follow up.

Mortality

Four patients died (11. 8%). Three died from cerebral infarction after MCA injury during dissection (two clinoidal meningioma- one middle sphenoidal meningioma). Another patient died after evacuation of ICH (spheno-cavernous). One patient (spheno-cavernous) died after recurrent surgery and postoperative irradiation and her general condition was poor.

Degree of tumor removal

Total resection (Simpson Grade 2) was achieved in 14 patients (41. 2%)

[Five lateral sphenoid (1oo%) [Fig. 1, A- B- C- D & Fig. 2 A- B], seven middle sphenoid (87. 5 %) [Fig. 3, A- B- C- D], and two medial sphenoid (20 %) [Fig. 5, A- B- C- D]. Subtotal resection (Simpson Grade 3) was

achieved in nine patients (26. 5%) [One midd1e sphenoid (11. 1 % -Fig. 4 A, B, C, D), three medial sphenoid (33. 3 %), and five spheno-cavernous (55, 6 %)].Subtotal removal (Simpson Grade 4) was obtained in 11 patients (32. 6 %) [Five medial sphenoid (45. 5 %), and six spheno-cavernous (54. 5 %) (Fig. 6 A- B- C- D]. [table 3].

Radiosurgery and conformal radiotherapy

Gamma knife was applied in three patient having spheno-cavernous meningiomas, two of them with Simpson grade 3- removal and another with grade 4- removal. Neither recurrence, nor regrowth was observed during the follow up. Another four patients with spheno-cavernous residual tumor received conformal radiation, while another three patients with spheno-cavernous meningiomas with C S residue still under periodic follow up.

Tumor recurrence

In this series, recurrence was observed in four patients (11. 8%). One patient with lateral sphenoid meningioma showed recurrence after complete excision (Simpson grade 2) five years after surgery. Another surgery was performed and the patient received conformal irradiation. The second case of recurrence was observed in one patient with middle sphenoid meningioma in whom subtotal removal was achieved (Simpson grade 3) and the patient refused surgery and received conformal radiation therapy. The third case of recurrence was observed in another patient with medial sphenoidal meningioma after subtotal resection. In the fourth case, the recurrence occurred after incomplete excision (Simpson Grade 4) of spheno-cavernous meningioma two years after surgery and conformal irradiation with cyto-reduction were done again. However, the patient can not tolerate the irradiation as the general condition was very poor and died after four months of follow up.

Table (1) approaches used for sphenoid meningiomas

		Approach selection	
		Frontotemporal with O Z osteotomy	**Frontotemporal**
Location	Lateral sphenoid	0	5
	Middle sphenoid	0	8
	Medial sphenoid	0	10
	Sphenocavernous	11	0
Total		11	23

Table (2) Neuro-imaging features

		Location			
		Lateral sphenoid	**Middle sphenoid**	**Medial sphenoid**	**Sphenocavernous**
Peritumoral edema	Absent	2	5	7	9
	Present	3	3	3	2
Tumor calcification	Absent	4	5	8	11
	Present	1	3	2	0
Hyperostosis	Absent	2	7	10	11
	Present	3	1	0	0
Encasement of the ICA	Absent	5	6	7	6
	Present	0	2	3	5

Table (3) Simpson Grading

	Simpson Grading			
Location	**2**	**3**	**4**	**Total**
Lateral sphenoid	5	0	0	5
Middle sphenoid	7	1	0	8
Medial sphenoid	2	3	5	10
Sphenocavernous	0	5	6	11
Total	14	9	11	34

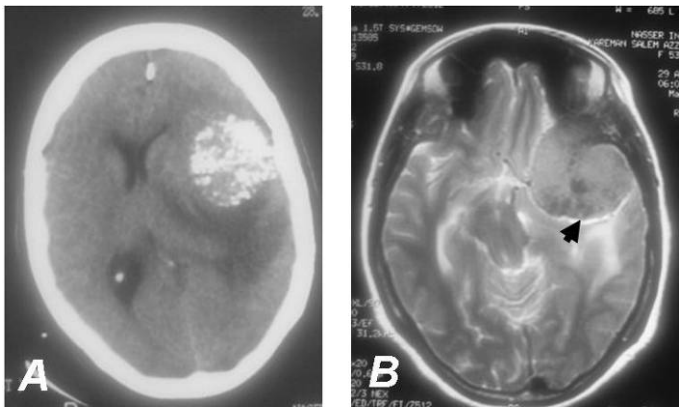

Fig.1 (A, B). In (A) axial CT scan demonstrates calcification, and (B) axial pre operative T2- weighted MRI showing lateral sphenoid wing meningioma. The black arrowhead demonstrates intact arachnoid cleavage line.

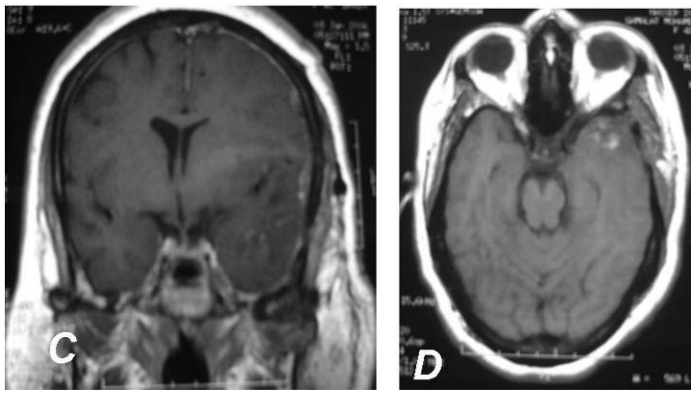

Fig. 1 (C, D). In (C) coronal, and (D) axial post operativeT-1 weighted MRI with Gd-DPTA showing total tumor removal of lateral sphenoid wing meningioma via fronto-temporal craniotomy.

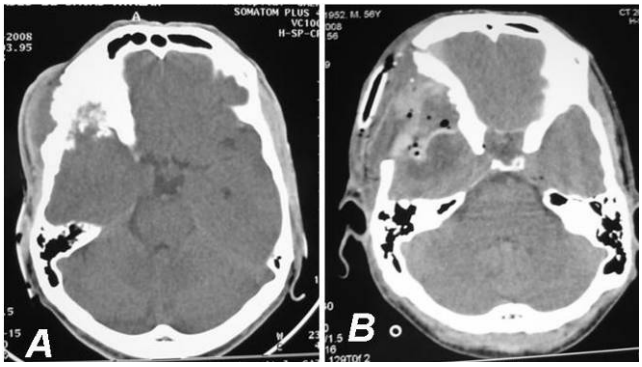

Fig. 2 (A, B). In (A) axial CT scan demonstrates small lateral sphenoidal meningioma with hyperostosis and soft exta-calvarial soft tissue mass. In (B) post operative CT scan with intravenous contrast showing total tumor removal after fronto-temporal craniotomy, with drilling of the hyperostotic bone.

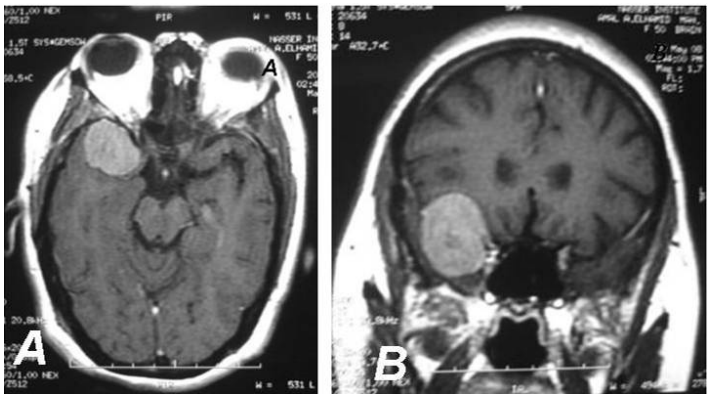

Fig. 3 (A, B). In (A) pre operative axial T-1 weighted MRI and (B) coronal T1- weighted MRI with Gd- DPTA showing middle sphenoidal meningioma.

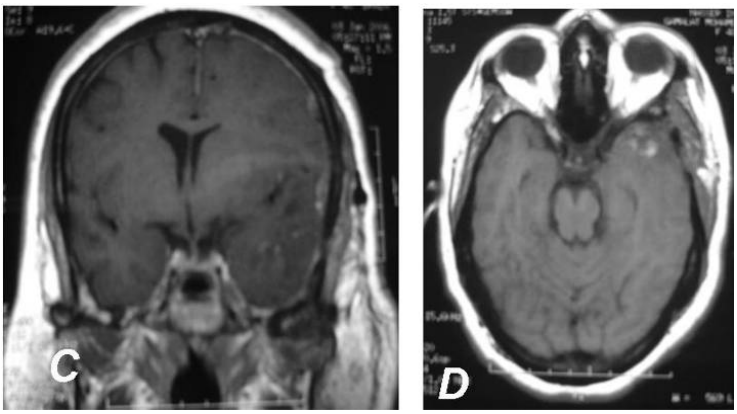

Fig. 3 (C, D). In (C) post operative coronal T-1 weighted MRI, and (D) axial T1- weighted MRI with Gd- DPTA showing total tumor removal of middle sphenoidal meningioma.

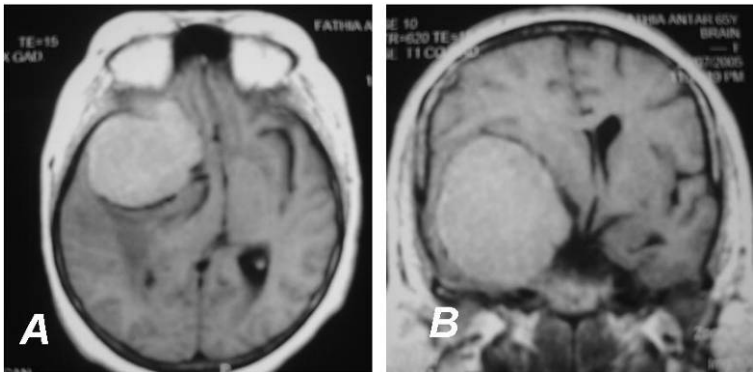

Fig. 4 (A, B). In (A) pre operative axial T-1 weighted MRI, and (B) coronal T1- weighted MRI with Gd- DPTA showing large middle sphenoidal meningioma with encasement of MCA .

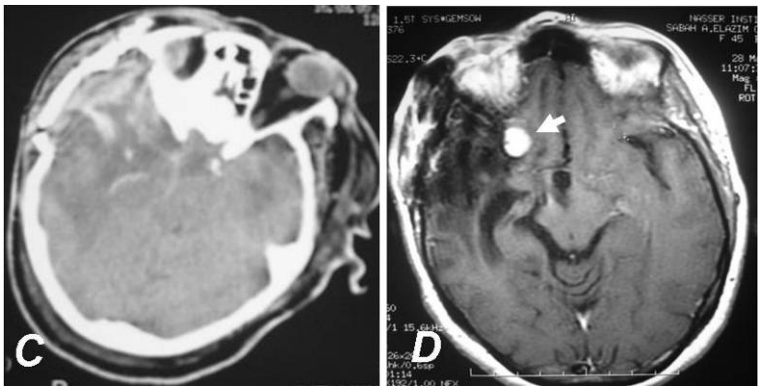

Fig. 4 (C, D). In (C) axial pos operative CT scan demonstrates post operative edema, and subarachnoid hemorrhage with acute cerebral infarction along MCA territory, and (D) axial post operative T1- weighted MRI with Gd- DPTA showing subtotal removal and encephalomalacia related to MCA infarction (white arrowhead demonstrates the residual around ICA bifurcation).

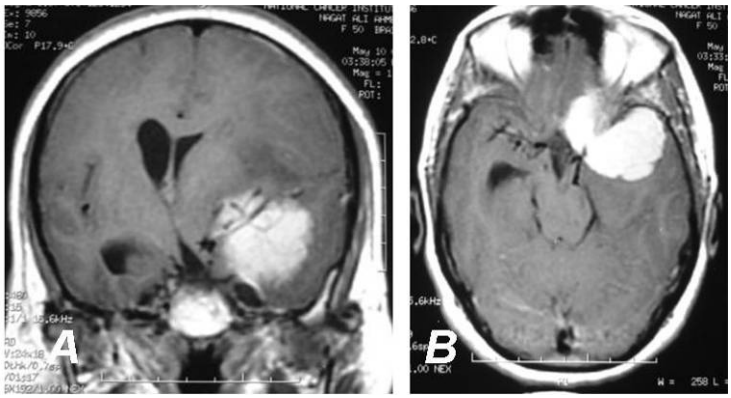

Fig. 5 (A, B). In (A) pre operative coronal T-1 weighted MRI and (B) axial T1- weighted MRI with Gd- DPTA showing large medial sphenoidal meningioma with encasement of supraclinoidal ICA and MCA.

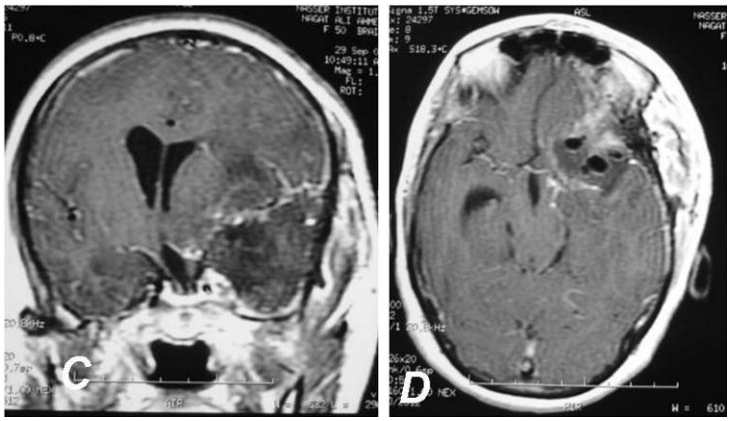

Fig. 5 (C, D). In (C) post operative coronal T-1 weighted MRI, and (D) post operative axial T1- weighted MRI with Gd- DPTA showing total tumor removal of medial sphenoidal meningioma via fronto-temporal craniotomy without vascular insult.

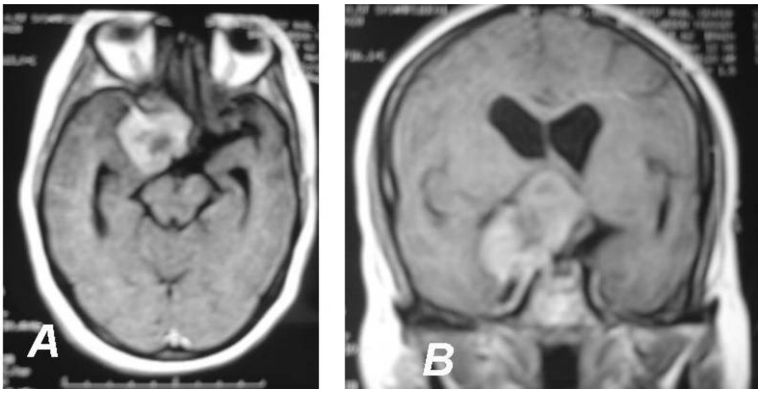

Fig. 6 (A, B). In (A) pre operative axial T-1 weighted MRI, and (B) coronal T1- weighted MRI with Gd- DPTA showing large spheno-cavernous meningioma with C S invasion, and encasement of cavernous carotid and supraclinoidal ICA.

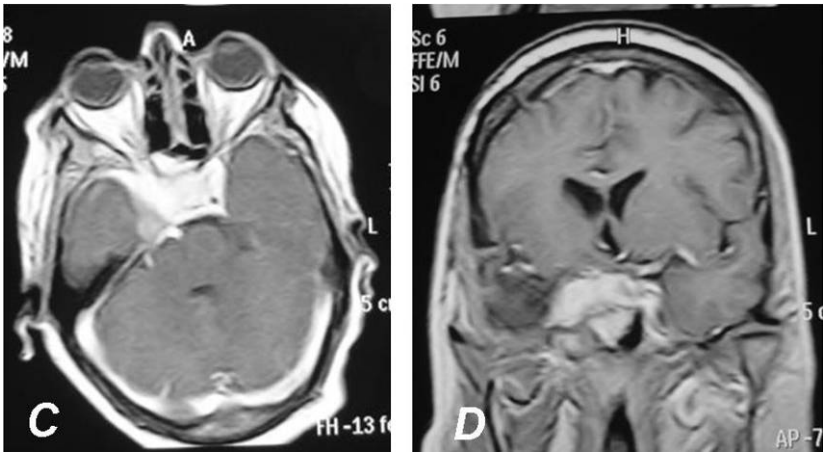

Fig. 6 (C, D). In (C) post operative axial T-1 weighted MRI , and (D) post operative coronal T1- weighted MRI with Gd- DPTA showing subtotal tumor removal of medial sphenoidal meningioma (Simpson grade 4) after fronto-temporal craniotomy with O- Z osteotomy.

DISCUSSION

In 1938, Cushing and Eisenhardt classified meningiomas arising from the sphenoid ridge into the following three groups based primarily on the unique tumor-induced clinical presentation: 1) deep, inner (or clinoidal); 2) alar or middle; and 3) pterional or outer[8].

Al-Mefty[2,3] identified three distinct groups of clinoidal meningiomas on the basis of the site of tumor origin and the presence/absence of the arachnoidal plane between the tumor and the ICA. Group 1 tumors were those encasing and directly attaching to the ICA adventitia, without a definable arachnoidal plane between the tumor and ICA. In this group, total resection was not possible in any of the three patients. Group 2 consisted of tumors with a separate arachnoidal plane between the tumor and the ICA, which facilitated total removal. Group 3 tumors were those originating at the optic foramen.

Tobias et al.[26] believe that Al-Mefty's Group 3 tumors were, as his own description implies, actually optic nerve sheath or optic foramen meningiomas, and not truly representative of clinoidal meningiomas.

Nakamura et al.[18] classified medial sphenoid wing meningiomas into two different groups on the basis of preoperative radiological findings.

Group 1 comprised tumors without cavernous sinus involvement. Group 2 included tumors with cavernous sinus involvement.

In the current study, on the basis of preoperative imaging studies and after intra-operative inspection and exploration, the patients were classified into four subtypes, lateral, middle, medial (Clinoidal without CS invasion), and spheno-cavernous (with CS invasion) subtypes. In large tumors involving the medial sphenoid and cavernous sinus, the exact site of origin (medial sphenoid compared with cavernous sinus) is often difficult to determine. Therefore, the term spheno-

cavernous meningioma involved tumor that extend on both medial sphenoid and cavernous sinus, an opinion which was previously mentioned in literature[18]. In our study, surgical approach was selected according the location of the tumor its basal attachment and the aim of surgery either radical or conservative surgery depending on the preoperative imaging study. Fronto- temporal approach was utilized for lateral, middle, and medial (Clinoidal) variant, while fronto-temporal craniotomy with O–Z osteotomy was tailored for spheno-cavernous subtype.

Lateral, and middle sphenoid wing meningiomas

In the middle and lateral sphenoidal wing meningiomas, the gold standard is a seemingly complete microsurgical removal that aims to cure at the first operation. Complete removal relieves the patients from symptoms and from hyperostotic bone and periorbital involvement which cause ophthalmologic symptoms and responsible for recurrences.

In the current study, five patients with lateral sphenoid meningiomas, and eight patients with middle sphenoid meningiomas were operated upon via simple fronto-temporal craniotomy without O-Z osteotomy. Total tumor removal (Simpson grade 2) with cauterization of the dura was achieved in all five patients (100%) with lateral sphenoid meningioma. In this group, no mortality occurred; however, one patient showed recurrence five years after surgery (atypical meningioma) and re-operated upon again. Total tumor removal (Simpson grade 2) was achieved in seven patients (87,5%) with middle sphenoid meningiomas. However, one of them died from MCA injury. Subtotal removal (Simpson grade 3) was achieved in one patient out of eight (12.5%). In this group, recurrence was observed in one patient who refused re-do and received conformal radiation therapy.

A minority of middle and lateral sphenoidal meningiomas reaches to MCA and its branches, and a small branch attached or buried to the tumor may tear its base on a major branch, that finally has to be sacrificed to stop the leakage. Ipsilateral MCA infarct is reported in the literature, and MCA encasement is one of the limiting factors against radical removal of middle sphenoidal meningiomas[1,11,18]. Recurrence in this group (two patients out of 13) [15.4%], was related to incomplete removal of tumor, extension into superior orbital fissure, sphenoid hyperostsis, and presence of atypical meningioma variant.

Medial (Clinoidal), and spheno-cavernous meningiomas

Despite an improved orientation by understanding the microsurgical anatomy and by advances in standard operative technique, the surgical resection of sphenoid meningiomas involving cavernous sinus remains a significant challenge. Surgical morbidity associated with aggressive resection of meningiomas involving the cavernous sinus remains high[1,6,7,9,19]. In the current study, subtotal resection (Simpson Grade 3) was achieved in eight out of 21 patients (38.1%) [Three medial sphenoid, and five spheno-cavernous]. Subtotal removal (Simpson Grade 4) was obtained in 11 out of 21 patients (52.4%) [Five medial sphenoid and six spheno-cavernous].

Also we have three deaths out of 21 patients (14.3%). In cases with extensive cavernous sinus involvement by fibrous and tough tumor, surgery was stopped after confirmation of the

following: 1) gross-total resection of the intradural extracavernous portion of the tumor and removal of any accessible tumor-involved dura; 2) decompression of the optic nerve; and 3) decompression of the oculomotor nerve. We believe in conservative surgical strategy in cases with cavernous sinus involvement (Spheno-cavernous subtype) for many reasons. First, disruption of the fine blood supply of the ocular CNs may occur during dissection of cavernous sinus meningiomas[1,12,15]. Second, dissection of the meningioma from the CNs may be impossible because of the arachnoidal plane and tumor infiltration of the nerves[10,16]. Finally, meningiomas may infiltrate the adventitia of the C4 segment of the ICA[14,24]. Sacrifice of the ICA followed by bypass surgery is also associated with high rates of morbidity and even mortality[24].

The rate of total resection for medial sphenoid wing meningiomas in earlier series ranged from 23 to 50% [8, 20], and mortality rates associated with removal of these tumors ranged from 15 to 43%[7,8,13,20]. Recent advances in cranial base approaches, microsurgical techniques, neuro-imaging, and neuro- anesthesia contributed to an improved extent of tumor resection, morbidity, and mortality. Total resection rates in more recent surgical series were reported to range between 59 and 86.7%[1,2,5,17,18,21,22]. However, the mortality rate still remained high, up to 14.5%, with incidence of permanent profound neurological deficit at 4 to 29 %[2,4,5,21].

In our series, we have three recurrences out of 21 cases with clinoidal and spheno-cavernous meningiomas (14. 3%). The major reason for this recurrence is incomplete removal due to C S involvement.
Conservative surgical strategy for clinoidal and spheno-cavernous meningiomas for better functional outcome should be taken in mind particularly with the advent of radiosurgery. Residual tumor in the medial compartment may be treated with some form of radiation therapy or clinical and radiological observation.

CONCLUSION

The surgical treatment of medial sphenoid wing meningiomas still represents a difficult task for neurosurgeons. Lateral and medial sphenoidal meningiomas present a more favorable outcome if compared with medial clinoidal and spheno-cavernous meningiomas. Location of the meningioma is an important factor determining the degree of tumor resectability. Encasement of ICA and / or MCA and their branches together with CS invasion and extension into superior orbital fissure are limiting factors for radical removal. Presence of hyperostosis, incomplete tumor removal, and atypical histopathological variant are factors responsible for recurrence. Conservative surgical strategy for clinoidal and spheno-cavernous meningiomas for better functional outcome should be taken in mind particularly with the advent of radiosurgery

REFERRENCES

1. **Abdel-Aziz KM, Froelich SC, Dagnew E, Jean W, Breneman JC, Zuccarello M, van Loveren HR, Tew JM, Jr.:** Large sphenoid wing meningiomas involving the cavernous sinus: conservative

surgical strategies for better functional outcomes. Neurosurgery 54:1375-1383, 2004

2. **Al-Mefty O:** Clinoidal meningiomas. J Neurosurg 73: 840–849, 1990.
3. **Al-Mefty O:** Clinoidal meningiomas, in Al-Mefty O (ed): Meningiomas. New York: Raven Press, pp 427–443, 1991.
4. **Basso A, Carrizo A:** Sphenoid ridge meningiomas, in Schmidek HH (ed): Operative Neurosurgical Techniques: Indications, Methods, and Results. Philadelphia, W.B. Saunders, pp 316–324, 2000.
5. **Benjamin V, McCormack B:** Surgical management of tuberculum sellae and sphenoid ridge meningiomas, in Schmidek HH (ed): Operative Neurosurgical Techniques: Indications, Methods, and Results. Philadelphia, W.B. Saunders, pp 305–315, 2000.
6. **Biglan AW, Sekhar LN, Cheng KP, Wright DC:** A protocol for measuring ophthalmic morbidity and recovery after cranial base surgery. Skull Base Surg 4:26–31, 1994.
7. **Bonnal J, Thibaut A, Brotchi J, Born J:** Invading meningiomas of the sphenoid ridge. J Neurosurg 53:587–599, 1980
8. **Cushing H, Eisenhardt L:** Meningiomas: Their Classification, Regional Behavior, Life History, and Surgical End Results. Springfield, Charles C Thomas, 1938
9. **DeMonte F, Smith H, Al-Mefty O:** Outcome of aggressive removal of cavernous sinus meningiomas. J Neurosurg 81:245–251, 1994
10. **El-Kalliny M, van Loveren HR, Keller JT, Tew JM Jr:** Tumors of the lateral wall of the cavernous sinus. J Neurosurg 77:508–514, 1992
11. **Jaaskelainen J, Ohman J, Kotilainen P, Munyao N, Randell T, Hernesniemi J:** Sphenoid wing meningioma- outer and middle. In: Kaye AH, Black PM (eds) Operative neurosurgery, vol. 1.Churchill, Livingstone, pp 587-604, 2000
12. **Knosp E, Müller G, Perneczky A:** The blood supply of the cranial nerves in the lateral wall of the cavernous sinus, in Dolenc VV (eds): The Cavernous Sinus. Berlin, Springer-Verlag , pp 60–68, 1987
13. **Konovalov AN, Fedorov SN, Faller TO, Sokolov AF, Tcherepanov AN:** Experience in the treatment of the parasellar meningiomas. Acta Neurochir Suppl (Wien) 28:371–372, 1979.
14. **Kotapka MJ, Kalia KK, Martinez AJ, Sekhar LN:** Infiltration of the carotid artery by cavernous sinus meningiomas. J Neurosurg 81:252–255, 1994
15. **Krisht A, Barnett DW, Barrow DL, Bonner G:** The blood supply of the intracavernous cranial nerves: An anatomic study. Neurosurgery 34:275–279, 1994.
16. **Larsen JJ, van Loveren HR, Balko MG, Tew JM Jr:** Evidence of meningioma infiltration into cranial nerves: Clinical implications for cavernous sinus meningiomas. J Neurosurg 83:596–599, 1995.
17. **Lee JH, Jeun SS, Evans J, Kosmorsky G:** Surgical management of clinoidal meningiomas. Neurosurgery 48:1012–1019, 2001.
18. **Nakamura M, Roser F, Jacobs C, Vorkapic P, Samii M:** Medial sphenoid wing meningiomas: clinical outcome and recurrence

rate. Neurosurgery 58:626-39, discussion, 2006.

19. **O'Sullivan MG, van Loveren HR, Tew JM Jr:** The surgical resectability of meningiomas of the cavernous sinus. Neurosurgery 40:238–244, 1997
20. **Pompili A, Derome PJ, Visot A, Guiot G:** Hyperostosing meningiomas of the sphenoid ridge: Clinical features, surgical therapy, and long-term observations: Review of 49 cases. Surg Neurol 17:411–416, 1982.
21. **Risi P, Uske A, de Tribolet N:** Meningiomas involving the anterior clinoid process. Br J Neurosurg 8:295–305, 1994.
22. **Samii M, Ammirati M:** Medial sphenoid wing meningiomas, in Surgery of Skull Base Meningiomas. Berlin, Springer-Verlag, pp 35–41, 1993.
23. **Sekhar LN, Burgess J, Akin O:** Anatomical study of the cavernous sinus emphasizing operative approaches and related vascular and neural reconstruction.Neurosurgery 21:806–816, 1987.
24. **Shaffrey ME, Dolenc VV, Lanzino GL, Wolcott WP, Shaffrey CI:** Invasion of the internal carotid artery by cavernous sinus meningiomas. Surg Neurol 52:167–71, 1999.
25. **Simpson D:** The recurrence of intracranial meningiomas after surgical treatment. J Neurol Neurosurg Psychiatry 20:22–39, 1957.
26. **Tobias S, Kim CH, Kosmorsky G, Lee JH:** Management of surgical clinoidal meningiomas. Neurosurg Focus 14:e5, 2003.