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The extended pterional approach for midline anterior skull base meningiomas. Technical considerations and clinical outcome

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ABSTRACT

Background: Various surgical approaches for the management of midline anterior skull base meningiomas exist in the literature. The main surgeon target is proper selection the appropriate approach that achieves total removal of the lesion without causing morbidity or mortality and facilitates safe effective removal of the tumour.

Objectives: To evaluate the role of the extended pterional approach for excision of midline anterior skull base meningiomas as regarding the effectiveness, extent of resection and surgical outcome.

Patients and methods: This retrospective study involved 23 cases with midline anterior skull base meningiomas resected through the extended pterional approach. Patients' clinical data, operative notes, imaging studies and clinical follow-up data were analyzed and evaluated.

Results: Tumors studied were 9 olfactory groove meningiomas, 8 tuberculum Sellae meningiomas, 4 planum sphenoidale meningiomas and 2 diaphragma sellae meningiomas. Gross total resection tumour excision in 15 cases (64.5%), subtotal excision in 5 cases (21.5%) and partial excision in 3 cases (14%). Complications were diabetes insipidus (2 cases 8.6%), CSF rhinorrhea (3 cases 12.9%) and visual deterioration (3 cases 12.9%). We had two cases of mortality.

Conclusion: The extended pterional approach allows safe and effective removal of midline anterior skull base meningiomas. It expands the exposure offered by the classic pterional approach and minimizing the necessity for applying fixed brain retraction with good cosmetic outcome and less approach-related morbidities in comparison with the extensive skull base approaches.

Keywords
extended pterional,
meningioma,
skull base,
extent of resection

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INTRODUCTION

Meningiomas are benign slowly growing tumors originating from arachnoid cap cells and represent almost 20% of primary intracranial tumors. Although it's benign nature; the existence of meningiomas in certain location is challenging for neurosurgeons. Meningiomas occurring in the midline anterior skull base are among those challenging cases. Depending on the site of origin; midlineanterior skull base meningiomas are classified into: Olfactory groove menin-

giomas planum sphenoidale meningiomas, tuberculum sellae meningiomas, diaphragma sellae meningiomas and dorsum sellae meningiomas. The clinical presentation is variable and varies according to site or origin and size of the tumor but commonly present with frontal manifestations, headache, visual impairment and occasionally manifestation of hypothalamic dysfunction. The surgical challenge of these tumors is how to achieve radical tumor resection without endangering the important neurovascular structures in the vicinity of these tumors. One important step to achieve such goal is choosing the proper approach to achieve adequate tumor resection with minimal morbidities including the approach related complications [2,5,7,9,13,18,22,26].

The surgical approaches utilized to remove midline anterior skull base meningiomas include the pterional, the cranio-orbito-zygomatic, the sub-frontal, and the anterior interhemispheric approaches. Each approach has its advantage and its limitations. The appropriate approach should allow adequate tumor exposure, easily dissection from the surrounding important structures without the need for applying excessive brain retraction. The goal is usually achieved with approaches including the cranio-orbito-zygomatic approach and despite it provide the surgeon with adequate exposure he needs but the approach has its potential functional and cosmetic morbidities [1,4,7,10, 14,18,20,28].

In this study; we reported our experience with extended pterional approach as it allow safe and adequate exposure to most of the midline anterior skull base meningiomas and discussing our surgical results for such challenging meningiomas.

Patients and methods

Retrospective study including twenty-three patients with midline anterior fossa meningiomas were operated up on via the extended pterional approach in the Neurosurgery Department, Mansoura University during the period from February 2015 till July 2019. Patients' demographic, clinical, radiological and operative data are collected and retrospectively analyzed. Duration of clinical presentation varied from 6 to 72 months. Origin of the meningiomas was assessed from preoperative magnetic resonance imaging studies and confirmed from the surgeon operative data. The extent of tumor resection was evaluated via the operative notes and postoperative magnetic resonance imaging studies done 3 months after surgery.

Patients were operated up on via the extended pterional approach that include the Yasergil standard pterional approach with modifications including extension of the craniotomy to the frontal bone to allow access via the sub-frontal corridor and adding osteotomy along the lateral sphenoid wing toexpose the superior orbital fissure and drilling the orbital roof to flatten its surface and expand the exposure via the sub-frontal corridor. The dura is opened in a curvilinear fashion over the sylvian fissure and the incision is directed toward the falciform ligamentproviding unobstructed working angles for the para-sellar and sub-frontal corridor.

We routinely do a post contrast computed tomography scans in the first day after surgery to check for any approach related problems. All patients were then followed up by doing Magnetic Resonance Imaging study 3 months after surgery and then yearly. The mean follow-up period was 26 months, range (6-50 months).

Results

Retrospective analysis of 23 patients with midline anterior fossa meningiomas underwent surgery through the extended pterional trans-sylvian approach.The range of patients' age in our study from22 years to 63 years (the mean age was 51.96±10.81 standard deviation. There was a significant female predominance (n=18, 78.3%) females and males were (n= 5, 21.7%).

Duration of symptoms ranged from 5 to 108 months (mean: 10 months). Visual diminution was the most common clinical presentation in our patients in 18 cases (78.2%), followed by headache in 16 cases (69.5%) then frontal manifestations in 8 cases (34.8%) and anosmia occurred in 4 cases (17.4%), fundoscopic examination: bilateral papilledema was detected in 15 cases (65.2%). Unilateral optic atrophy was in 4 cases (17.4%), bilateral optic atrophyin 3 cases (13.1%). Unilateral papilledema with optic atrophy in the other side (Foster-Kennedy syndrome) occurred in 2 cases (8.7%) (Table 1).

The origin of the meningioma was the olfactory groove in 9 cases, thetuberculum sellae in 8 cases, the planum sphenoidale in 4 cases and the diaphragma sellae in 2 cases. Histopathological diagnosis of the meningiomas were; meningothelial

type in 10 cases, transitional type in 6 cases, psammomatous type in 4 cases, fibrous type in 2 cases and atypical type in only one case. We had 12 cases of medium sized meningiomas, 9 cases of large sized meningiomas and 2 cases of giant meningiomas (Table 2).

Gross total resection (Simpson grades I) wasachieved in 15 patients (65.3%). Subtotal resection (Simpson grades II &III) was achieved in 5 cases (21.7%). Partial resection (Simpson grades IV) was achieved in 3 cases (13.1%). Table (3) demonstrate the extent of resection in correlation to meningioma location and tumor size. Total resection was more feasible for olfactory groove meningiomas (in eight of the nine cases in our study). Also, the extent of total resection was achieved more in small sized meningiomas compared to medium and large sized ones. Regarding the visual outcome (table 7); 13 patients (56.5%) out of the 18 cases presented with visual disturbances showed post-operative visual improvement, 5 patients (21.7%) remained stable while 2 patients (8.6%) had post-operative visual deterioration which was transient in one of them.

No major post-operative morbidities occurred in our operated cases (Table 4). No post-operative morbidities happened in 12 cases (52.2%). Frontal manifestations were the most common morbidities and occurred in 4 cases (17.4%). 3 cases experienced postoperative diabetes insipidus (12.9%) (transient in 2 cases). Post-operative seizures occurred in 2 cases. 2 cases (8.6%) had post-operative visual deterioration that was transient in one of them. One case (4.3%) of tuberculum sellae meningioma developed transient CSF rhinorrhea that was managed conservatively with transient lumbar drain.

The average duration for follow-up in our study was 25 months, ranged from 6 to 50 monthswith no tumor recurrences reported in the follow-up period. Four cases were offered post-operative adjuvant treatment (17.3%) in the form of Gamma knife radiosurgery in three cases and conformal 3-dimensional radiotherapy in one patient. We had two mortalities (8.6%) in our study (table 4). One mortality happened from intraoperative vascular injury; resulted in massive infarction of both frontal lobes and the 2nd case died from severe hypothalamic dysfunction.

Illustrated cases

Case 1: 64 years old female patient with suprasellar meningioma (Fig. 1 a & b); subtotal resection was achieved leaving a small part of tumor attached to the pituitary stalk (Fig. 1 c & d).

Case 2: 39 years old male patient with large suprasellar meningioma extending superiorly to 3rd ventricle (Fig. 2 a & b) that totally removed via extended pterional approach (Fig. 2 c&d).

Case 3: 50 years old female patient with suprasellar meningioma (Fig. 3 a & b) that totally excised (Fig. 3 c & d).

Fig. 1 (a)

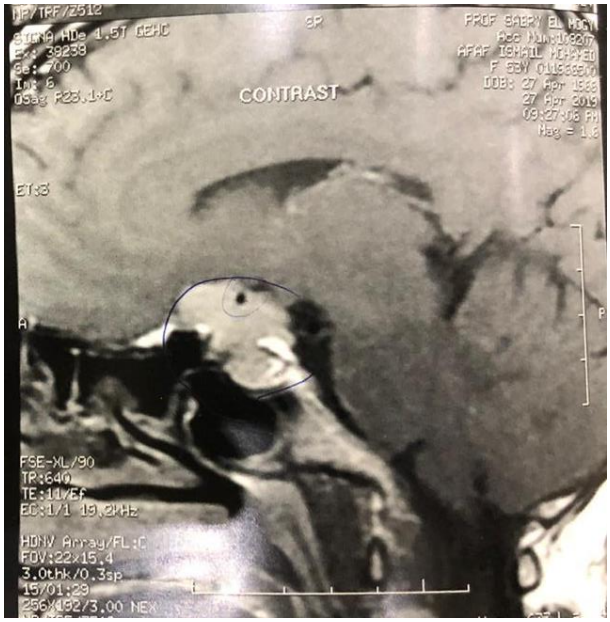

Fig. 1 (b)

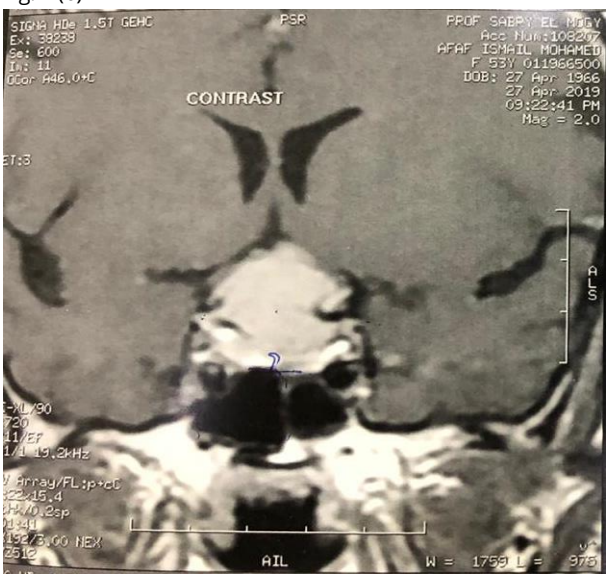

Fig. 1 (c)

Fig. 1 (d)

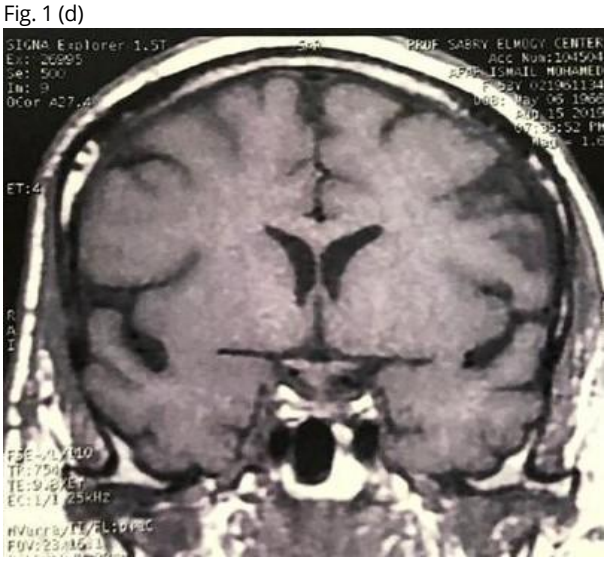

Figure 1. Preoperative MRI image of suprasellar tumor sagittal view (a), coronal view (b), postoperative follow-up MRI images sagittal view (c), coronal view (d).

Fig. 2 (a)

Fig. 2 (b)

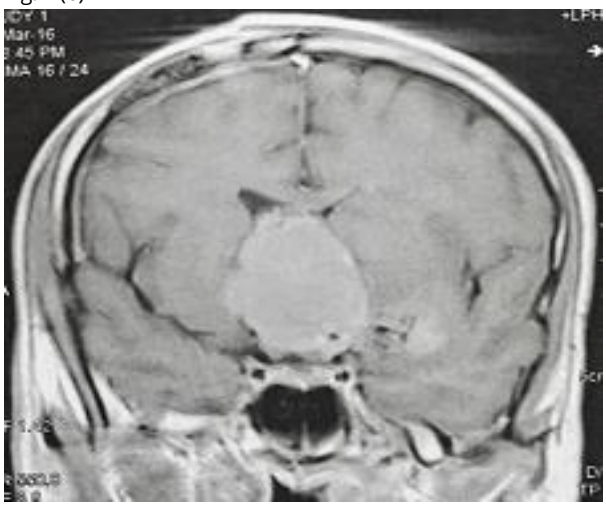

Fig. 2 (c)

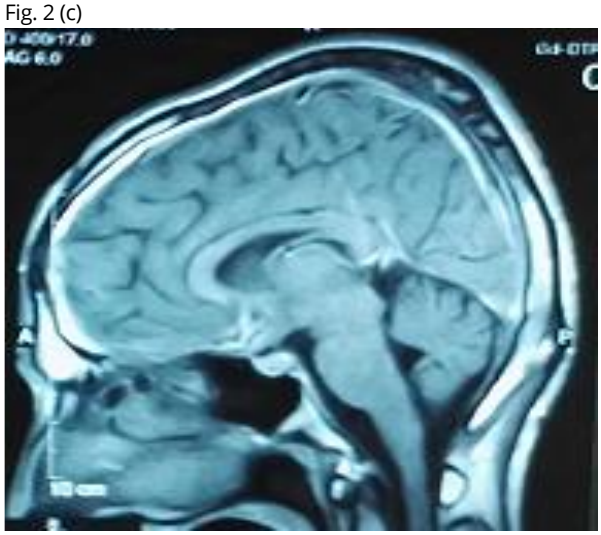

Fig. 2 (d)

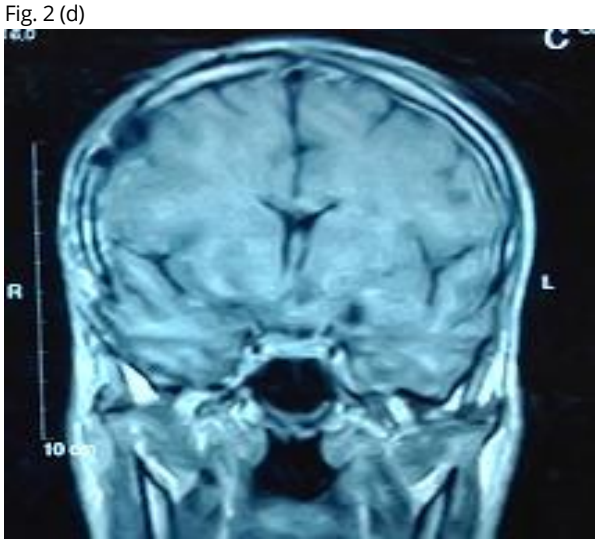

Figure 2. Preoperative MRI image of suprasellar tumor sagittal view (a), coronal view (b), postoperative follow-up MRI images sagittal view (c), coronal view (d).

Fig. 3 (a)

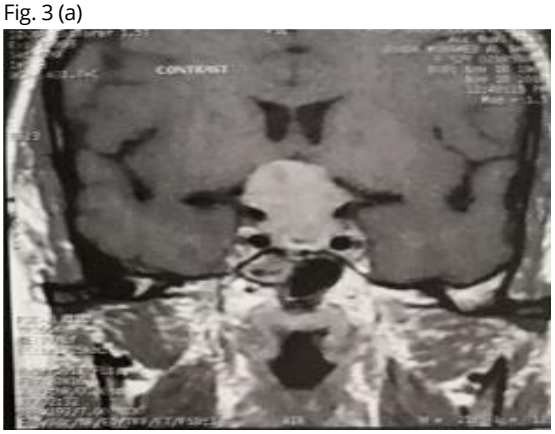

Fig. 3 (b)

Fig. 3 (c)

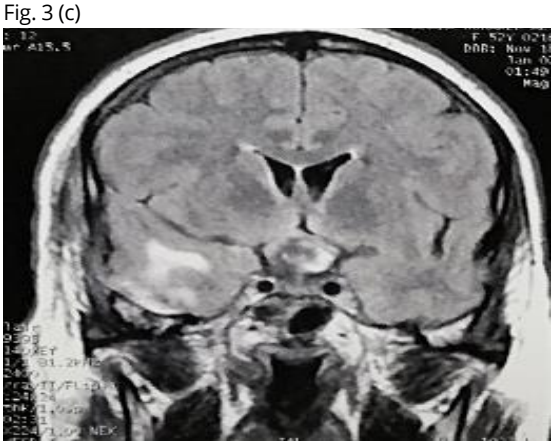

Fig. 3 (d)

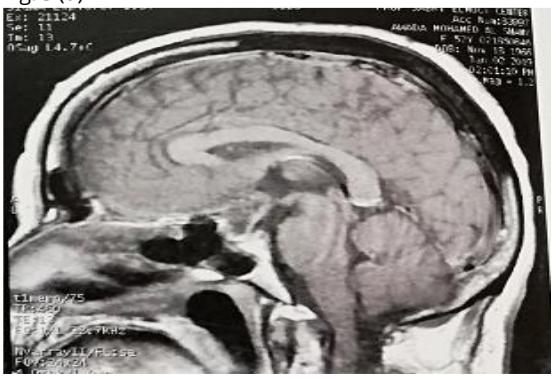

Figure 3. Preoperative MRI image of suprasellar tumorcoronal view (a), sagittal view (b), postoperative follow-up MRI images coronal view (c),s agittal view (d)..

Table 1. Clinical presentation of our case series.

Clinical	Number	Percentage
Visual manifestations	18	78.2%
Headache	16	69.6%
Behavior changes	8	34.8%
Anosmia	4	17.4%
Seizure	3	13.1%
Hormonal disturbance	1	4.3%
Fundoscopy • Bilateral Papilledema • Unilateral optic atrophy • Bilateral optic atrophy • Foster-Kennedy syndrome	 15 4 3 2	 65.2% 17.4% 13.1 8.7

Table 2. Classification of tumor types according to origin, histopathological examinationand tumor size (distribution, average).

Tumor origin	Number	Percentage	Average Size in cm^3 (range of size)
Olfactory Groove	9	(39.1%)	5.14 (3.7 – 6.5)
Tuberculum sellae	8	(34.8%),	3.95 (3.6 - 4.2)
Planum sphenoidale	4	(17.4%)	3.80 (3.5 – 4.3)
Diaphragma sellae	2	(8.7%)	3.65 (3.5 – 3.8)
Histopathological types			
Meningothelial type	10	(43.5%)	
Transitional type	6	(26.1%)	
Psammomatous type	4	(17.4%)	
Fibrous type	2	(8.7%)	
Atypical meningioma (WHO grade II)	1	(4.3%)	
Tumor size			

Medium2-4cm3	12	52.2%
Large 4-6	9	39.2%
Giant >6	2	8.6%

Table 3. Correlation between EOR and location of meningioma and tumor size.

	GTR Grade I	**STR Grade II & III**	**Partial Grade IV**	**Total**
Meningioma location				
Olfactory groove	8 (34.4%)	1(4.3%)	0	9
Planum sphenoidale	4 (17.2%)	2 (8.6%)	2 (8.6%)	8
Tuberculum sellae	2 (8.6%)	1 (4.3%)	1 (4.3%)	4
Diaphragma sellae	1 (4.3%)	1 (4.3%)	0	2
Meningioma size				
2cm - 3.9 cm.	9 (39%)	2 (8.6%)	1 (4.3%)	12
4cm - 5.9 cm.	4 (17.2%)	3 (13%)	2 (8.6%)	9
>6cm	2 (8.6%)	0	0	2

Table 4. Visual and surgical outcome and complication of extended pterional approach in anterior skull base meningiomas.

	Number	***Percentage***
Surgical outcome		
GTR	15	64.5%
STR	5	21.5%
Partial	3	14%
Mortality	2	8.6%
Complications		
Frontal manifestations	4	17.4%
Seizures	2	8.6%
Diabetes insipidus	3	12.9%
Transient CSF rhinorrhea	1	4.3%
Visual deterioration	2	8.6%
Visual outcome		
Improved vision	14	60.7%
Stable vision	5	21.7%
Visual deterioration (one is transient)	2	8.6%

Table 5. Review of literature of case series of microsurgical management of anterior skull base meningiomas

Case series	**Year**	**No. Patients**	**GTR (%)**	**Visual Improvement (%)**	**Recurrence (%)**	**Mortality (%)**	**Years of F/U**
Recent series	2019	23	64.5	78.1	N/A	8.6	4.6
Lynch et al.	2015	38	86	89.4	5.2	2.6	5.7
Romani et al.	2009	65	91	21.4	9	0	3.7
Bassioni et al.	2007	55	100	83.3	8.9	0	N/A
Colli et al.	2007	17	94.1	N/A	0	11.8	4.2
Hentschels and Demonte	2003	13	85	92.3	0	0	2
Goel et al.	2002	70	84	N/A	1.4	2.8	N/A
Jallo&Benjamim	2002	23	86.9	55	4.5	8.6	93
Fahlbusch& Schott	2002	47	98	80	4.2	0	N/A
Zeugaridis et al.	2001	62	N/A	65	N/A	3.2	5.2

Turazzi et al.	1999	37	100	100	0	2.7	4
Al-Mefty	1993	35	91	25	N/A	8.6	N/A
Ojemann	1991	14	71	73	N/A	0	N/A
Solero et al.	1983	55	78	60	3	2.3	N/A
Symon &Rosentein	1977	33	82	N/A	3.1	3	N/A

Discussion

Midline anterior skull base meningiomas have only and exclusively treated through direct microsurgical excision. The main neurosurgical challenge is to achieve total surgical excision with no or minimal postoperative morbidities. However, the surgical difficulties are facilitated by improved microsurgical facilities, more understanding of the microsurgical anatomy through adequate neurosurgical training and progressive learning curve and feasibility of variable surgical approaches. Effective reaching the surgical target with minimal normal anatomical disruption is the cornerstone of the surgeon focus [1,3,4,6,8,11,14,16,25].

A wide range of surgical approaches have been described in the literature totreat midline anterior skull base meningiomas, including the pterional approach with its modifications and the sub-frontal approach with unilateral or bilateral sub-frontal exposure. Each of these approaches has its advantages as well as its limitations. Approach selection is dependent on the tumor size, location, and pattern of extension, tumor relation to the important neurovascular structures and the surgeon's experience and familiarity with the approach [2,3,9,12,15,17,19,25,27].

Many authors advocated the bilateral sub-frontal craniotomy for large symmetrical midline lesions with its advantage of wide exposure of the anterior cranial base and excellent view for dissection of the both anterior cerebral arteries and the optic pathways. Other authors prefer to use the unilateral sub-frontal corridor which can allow tumor resection without the increased risk encountered in the bilateral sub-frontal exposure. In many other cases series; the fronto-lateral approaches including the pterional approach, the cranio-orbito-zygomatic approach and the extended pterional approach were preferred by the neurosurgeons to remove midline anterior skull base meningiomas [1, 3,7,15,20,21,23,24,25,27].

The extended pterional approach provides certain advantages compared to the bi-frontal craniotomy. It provides the shortest distance to the tuberculum sellae. It allows early exposure to the basal cisterns for CSF release to have good brain relaxation to minimize frontal lobe retraction. Also, sylvian fissure dissection provided by the approach allow untethering of the frontal lobe from temporal lobe facilitating full exposure of the neurovascular structures with minimal or no frontal lobe retraction which is difficult to achieve from the bilateral or unilateral sub-frontal exposure. Moreover, the extended pterional approach provides the surgeon with more working angles for tumor exposure and dissection that cannot be achieved from the sub-frontal approach. The extended pterional approach can replace bi-frontal craniotomy for resection of giant midline intradural anterior skull base tumors except for extradural skull base tumors extending to the intradural space [3,4,6,10,15,20,24,25,26,27].

Pterional craniotomy is a highly flexible skull base approach that gives excellent exposure of the anterior cranial fossa, the circle of Willis, and the interpeduncular region. Because of its simplicity, flexibility, efficiency; this approach is most utilized for pathologies along the anterior skull base. The major limitation for this exposure is the need for more frontal lobe retraction for lesion with more superior extension reaching the third ventricle and when the tumor extends inferolateral in skull base. The cranio-orbito-zygomatic approach can expand the exposure for the hidden areas for the classic pterional approach involving the orbital apex, the paraclinoid and parasellar areas, the cavernous sinus and the interpeduncular fossa. Tumors with significant superior extension can be addressed well with expanded inferior-to-superior and medial to lateral operative working angles provided by the cranio-orbito-zygomatic approach. The cranio-orbito-zygomatic approach is a more complex approach and technically demanding with the concern regarding the cosmetic problems due to the

extensive osteotomes necessary for the exposure [2,3,8,9,13,15,22,24,25,26,28].

The extended pterional approach is a modification of the classic pterional approach that obviates the limitation of the classic approach for skull base exposure and minimizes the necessity for the more extensive cranio-orbito-zygomatic approach. The additional osteotomes at the sphenoid wing and orbital roof expands the sub-frontal trajectory to the midline anterior skull base without necessity for more frontal lobe retraction. The osteotomy of the orbital roof gives most of the advantages of that provided by the cranio-orbito-zygomatic approach with less chance for cosmetic deformities [2,3,15,24,25,26].

In our study; the mean age of the cases in our study was 51.96 years. Most of our cases were in their 5th and 6th decades and 78.3% of our cases were females. Visual manifestations were the most presenting symptoms followed by headache, frontal manifestation then anosmia and behavioral changes. The demographic data and the clinical manifestations of our cases were like other reports in the literatures discussing this pathological entity [1,5,6,11,12,21,27].

The onset of clinical presentation for midline anterior skull base meningiomas corelated the origin of the meningiomas. More anteriorly located tumors like olfactory groove meningiomas may reach large size before being symptomatic. Earlier clinical presentation in smaller sized meningiomas originating in a close proximity to the optic nerves and the chiasm. In our study, the average size for the OGMs was 5.14 cm for the TSMs was 3.95 cm while the average size of the PSMs was 3.80 cm [2,4,5,9,11,15,27].

Gross total resection (GTR) was achieved in 15 (65.3%) patients and subtotal resection in 5 (21.7%). The highest percentage of gross total tumor excision was in OGM cases (8 tumors out of 9), followed by PSMs (4 tumors out of 8), and then TSMs (2 tumors out of 4) .The extent of tumor resection of midline anterior skull base meningiomas was addressed in many case series with variation in results depending on what is defined as total or near total resection in each series. Several studies have advocated that attempting gross total resection should not be with the price of endangering the vision or the hypothalamic function. The extent of gross total tumor resection of such meningiomas varied from 35% to 100% (table 5). The appropriate approach selection is crucial to improve the extent of resection as reported in many series. Skull base approaches including the cranio-orbito-zygomatic and cranio-orbital approach facilitated adequate tumor exposure and better achievement of tumor resection but with increasing cosmetic morbidities. The extended pterional approach used in our case series facilitated more adequate exposure of the tumor with minimal cosmetic sequalae [2,4,5,8,9,13,15,18, 19,23,24,25,26,27].

The preservation of vision is one of the cardinaltargets of surgical management. Some case series concluded that better visual outcomes are associated with tumors smaller than 3 cm than tumors larger than 3 cm in diameter[2,8,16]. In our series, improvement of vision occurred in 60.7% of patients and preserved vision with no further deterioration in 21.7%.

Surgery for midline anterior skull base tumors still carry the risk for postoperative morbidities despite the improvement achieved in the modern neurosurgical facilities. In our study, the highest complication rate was frontal manifestations; behavior changes (n=4, 17.4%), diabetes insipidus (n=3, 12.9%), CSF rhinorrhea (n=1, 4.3%) then visual deterioration (n=1, 4.3%). Cushing reported an operative mortality of 27.5%. As a result of the refinements of microsurgical techniques, death rates had declined in subsequent series. Al-Mefty[15] and Solero et al.[27] observed higher mortality rates in patients with tumors exceeding 3 cm in diameter, compared with mortality rates in patients with smaller tumors. In our study there were only 2 mortalities (8.6%). In our series, 11patients (47.8%) harbored large or giant tumors, but we noticed that there was no increase in mortality in this group of patients [2,7,9,15,18,19,22,25].

Several series have been published on midline anterior skull base tumors (table 5) with long term follow up for recurrences beyond 10 years following Simpson 1 or 2 grade resections. In current study, no tumor recurrences recorded during the follow up period which extended up to 54 months. A longer follow up period is crucial for better assessment of the actual recurrence rate [3,6,7,8,15,23,27].

Conclusion

The extended pterional approach allows safe and effective removal of midline anterior skull base meningiomas. It expands the exposure offered by

the classic pterional approach and minimizing the necessity for applying brain retraction with good cosmetic outcome and less approach related morbidities related to the more extensive skull base approaches.

Abbreviations

EOR= extent of resection, COZ= cranio-orbito-zygomatic, ICT= intracranial tension, CSF= cerebrospinal fluid, OGM= olfactory groove meningioma, GTR= gross total resection, STR= subtotal resection, TSM= tuberculum sellae meningioma, PSM= planum sphenoidale
meningioma.

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