EXTENDED BIFRONTAL CRANIOTOMY FOR MIDLINE ANTERIOR FOSSA MENINGIOMAS: MINIMIZATION OF RETRACTION-RELATED EDEMA AND SURGICAL OUTCOMES

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OBJECTIVE: Meningiomas of the anterior cranial base can be approached with a variety of techniques. The extended bifrontal approach is often thought to be associated with increased morbidity because of the need for extensive removal of the bone and longer surgical times. The authors have attempted to quantitate retraction-related edema occurring after surgery to determine whether the extra bone removal limits retraction and reduces the chance of brain injury.

METHODS: Charts were reviewed for patients who underwent extended bifrontal craniotomies performed for meningiomas at the University of California, San Francisco, between 1997 and 2005. Magnetic resonance imaging scans obtained before and after surgery were reviewed for brain edema as indicated by fluid-attenuated inversion recovery/T2 abnormality and grouped into four categories: A, no edema; B, edema restricted to the gyrus rectus; C, edema beyond the gyrus rectus; and D, extensive bifrontal edema.

RESULTS: Forty-five patients were identified. Fifty-four percent of patients had tumors with a diameter of more than 4 cm. Simpson Grade 2 or 3 resection was achieved in 82% of patients, and the average operative time was 12.3 hours. Vision outcome was favorable in 74% of patients. Extent of fluid-attenuated inversion recovery abnormality remained unchanged in 87.5%, with 91% of patients in categories A or B edema remaining in those categories after surgery. There were no infections and there were two cerebrospinal fluid leaks.

CONCLUSION: The extended bifrontal approach is a safe surgical procedure with limited morbidity that the authors think: 1) prevents secondary brain injury from excessive retraction; 2) offers great flexibility of view for the surgeon; and 3) should be considered the preferred approach compared with the standard bifrontal craniotomy for large tumors of the anterior cranial base.

KEY WORDS: Anterior fossa, Bifrontal craniotomy, Meningioma, Olfactory groove, Planum sphenoidale, Tuberculum sellae

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Meningiomas in the anterior cranial base comprise 40% of all intracranial meningiomas and arise from distinct anatomic locations (5, 16, 19). Midline tumors originate from the olfactory groove, planum sphenoidale/tuberculum sellae, and diaphragma sellae, whereas eccentrically located tumors originate from portions of the sphenoid wing (clinoidal, middle, and lateral parts), cavernous sinus, and optic sheath. Olfactory groove and planum/tuberculum meningiomas each comprise approximately 10% of all intracranial meningiomas and make up almost half of all anterior cranial base meningiomas (7, 12, 14, 24). Olfactory groove meningiomas typically occupy a space relatively distant from vital neurovascular structures, and these tumors usually grow to extensive size before reaching diagnosis. In contrast, planum/tuberculum meningiomas may present with visual disturbances from compression of the optic apparatus with relatively small tumor volumes, but may also grow to significant sizes (9).

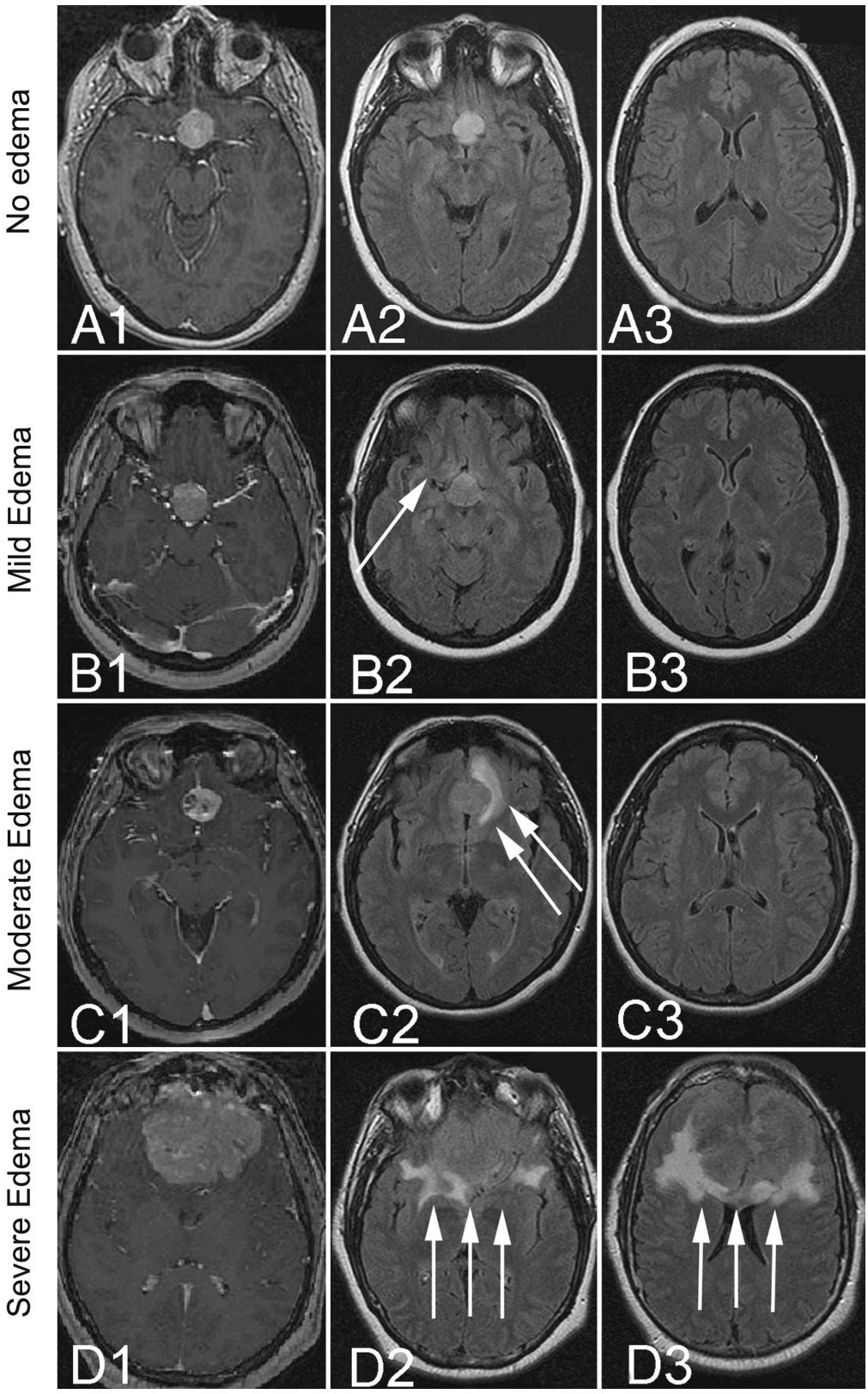

FIGURE 1. *Preoperative MRI scans showing tumor measurements and edema scale.* Left column*, preoperative gadolinium-enhanced T1-weighted axial MRI scans at maximal diameter were used for tumor size measurements. Fluid-attenuated inversion recovery MRI scans in the axial* (middle column*) and coronal* (right column*) planes were used to measure the degree of cerebral edema in four categories:* A*, no edema;* B*, edema limited to the gyrus rectus (mild;* single arrow*);* C*, edema extended beyond the gyrus rectus (moderate;* double arrows*);* D*, extensive bilateral edema (severe;* triple arrows*).*

Most studies have reported excellent clinical and surgical outcome after operation for these tumors (2, 4, 7, 9, 11, 12, 15). However, complications occur in up to 20% of patients, and the morbidity of excessive brain retraction from standard subfrontal or unilateral approaches is seldom discussed (9, 12, 20). Although the goal of surgery is safe gross total excision of tumor to prevent recurrence, subtotal resection is associated with recurrence of tumor in 23% of olfactory meningiomas (14). Tuberculum meningiomas often extend into one or both optic canals, causing prechiasmatic visual deficits, which is an underappreciated fact in the current surgical literature. Complete tumor removal involves opening of the falciform ligament and optic canals unilaterally, or bilaterally where indicated.

Although controversy exists as to the best surgical approach, several approaches have been reported for a variety of tumor sizes and attachments in this area. The pterional, unilateral subfrontal, and orbitofrontal approaches may be used alone or in combination for small to medium tumors, whereas a bifrontal approach may be performed for larger tumors. We have come to appreciate the flexibility and

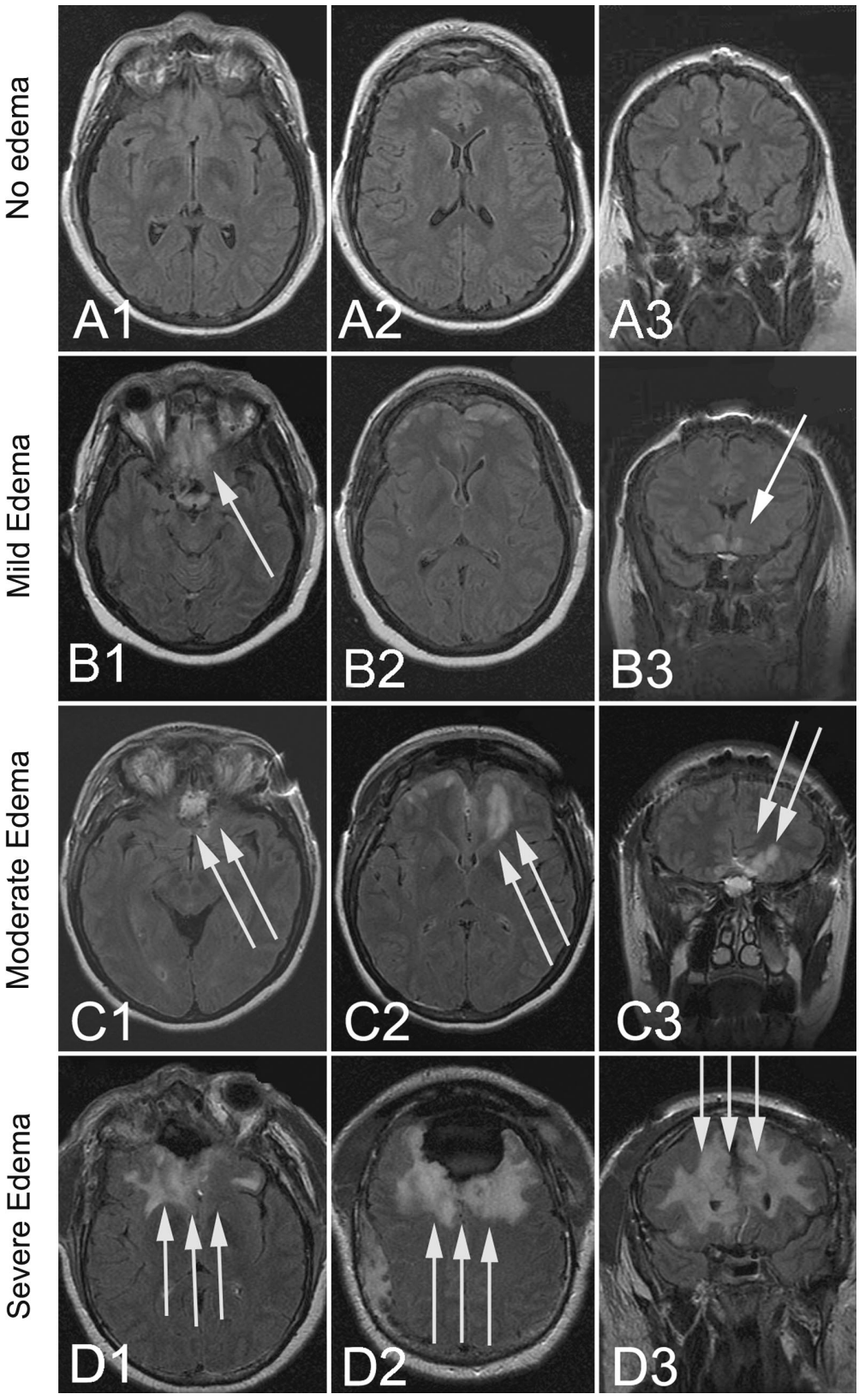

FIGURE 2. *Postoperative MRI scans showing the edema scale: fluid-attenuated inversion recovery MRI scans in the axial* (left and middle columns) *and coronal* (right column) *planes were used to assess cerebral edema into four categories:* A, *no edema;* B, *edema limited to the gyrus rectus (mild;* single arrow*);* C, *edema extended beyond the gyrus rectus (moderate;* double arrows*);* D, *extensive bilateral edema (severe;* triple arrows*). The postoperative images shown are from the same patients as those in Figure 1.*

limited morbidity rate associated with the extended bifrontal craniotomy to reach tumors of this region. Bilateral orbital osteotomy with bifrontal exposure provides excellent views of the entire tuberculum sellae and proximal medial portion of the optic canal; it also allows the option of lateral rotation to open the proximal sylvian fissure to identify the optic nerves displaced by tumor, similar to a pterional approach. The supraorbital osteotomy greatly reduces the extent of frontal retraction, limiting postoperative neuropsychological sequelae and cerebral edema.

Our study reviews characteristics and outcomes in patients treated for midline anterior fossa meningiomas with the extended bifrontal craniotomy at the University of California, San Francisco. The purpose of our study was to evaluate clinical and surgical outcomes in our patient cohort and to investigate changes in cerebral edema before and aftersurgery using the extended bifrontal technique.

PATIENTS AND METHODS

All patients treated with an extended bifrontal craniotomy at the University of California, San Francisco, between Janu-

ary 1997 and March 2005 for a diagnosis of meningioma were included in the study cohort. This limited period was selected because all imaging was saved in digital format beginning in 1997 and could be retrieved and reviewed readily. All patient charts and medical records were reviewed retrospectively. In addition to standard patient variables, preoperative tumor volume and degree of cerebral swelling before and after tumor resection were determined based on pre- and postoperative magnetic resonance imaging (MRI) scans. T1-weighted gadolinium-enhanced sequences were used to measure preoperative tumor dimensions (*Fig. 1*). Fluid-attenuated inversion recovery, T2-weighted sequences, or both were used to measure the degree of cerebral edema and to categorize the edema before surgery (*Fig. 1*) and after surgery (*Fig. 2*) into four categories as follows: A, no edema; B, edema restricted to the gyrus rectus (mild); C, edema beyond the gyrus rectus (moderate); D, extensive bifrontal edema (severe). The first and senior authors (JHC, MWM) evaluated postoperative images while blinded to corresponding preoperative imaging. All postoperative imaging was obtained before discharge. Extent of tumor resection was based on the surgeon's Simpson grade scoring, and gross total resection was confirmed by contrast-enhanced MRI scans. Visual status was assessed by ophthalmological examination with Humphrey visual field testing and visual acuity testing. Fisher's exact test was used for statistical analysis at P values equalling 0.05 level.

Surgical Description

The choice of surgical approach depends on the size and location of tumor, involvement of neurovascular structures, and surgeon preference and comfort level. Of the several options available—standard bifrontal, extended bifrontal, unilateral subfrontal, and pterional—each has its advantages and disadvantages regarding ease, safety, avoidance of complications, and extent of exposure. Also, patients with reoperation require special attention to which approach had been used previously to accommodate successfully for skin incision and bone cuts.

We prefer the extended bifrontal exposure for deep midline tumors of the anterior fossa because it provides excellent visualization of bilateral anatomy and minimizes retraction on the frontal lobes during surgery. For all procedures scheduled for more than 6 hours, we book two attendings to allow for shared surgical duties. The senior author (MWM) performed the primary exposure for each patient in this series. Before final positioning, cerebrospinal fluid diversion was established via a lumbar subarachnoid drain or, in rare circumstances, external ventricular drain. All patients receive standard intravenous antibiotic prophylaxis and corticosteroid boluses at the start of surgery and every 6 hours during surgery.

The patient was positioned supine on the operating room table, with the neck flexed on the chest and the head extended on the neck. Draping for a bicoronal incision was performed with care not to place draping towels above the eyebrows because this creates too much pressure for the skin when the scalp flap is turned forward. A small quadrant of the abdomen was prepared for the harvesting of a fat graft to cover the sphenoid sinus mucosa after the tuberculum sellae was drilled out. A standard bicoronal scalp incision was turned down and care was taken not to incise the pericranium. The pericranium was elevated off the superior temporal lines bilaterally to the supraorbital margins. Supraorbital nerves were dissected from their notches of foramina, and the periorbita was dissected from the roof and lateral walls of the orbit. The pericranium was reflected past the nasofrontal suture. The temporalis muscles were released from the superior temporal line, leaving a cuff of muscle to reattach to at closure. The bifrontal bone flap then was elevated and the dura mater was dissected from the roof of the orbits bilaterally. In the midline, the dura mater should not be reflected posterior to the crista galli to avoid damaging the olfactory nerves.

With the extradural dissections completed, an oscillating saw was used to make cuts at the level of the frontozygomatic suture laterally, continuing from the cranial side through the roofs of the orbits in front of the crista galli. Close to the midline, the roof of the frontal sinus was entered so that the tip of the blade could not be seen from the orbital side. Usually, the limit for the orbital cut was a short distance down the medial side of the orbit, and these two bone cuts were connected using the oscillating saw and cutting down on the nasofrontal suture. The supraorbital osteotomy bone piece could then be removed and the mucosa stripped from frontal sinus recesses on both the craniotomy flap and supraorbital osteotomy to prevent development of mucoceles in the late follow-up period.

The exposed frontal sinus then was plugged using gelatin foam and covered with cottonoids. The dura was then opened a finger's breadth above the orbits and the dura sutured forward. The superior sagittal sinus was suture ligated, and the falx was cut back through its free edge inferiorly. Rubber dams were used to cover the inferior frontal lobes, and the olfactory tracts were then dissected using the operating microscope posteriorly to the medial and lateral striae and were covered with small thin rubber dams. Unless the nerves are covered, they become dry and nonfunctional by the end of the procedure. The olfactory tract can be spared bilaterally in cases involving small tumors and often unilaterally, even in cases of larger ones. We use a single retractor blade, directing it as needed for the appropriate exposure. In this way, prolonged retraction over any one area is avoided.

As soon as the tumor was identified, the first objective was to determine the position of the optic nerves. For very large tumors, this cannot be established until the tumor is debulked. This process was begun in the midline, taking down the basal dural attachments and working straight back in and just off the midline. As soon as the optic nerves were identified, the tumor was debulked to allow dissection of the arachnoid plane separating the nerve and planum/tuberculum tumor. For large planum and tuberculum tumors, great care must be taken not to damage the small superior hypophyseal branches arising from the medial wall of the carotid artery supplying the optic chiasm and stalk.

The A1 segments of the anterior cerebral artery and the anterior communicating artery can be seen and must be dissected from the surface of large tumors. Branches of the medial orbital frontal and frontopolar arteries supply larger tumors. After most of the tumor was removed, we attended to the region of the optic canal and tuberculum sellae. Tumors frequently extend down the proximal medial aspect of the optic canal, attaching at its junction with the chiasmatic sulcus. The falciform ligament can be cut and the roof of the optic canal drilled out to ensure tumor removal. To remove tumor extending over the tuberculum sellae, this bone should be resected. The dura was incised from the optic canals bilaterally and reflected back over the tuberculum sellae. A diamond drill was then used to drill down the tuberculum sellae to the level of the anterior intercavernous sinus. After the sphenoid sinus mucosa was exposed, care was taken to keep it intact by dissecting it away from bone and covering it with a small cottonoid. After the tuberculum sellae was removed, the dural cuff was excised, exposing any remaining tumor and the diaphragma sellae. At the completion of tumor excision, fibrin glue was used to secure a small fat graft over the sinus opening. After the dura was closed, the pericranium was reflected over the exposed frontal sinus and the supraorbital osteotomy bone piece was then resecured using plates and screws. The remaining closure was completed in standard fashion.

RESULTS

Demographics and Presenting Symptoms

Forty-five patients were included in our cohort (*Table 1*), with the mean age at diagnosis of 51.5 years (range, 29–75 yr). The female-to-male ratio was 2:1. There were no ethnic or racial propensities. Tuberculum/planum meningioma predominated among those whose maximal tumor diameter was less than 4 cm (21 out of 23 patients). However, among patients with tumor maximal diameter more than 4 cm, olfactory meningiomas were present in eight out of 22 patients, with the remaining 14 patients having tuberculum/planum tumor locations. Visual abnormalities occurred predominantly in patients with tuberculum/planum tumors, whereas changes in mental status or personality occurred evenly across tumor locations (*Table 2*). The most common presenting symptom was vision change in 30 patients (66.6%). Reduced visual acuity was found in 15 patients, whereas formal visual field testing showed defects in 17 patients. An afferent papillary defect was present in five patients. Vision was normal in eight patients, and only one patient had insufficient information regarding visual symptoms. Headache and mental status changes were also common, reported in 15 and 10 patients, respectively. Diabetes insipidus was present in one patient.

TABLE 1. Patient demographics and tumor characteristics[a]

Variable	Total	More than 4 cm	Less than 4 cm	Unknown
No. of patients	45	22	19	4
Male	12	9	2	1
Female	33	13	17	3
Average age (yr)	51.5	57.2	45.4	0
Average follow-up (mo)	27.6	33	22.3	6
Extended bifrontal	40	18	19	3
Standard bifrontal	5	4	0	1
Staged surgery	2	2	0	0
Multiple tumors	3	2	1	0
Olfactory tumor	10	8	2	0
Tuberculum/planum tumor	31	11	16	4
Prior surgery	3	2	1	

[a] Average widest diameter of tumors in this series was 4.1 cm. Age and sex profiles were consistent with previous reports. Tuberculum/planum tumors predominated in this series compared with olfactory tumors.

TABLE 2. Preoperative signs and vision status[a]

Variable	Total	Tuberculum		Olfactory	
		More than 4 cm	Less than 4 cm	More than 4 cm	Less than 4 cm
Headache	18	5	10	2	1
Vision abnormality	36	14	20	2	0
Fields	23	8	14	1	0
Acuity	16	6	8	2	0
Normal	8	1	2	4	1
Unknown	2	0	0	2	0
Mental status	11	4	0	6	1
No smell	6	2	1	2	1
Other	6	3	1	2	0

[a] Visual abnormality was the most frequently encountered preoperative sign, followed by headache and mental status change. Tuberculum meningiomas presented with visual abnormality at both large and small sizes.

Surgical Approaches and Operative Variables

The mean operative time was 12.5 hours (range, 8–16 h). The mean estimated blood loss was 943 ml (range, 500–2000

TABLE 3. Operative characteristics[a]

Variable	Total	More than 4 cm	Less than 4 cm	Unknown
WHO grade I	40	18	18	4
WHO grade II	5	4	1	0
Simpson grade I	21	11	9	1
Simpson grade II	16	9	10	1
Simpson grade III+	9	3	4	2
Operative time (h)	12.5	13.5	11.7	0
Estimated blood loss (ml)	943	1072	819	0
ICU stay (d; average)	1.5	2.6	1.9	0
3 or more days in ICU	7	7	0	0
Rehabilitation/SNF	12	12	0	0
Day of MRI scan	1.4	3.5	1.3	
Optic canal	16	5	11	

[a] WHO, World Health Organization; ICU, intensive care unit; SNF, skilled nursing facility; MRI, magnetic resonance imaging. Most patients in this series received favorable Simpson grade restrictions of their meningiomas. Having a tumor more than 4 cm increased the proportion of patients requiring more than 3 days in the ICU. Extension of tumor into the optic canal was more commonly observed in patients with tumors less than 4 cm, correlating with significant visual defects detected in these patients.

ml). Blood transfusions were required in only two patients in whom estimated blood loss exceeded 1 L. Optic canal involvement with tumor was found in at total of 16 patients, with seven requiring bony drilling in addition to cutting of the falciform ligament. Bilateral optic canal involvement was observed in only two patients (*Table 3*).

Outcome Data

The extent of Simpson grade-based resection was judged according to the primary surgeon's operative report, and gross total resection was confirmed with contrast-enhanced MRI scans. Simpson Grade 1 and 2 resections were achieved in 36 patients (80%), whereas Simpson Grade 3 to 5 resections were identified in nine patients (20%; *Table 3*). All patients in whom subtotal resection was performed were referred for external-beam radiotherapy. The mean length of hospital stay was 6.5 days, whereas mean ICU stay was 1.5 days. Seven patients with tumor size more than 4 cm required more than 3 days of ICU care, whereas no patients with tumor size less than 4 cm required more than 3 days of ICU care (statistically significant, $P = 0.03$). Thirty-three patients (73.3%) were discharged to home, whereas 12 patients (26.6%) were sent for acute rehabilitation before returning home or for skilled nursing care. In a mean follow-up period of 27.6 months, clear improvement in vision was demonstrated in 22 patients (48.8%), and preserved vision with no further deterioration was demonstrated in 8 patients (17.7%; *Table 4*). Three patients (6.6%) experienced worsened vision after surgery. No deaths occurred during the follow-up period. There were no cases of new endocrinological deficits. Complications occurred in five patients (*Table 5*). There were no infections related to the surgical site.

MRI Evaluation

Preoperative cerebral edema was related to tumor size, with increasing edema seen with larger tumors (*Table 6*). Pial feeders were not related to the presence or absence of cerebral edema in our cohort, but seemed to trend toward more severe edema when pial feeders were present. All but five patients had complete preoperative and postoperative MRI scans for evaluation of cerebral edema as described above. Postoperative MRI scan were performed at an average of 1.4 days after surgery. Most patients in our cohort demonstrated no change in edema (*Table 7*). Only four patients experienced worsening edema, three of whom had maximal tumor diameter of more than 4 cm. We also found that 91% of patients with no or minimal cerebral edema before surgery (Category A or B) remained so after surgery in our cohort using the extended bifrontal approach (*Table 7*). This difference was statistically significant using Fisher's exact test at P levels equalling 0.01.

DISCUSSION

Meningiomas of the anterior cranial base generally are considered curable lesions if complete resection is achieved. The challenge in safely removing these tumors lies in the surgeon's ability to visualize relevant anatomy adequately and to minimize injury to surrounding normal tissue. Midline anterior cranial base meningiomas have the added challenges of growing bilaterally, reaching impressive tumor size and compressing the optic apparatus significantly. Several recent case series have reported overall favorable results for the surgical removal of olfactory and planum/tuberculum meningiomas, with recovery of vision in 40 to 80% of patients, Simpson Grade 2 or 3 resections in most

TABLE 4. Postoperative visual outcome[a]

Outcome	Total	More than 4 cm	Less than 4 cm
Improved	20	8	11
Same	9	4	3
Worse	3	2	1
Unknown	7	5	1

[a] Most patients experienced favorable improvement or preservation of vision. In this series, vision improved in a higher proportion of patients with tumors less than 4 cm than in those with tumors more than 4 cm.

TABLE 5. Complications[a]

Variable	Total	More than 4 cm	Less than 4 cm
Complications	5	4	1
CSF leak	2	2	2
Mucocele	1	1	0
Infection	0	0	0
Hematoma	3	2	1

[a] CSF, cerebrospinal fluid. Complications occurred rarely in this series. No infections were observed during the reported follow-up. CSF leaks were treated successfully with lumbar subarachnoid drainage for 3 to 5 days and bedrest. Hematoma complications were managed successfully with revision surgery.

TABLE 6. Preoperative edema: Associations and measurements for tumors[a]

	Total	A (no edema)	B (mild)	C (moderate)	D (severe)
Less than 4 cm	20	13	3	3	1
More than 4 cm	22	4	3	5	10
Pial supply					
Yes	6	0	1	1	4
No	10	0	2	4	4
No AG	6	4	0	0	2

[a] AG, angiogram.

operations, and complication rates ranging from 5 to 20% (2, 7–9, 12, 15, 17, 24). However, the choice of operative approach and technique has varied and no consensus exists among surgeons.

For olfactory meningiomas, which typically grow to impressive size before diagnosis, most surgeons prefer a bifrontal craniotomy for the largest tumors without removal of the supraorbital bar. This approach is relatively uncomplicated and can be performed quickly. However, significant frontal lobe retraction is frequently required to obtain a sufficient trajectory of view to the inner portions of the anterior fossa. Cerebral edema can be exacerbated and new retraction injury can occur. Unilateral approaches for olfactory meningiomas have been advocated by some authors (24, 26). Notably, Turazzi et al. (24) reported 70 cases of olfactory meningioma removed through a pterional craniotomy. They reported complete removal of all tumors and no complications during their follow-up period. Unfortunately, there was no attempt at quantifying imaging changes that might have reflected injury to the brain parenchyma after surgery, and no information regarding operative times or length of hospital stay was reported, making their results difficult to compare with ours.

The choice of operative approach in removing planum/tuberculum meningiomas is even more variable. Usually affecting vision bilaterally, symptoms are often worse on one side and surgeons tend to favor unilateral approaches on the side of worse vision. Pterional and orbitozygomatic approaches are the most popular and usually result in acceptable outcomes, especially for tumors with smaller sizes (<4 cm) (2, 7, 9, 12, 15, 18, 23). However, excessive retraction may be required to obtain adequate visualization of contralateral structures, and only a limited corridor is provided while working close to the optic apparatus, especially for larger tumors. As with the unilateral approach, visualization of the medial ipsilateral chiasmatic sulcus and tuberculum is obscured by the ipsilateral optic nerve, which cannot be retracted.

We favor the extended bifrontal craniotomy for approaching large olfactory groove meningiomas more than 3 cm and almost all planum/tuberculum meningiomas. Bifrontal exposure not only allows for wide exposure and flexibility of surgical trajectories, but also limits excessive retraction during these long operations. By extending the craniotomy with removal of the supraorbital bar, a truly low trajectory is offered, thereby minimizing retraction on the frontal lobes and limiting the force applied to the brain, which may exceed capillary closing pressure, thus generating the potential for cortical and subcortical ischemic injury.

In our series, we have shown that the extended bifrontal craniotomy can be applied safely without additional morbidity. Previous studies have described this approach for transbasal craniotomy for lesions involving the paranasal sinuses (3, 6, 8, 10, 13, 25), but no reports have been published assessing its application in the removal of meningiomas. The unique feature of our study lies in the pre- and postoperative assessment of cerebral edema in the immediate postoperative period. We think that the extended bifrontal approach reduces the incidence of new or worsened edema after surgery, which would contribute to faster and safer recovery and return to function. In fact, our series demonstrated that new edema occurred in only 7% of patients and in no patients was edema exacerbated. Intensive care unit days were minimal and average hospital length of stay was less than 1 week. Angiographic evidence of pial supply did not correlate with the presence of cerebral edema or its worsening after surgery, but these data were incomplete. Although the extended bifrontal approach may

TABLE 7. Postoperative edema change

Score	Preoperative (no. of patients)	Postoperative (no. of patients)			
		A (no edema)	B (mild)	C (moderate)	D (severe)
A (no edema)	17	8	9	0	0
B (mild)	6	0	4	1	1
C (moderate)	8	0	0	8	0
D (severe)	11	0	0	1	10

seem most useful for large tumors, we found that in patients harboring tumors less than 4 cm, 100% were discharged to home directly and no patients required more than 2 days of intensive care unit care.

The clear disadvantage of the extended bifrontal approach is the added surgical time and added potential for surgical complications. However, we found extremely low rates of the most commonly feared surgical complications, such as infection and cerebrospinal fluid leak. We attribute our low rates of complications to surgeon technique and careful closure using a vascularized pericranial graft to exclude the frontal and sphenoethmoid sinuses from the intracranial space. Cerebrospinal fluid drainage was not performed after surgery. Hemorrhagic complications (three patients) all occurred in the setting of early administration of low molecular weight heparin, given the morning after surgery. Interestingly, patients older than 65 years of age required additional intensive care unit days compared with younger patients, but there was no excess mortality in our older patients, in contrast to previously reported series (7, 9, 12, 15). We estimate the additional surgical time for a supraorbital bar osteotomy to be approximately 20 minutes with an additional 10 minutes during closure. Cosmetic results are generally excellent if care is taken to countersink miniplates and screws. Unfortunately, olfactory function was not assessed consistently in our series. Although several of our patients reported injury to only one olfactory nerve, some of these patients still reported subjective anosmia during follow-up examinations. Other published series of bifrontal and craniofacial approaches have reported excellent preservation of smell (1, 21, 22, 26). Also, the extended bifrontal approach does not guarantee a Simpson Grade 1 resection. The ability to achieve true gross total resection depends primarily on the extent of involvement with surrounding dura, bone, and neurovascular structures and histological grade. Although no new recurrences were found in our series, 10 years of follow-up is requisite before such claims can be justified.

CONCLUSION

The extended bifrontal craniotomy is an excellent approach for the removal of midline anterior fossa meningiomas. With this approach, new injury to the frontal lobes is avoided, as measured by the degree of cerebral edema seen on postoperative imaging, without the risk of disproportionate complications. Infections can be prevented with careful surgical technique. The benefit during surgery is wide and flexible exposure, allowing the surgeon to work safely around both optic canals and carotid arteries with more operative space. We recommend the extended bifrontal craniotomy as the preferred approach over standard bifrontal or unilateral craniotomy for large olfactory groove meningiomas more than 3 cm and all medium to large planum and tuberculum meningiomas.

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COMMENTS

The authors have quantified the damage done to the brain during the removal of anterior basal meningiomas using an extended subfrontal approach. The extended subfrontal approach was first de-

scribed by Sekhar et al (1). It may be considered a variation of the transbasal approach described by Patrick Derome and the "subcranial approach" described by Joram Raveh. It can be used for a variety of intradural and extradural tumors involving the anterior cranial base. For olfactory groove and plenum meningiomas, I prefer to use a combination of the frontoorbital approach and the lateral transsylvian approach, which allows the visualization of the critical neurovascular structures at the posterior pole of the tumor early and yet allows the advantages of the extended subfrontal approach (2). A study such as this is critical to join the debate regarding what is really a "minimally invasive approach." Are we talking about minimal invasiveness of the brain or minimal invasiveness of the bone (MG Yaşargil, personal communication, 1999)? A drawback of this study is that there were no controls. However, this study set a new standard for future comparison of patients operated by different techniques.

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1. Sekhar LN, Nanda A, Sen CN, Snyderman CH, Janecka IP: The extended frontal approach to tumors of the anterior, middle and posterior skull base. **J Neurosurg** 76:198–206, 1992.
2. Sekhar LN, Tzortzidis F: Resection of tumors by the fronto-orbital approach, in Sekhar LN, de Olivera E (eds): *Cranial Microsurgery, Approaches and Techniques*. New York, Thieme, 1999, pp 61–75.

The authors report on the retrospective series of 45 patients undergoing extended bifrontal craniotomy for midline subfrontal tumors. They describe the surgical technique and list their results. The key reason behind the authors' preference for this technique is a minimized brain retraction that reportedly results in less postoperative vasogenic edema. The salient feature of the technique described is a bilateral orbital roof osteotomy and, in select cases, a resection of the planum and the tuberculum sellae in addition to the standard bifrontal craniotomy. Other technical features include a unilateral or bilateral dissection of the olfactory nerves and section of the falciform ligament as indicated in patients in whom there is evidence of meningioma insinuation into the optic nerve canal. The excellent outcomes speak for themselves.

We have recently reported (1) on our technique and results in 24 patients with suprasellar meningiomas. We prefer to approach these tumors via a frontotemporal-pterional craniotomy that reaches across the midline and in conjunction with an orbitoclinoidal cranial base dissection. We do not use intraoperative lumbar drainage, but rely instead on a wide opening of the sylvian fissure for cerebrospinal fluid release. We think that this technique has a greater potential for preserving the olfactory nerve function, at least on the contralateral side, while offering the same degree of exposure and protection from undue brain retraction. The key feature of our technique is a strict adherence to the principle of carrying out the surgical dissection along the tumor-arachnoid plane and not along the arachnoid-neurovascular structures interface. This principle was, perhaps, somewhat underemphasized in the authors' report.

One of our guiding motives in cranial base surgery has been that surgical minimalism is not necessarily synonymous with minimal invasiveness. We are delighted to see that the authors evidently follow the same adage. However, I would like to suggest that striking a balance between the extent of an exposure and the need for such an exposure would appear to be an appropriate surgical strategy.

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1. Ciric IS, Rosenblatt S: Suprasellar meningiomas. **Neurosurgery** 49:1372–1377, 2001.

The authors presented a series of 45 cases of basal frontal meningiomas (olfactory groove, planum, and tuberculum sellae meningiomas) treated with the help of extended bifrontal craniotomy and achieved favorable results. They advocated this approach for treating not only large frontal basal meningiomas, but also for those whose size was smaller than 4 cm.

The authors quite thoroughly analyzed their experience, but it is a pity that they did not pay attention to such important qualities of tumors as texture (soft or hard), infiltration of the surrounding structure, vascularization, and incorporation of vessels in the tumor structure.

My opinion is that the extended approach can be indicated only for large, widespread tumors. Relatively small tumors (if they do not incorporate important vessels and their branches and do not invade in the surrounding structure) can be successfully removed using simple routine unilateral frontal or pterional mathods without any serious problems.

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