Transfrontal-Sinus-Subcranial Approach to Olfactory Groove Meningiomas: Surgical Results and Clinical and Functional Outcome in a Consecutive Series of 21 Patients

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■ BACKGROUND: **The transfrontal-sinus-subcranial approach (TFSSA) allows for direct exposure and removal of olfactory groove meningiomas (OGMs), without any brain retraction. Compared with other skull base approaches (e.g., fronto-orbitobasal, transbasal, subcranial, fronto-orbitozygomatic, and one-and-half approach), it could offer the same advantages but is less invasive.**

■ OBJECTIVE: **We report the results in a series of 21 consecutive patients with OGMs and operated on through TFSSA, to propose a viable alternative approach.**

■ METHODS: **Mean maximum tumor diameter was 45.9 ± 3.4 mm (range, 25–70 mm). The aim of surgery was Simpson grade I removal. Surgical, clinical, and functional outcomes were reported. Mean follow-up was 87 ± 7 months (range, 36–176 months).**

■ RESULTS: **In all patients, magnetic resonance imaging after surgery confirmed complete tumor removal. The recurrence-free survival rate was 100% and 85.7% at 5 and 10 years, respectively. Surgery-related mortality and major morbidity were 0% and 4.8%, respectively. Risk of anosmia significantly correlates with meningioma size ($P < 0.001$) and smell sense was preserved only in patients with tumors less than 4 cm in maximum diameter (4/7; 57.1%). A significant improvement of Mini Mental Standard Examination score was recorded at follow-up ($P < 0.001$) and no patients worsened their cognitive profile. Visual function improved in 7/8 (87.5%). Karnofsky Performance Scale score after surgery significantly increased ($P < 0.001$). According to the Glasgow Outcome Score, good outcome was achieved in 20 patients (95.2%).**

■ CONCLUSIONS: **Based on reported results, TFSSA allows complete tumor removal with good outcome and low complication rate. It may be proposed as a safe and effective approach to treat large and giant OGMs.**

INTRODUCTION

After the first successful resection of an olfactory groove meningioma (OGM) in 1885,[1] many approaches have been adopted: from bifrontal and pterional routes to skull base approaches to minimize brain retraction, even if the skull base approaches are too time consuming and technically demanding.[2-9] Furthermore other techniques, such as the endoscopic endonasal approach (EEA) and supraorbital approach have been proposed.[10-18] There are 2 main strategies in the treatment of OGMs. Several investigators recommended the removal of only the visible tumor and dural coagulation,[19-25] whereas others suggested an extensive resection of the meningioma, dura, and bone, particularly in young patients, because recurrence is frequent when a massive tumor infiltration into the ethmoid is evident.[2,5-7,9,26,27]

Key words
- Anterior cranial base
- Meningiomas
- Olfactory groove
- Skull base surgery
- Surgical outcome

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
CT: Computed tomography
EEA: Endoscopic endonasal approach
GOS: Glasgow Outcome Scale
KPS: Karnofsky Performance Scale
MMSE: Mini Mental State Examination
MRI: Magnetic resonance imaging
OGM: Olfactory groove meningioma
SG: Simpson grade
TFSSA: Transfrontal-sinus-subcranial approach
WHO: World Health Organization

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Hyperostosis of underlying bone in OGMs occurred commonly, and it was reported in 17%–78% of cases.[6,10,16,25,28-30] It is generally accepted that hyperostosis is the result of tumor microinvasion.[31] The histologic examinations have shown bone tumor cell infiltration in more than 70% of meningiomas with hyperostosis, probably mediated by a specific pattern of matrix metalloproteinase.[32,33] The frequency of ethmoidal bone invasion (occurring in 15%–73.7% of OGMs) may be supported by the thinness of the cribriform plate.[3-5,7,9,10,16,27,29] The involved bone has to be considered a potential point of recurrence after surgery, shown by the recurrence rate of 30% and 41% reported after 5 and 10 years, respectively.[34]

Bone invasion is not considered among the World Health Organization (WHO) criteria for grading meningiomas; however, there is some evidence that the extent of bone invasion can influence the clinical behavior of meningiomas and patient outcome.[31,33,34]

OBJECTIVE AND STUDY SIZE

Since 2001, the senior author has been using the transfrontal-sinus-subcranial approach (TFSSA), already described,[35] to achieve Simpson grade I (SGI) removal in midline anterior cranial base meningiomas, as a less invasive route, compared with other skull base techniques previously adopted. We report a series of 21 OGMs operated through TFSSA, analyzing surgical results, complications, and clinical and functional outcome.

METHODS

Population and Setting

Twenty-one consecutive patients harboring OGM, operated on through TFSSA from 2001 to 2014 at our institute, were considered. Inclusion criteria were 1) meningiomas originating from the midline anterior cranial fossa, along the dura of the crista galli, cribriform plate, and frontoethmoidal suture, and 2) newly diagnosed meningiomas. Medical charts, surgical records, and radiologic studies of the patients were prospectively collected and retrospectively analyzed. Informed surgical and research consents for data collection were routinely obtained for all patients. All procedures were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Variables, Data Source, and Measurement

All patients underwent complete neurologic and ophthalmologic evaluations before surgery, 6 and 12 months after. Anosmia was evaluated with a questioning test.

The Mini Mental State Examination (MMSE) was performed in all cases, except 1 amaurotic patient, to evaluate the cognitive function. The Karnofsky Performance Scale (KPS) was used to evaluate the functional impairment. The postoperative MMSE, the KPS, and the Glasgow Outcome Scale (GOS) were assessed 12 months after discharge.

All patients underwent head computed tomography (CT) scans before surgery and brain magnetic resonance imaging (MRI) before surgery, 6 and 12 months after surgery, and then yearly. Digital subtraction angiography was performed in only 3 cases of giant meningiomas; all other cases underwent angio-MRI (Figure 1).

The aim of surgery was SGI resection, confirmed on postoperative MRI. Recurrence was considered if new tumor was observable at follow-up MRI evaluation.

Surgical Technique

The patient is placed in the supine position, with the chest raised and the head elevated above the heart level; the head is extended with the vertex toward the floor. A bicoronal skin incision far posterior to the hairline is made. The pericranium and the skin are raised together to expose the orbital rim, the frontozygomatic suture, and the nasal process of the frontal bone up to the frontonasomaxillary suture in the midline. The supraorbital foramina are opened with a chisel and the supraorbital nerve and artery are freed. Six osteotomies are performed with reciprocating saw (Figure 2). The first 2 cuts are made vertically on the sagittal plane along each lateral border of the frontal sinus, usually at the supraorbital foramina/notches, from the orbital rim to the frontal bone. Then, a horizontal cut is made on the axial plane, connecting the previous 2, along the superior border of the frontal sinus. A fourth horizontal osteotomy is made at the level of the frontonasomaxillary suture and extended in depth along each medial orbital wall just anterior to the lacrimal crest. This osteotomy is linked bilaterally to the first 2 made on the orbital rim, completing the 2 cuts along the medial wall and orbital roof. The anterior wall of the frontal sinus is then lifted above with a chisel inserted as levers through the bone cuts. Frontal sinus boundaries can be assessed on CT preoperative images. In case of small sinus, the bone flap has to be extended slightly beyond the superior and lateral limits of the sinus, including the external layer of the frontal vault, which is cut obliquely nearly tangentially to augment the opening surface, allowing TFSSA to be performed in almost all cases.

The sinus mucosa is completely removed and the frontonasal ducts are packed with Surgicel (Ethicon Inc., Sommerville, New Jersey, USA) rolls, powered by vancomycin. The anterior ethmoidal arteries are identified, coagulated, and cut. The posterior wall of the frontal sinus is removed using the diamond burr. The crista galli is dissected from the dura mater and removed. In case of extension of the meningioma into the ethmoid, olfactory filaments are coagulated and cut at the extradural side, and the dura mater is dissected from the cribriform plate. The cranial base is drilled according to the bone invasion.

The dura mater is opened transversely on both sides of the midline near to the olfactory grooves. After coagulation of its implant, the tumor is debulked using an ultrasonic aspirator. The brain parenchyma is not retracted in any phase of the surgical procedure because gravity takes the frontal lobes away from the surgical field. Some pieces of absorbable hemostatic gelatin sponge are used to keep the brain away from the tumor during the dissection.

After removal of the tumor, a pericranium patch is sutured under the microscope. A wide pedicled frontal pericranium flap is reflected along the anterior cranial base to separate the cranial and

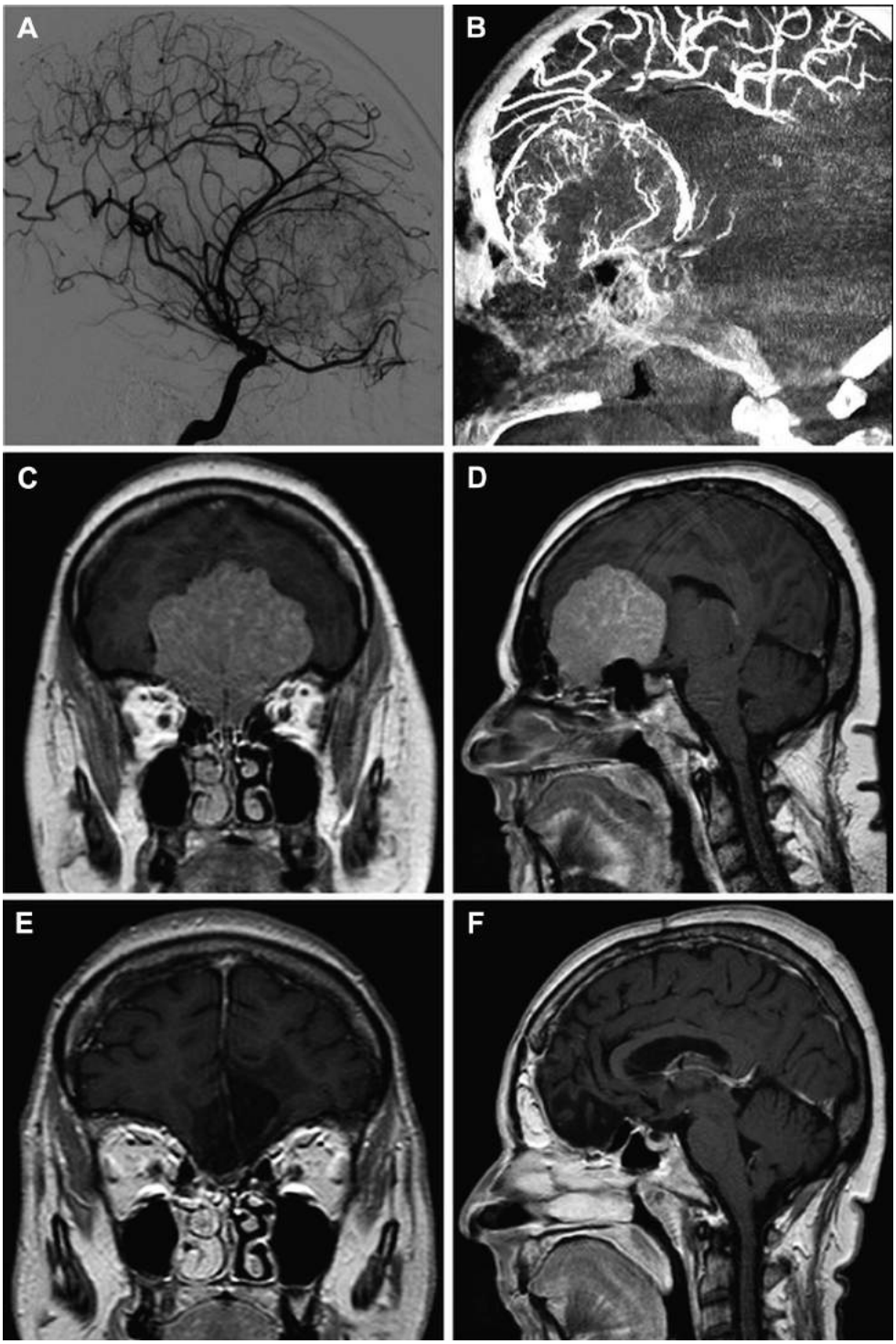

Figure 1. (**A** and **B**) Preoperative angiography during injection of internal carotid artery, showing anterior and posterior ethmoidal arteries. (**C** and **D**) Preoperative magnetic resonance imaging of large olfactory groove meningioma on coronal and sagittal view. (**E** and **F**) Magnetic resonance imaging on coronal and sagittal view obtained 24 months after surgery, showing complete tumor removal and skull base reconstruction with autologous tissue.

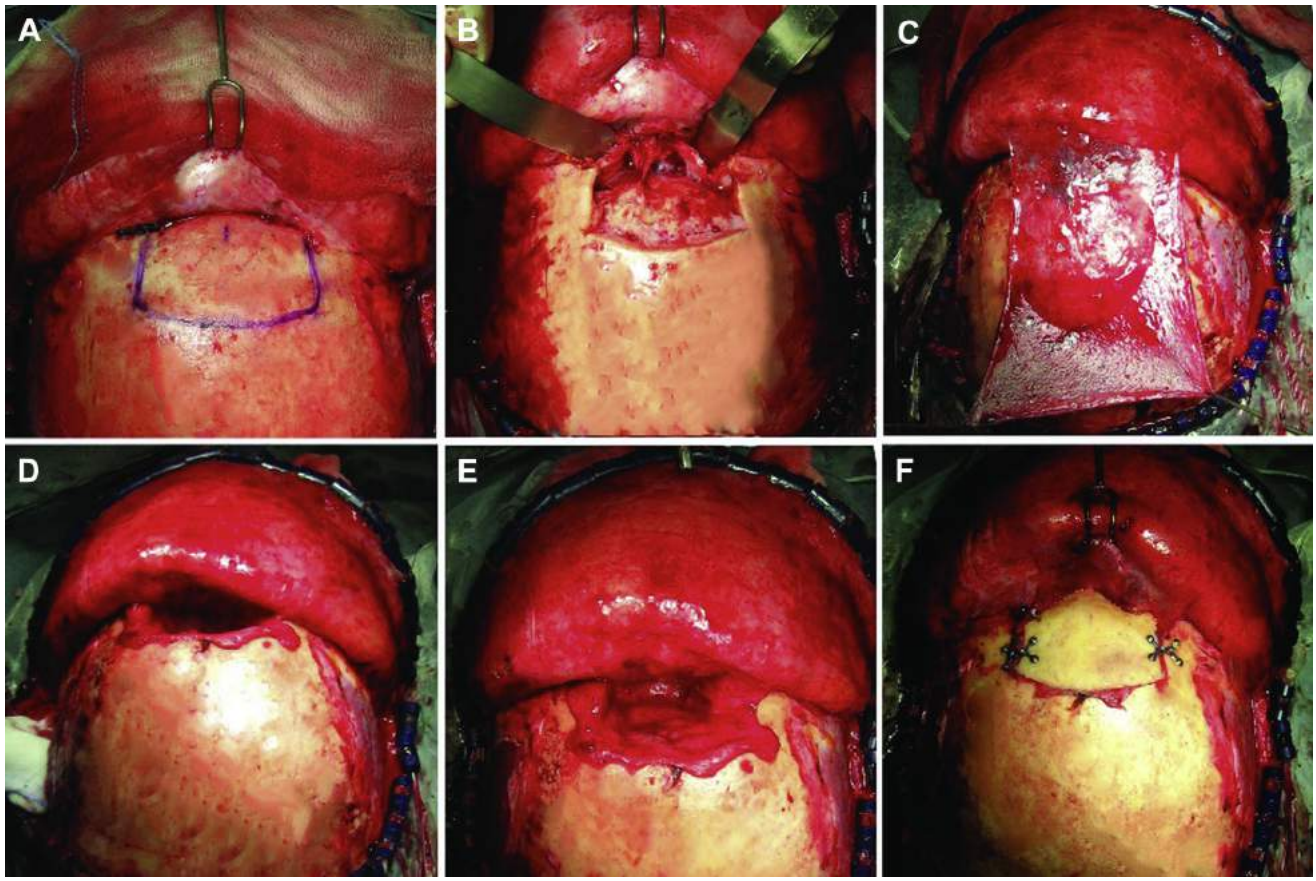

Figure 2. Intraoperative images. (**A**) Frontonasal osteotomy was planned; (**B**) anterior wall of the sinus was elevated and sinus mucosa removed; (**C**) a wide frontal pericranium flap was shown with a vascular pedicle; (**D** and **E**) the pericranium is reflected along the anterior cranial base to separate cranial and nasal compartments; (**F**) the anterior wall of the frontal sinus is repositioned and fixed with titanium microplates and screws.

the nasal compartments. If basal bone has been drilled extensively and a dead space is still present, some abdominal fat can be harvested and positioned between the 2 layers of the pedicled frontal pericranial flap. The anterior wall of the sinus is then repositioned and fixed with titanium microplates and screws.

Statistical Methods

All calculations were performed using the statistical package Stat View 5.0 (Abacus Concepts, SAS Institute Inc., Cary, North Carolina, USA). Continuous data were expressed as mean ± standard error. Categorical variables were compared with the Fisher exact 2-tailed test. Continuous variables of the 2 groups were compared with the unpaired t test, whereas for more than 2 samples the analysis of variance test was used. The paired t test was applied to dependent samples. The simple regression was used to analyze the relation between 2 continuous variables. Tumor recurrence-free survival was calculated using the Kaplan-Meier survival function. A P value of less than 0.05 was considered to indicate statistical significance.

RESULTS

Participants and Descriptive Data

Twelve patients were female (57.1%) and 9 male (42.9%). Patients' age ranged from 28 to 69 years (mean, 54.1 ± 2.5 years). The mean maximum diameter was 45.9 ± 3.4 mm (range, 25–70 mm). Tumors were classified according to their maximum diameter on MRI in small (<4 cm), large (4–6 cm), and giant meningiomas (>6 cm).

Clinical symptoms and signs at presentation are summarized in Table 1. Anosmia was the most frequent sign (11/21; 52.4%) and was related with tumor size ($P = 0.02$). Visual impairment and cognitive or mood disorders were recorded in 8 patients (38.1%), and they were associated with large or giant tumors in all cases. Frequency of anosmia, visual loss, cognitive dysfunction, bony changes, and extension into the ethmoidal sinus increased significantly with tumor size.

MMSE and KPS scores were inversely related with the maximum tumor diameter ($P < 0.001$; R^2, 0.702 and 0.571; Figure 3).

Table 1. Preoperative Characteristics of Patients According to Meningioma Size

Characteristics	Small (n = 9; 42.9%)	Large (n = 7; 33.3%)	Giant (n = 5; 23.8%)	Total (n = 21)	*P*
Asymptomatic*	5 (55.5)	1 (14.3)	—	6 (28.6)	
Neurologic unrelated symptoms/signs†	2 (22.2)	1 (14.3)	—	3 (14.3)	
Seizures	1 (11.1)	1 (14.3)	1 (20)	3 (14.4)	NS
Intracranial hypertension syndrome	—	4 (57.1)	1 (20)	5 (23.8)	
Cognitive and psychiatric disturbance	—	4 (57.1)	4 (80)	8 (38.1)	0.006
Visual deficit	—	4 (57.1)	4 (80)	8 (38.1)	0.006
Anosmia‡	2 (22.2)	4 (57.1)	5 (100)	11 (52.4)	0.02
Hyperostosis or bone invasion	3 (33.3)	6 (85.7)	5 (100)	14 (66.7)	0.02
Ethmoid invasion	—	1 (14.3)	3 (66)	4 (19.1)	0.02
Mini Mental State Examination (mean ± standard error; range)	29.8 ± 0.2	24.3 ± 2.3	21.5 ± 1.5	26.2 ± 1.1; 16–30	0.0046
Karnofsky Performance Scale (mean ± standard error; range)	97.8 ± 1.5	74.3 ± 7.2	54 ± 7.5	80 ± 5; 40–100	0.001

Values are number (%) except where indicated otherwise.
NS, not statistically significant.
*Six tumors were diagnosed incidentally during computed tomography scan performed for other reasons than minor head injury or headache.
†Tinnitus (1), vertigo (1), essential tremor (1).
‡Anosmia present at hospital admission.

Histologic examination was diagnostic in 19 cases (90.5%) for WHO grade I meningiomas and in the remaining 2 (9.5%) for WHO grade II atypical meningiomas.

Outcome Data

In all patients, postoperative MRI detected complete tumor removal. The dura mater and infiltrated basal bone were removed, achieving SGI (Figure 1). Mean follow-up was 87 ± 7 months (range, 36–176 months). One giant meningioma (4.8%) recurred 88 months after SGI surgery and was successfully treated by Gamma Knife radiosurgery (Elekta, Stockholm, Sweden). The recurrence-free survival was 100% and 85.7% at 5 and 10 years, respectively (100%–59% upper and lower 95% confidence intervals).

Main Results

No surgery-related mortality was recorded. Major morbidity, causing reoperation or permanent neurologic defect (excluding anosmia), occurred in 1 case (4.8%). The patient with a large OGM developed, 2 days after operation, a thrombocytopenia related to therapy with low-molecular-weight heparin: bruising throughout the body and left severe hemiparesis occurred caused by the CT right basal ganglia hemorrhage. Serial CT scans showed reabsorption of hemorrhage and complete recovery of the hemiparesis.

Minor transient complications occurred in 3/21 patients (14.3%): 2 cases of transient diplopia in vertical gaze, lasting a few weeks, and 1 deep vein thrombosis that required anticoagulant therapy for 6 months.

All 11 anosmic patients remained stable. Among 10 patients with normal smell sense or hyposmia before surgery, preservation of smell sense occurred in 4 patients (40%), all of whom had small tumors (4/7, 57.1% vs. 0/3, 0%; $P < 0.001$). However, anosmia has not been referred as an invalidating handicap for any of these patients.

Mental changes, documented in 8 patients before surgery, recovered completely after surgery in 4 cases (50%), improved in 2 (25%), and was unchanged in 2 (25%). No patients worsened their cognitive performance after surgery. The MMSE score improved significantly at follow-up ($P < 0.001$; Figure 4).

Among 8 patients with preoperative visual impairment, 6 showed complete recovery (75%) and 1 (12.5%) improvement of visual defect; only a long-standing blind patient did not recover (12.5%).

Other Analyses

The KPS score 12 months after surgery was significantly higher than before surgery ($P < 0.001$; Figure 4) and it improved in all cases (100%). Globally, a final good outcome (GOS score = 5) was achieved in 20 patients (95.2%) and moderate (GOS score = 3) in 1 (4.8%). Cosmetic outcome was highly satisfactory in every case.

DISCUSSION

Key Results

TFSSA allows removal of the infiltrated dural attachment and drilling the bone beneath the tumor insertion, achieving an SGI resection in all patients in our series, as confirmed at postoperative MRI. The only relapse occurred after long time and the

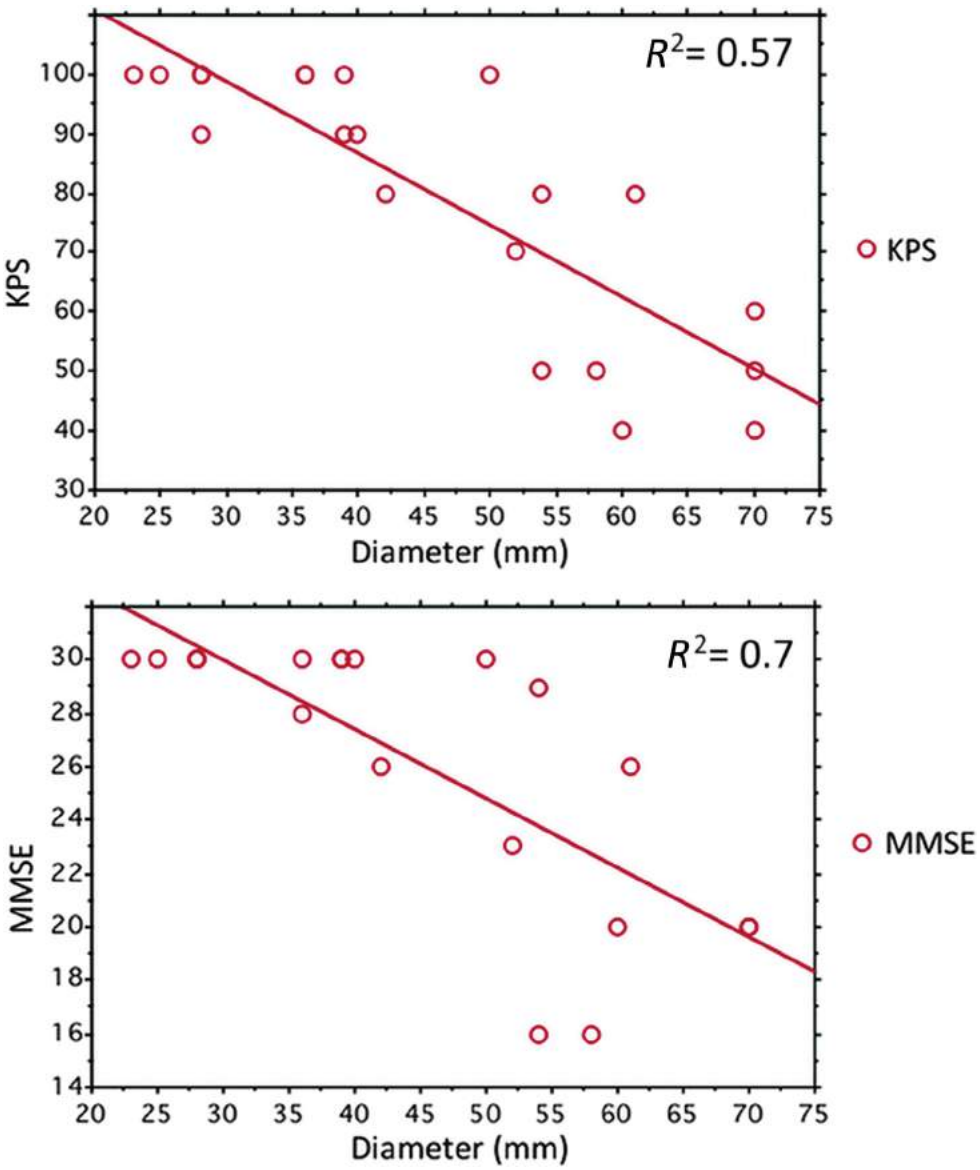

Figure 3. Upper scattergram of simple regression between Karnofsky Performance Scale (KPS) score and maximum diameters (cm); lower scattergram of simple regression between Mini Mental State Examination (MMSE) score and maximum diameters (cm).

recurrence-free survival at 5 years and 10 years was excellent (100% and 85.7%, respectively).

Reviewing the literature, the heterogeneity of approaches, the lack of distinction in SGI and II for each approach, together with the extreme variability of follow-up periods and criteria to evaluate the extent of removal (intraoperative view, post-operative CT scan, or MRI) explain why data are not conclusive in defining the role played by approach type and SGI or II in preventing recurrence of OGMs. Against this background, a reliable literature comparison of published data is unworkable and **Table 2** summarizes the series including SGI and II evaluated by the postoperative MRI and follow-up longer than 5 years. Bitter et al.[36] report the longest follow-up (10 years): this study comprised 61 OGMs operated on through the pterional route; tumor removal, including both SGI and II, was achieved in 98% of patients; recurrence occurred in 5% of patients during follow-up.

Few investigators have performed a statistical analysis comparing anterior, lateral, or skull base approaches in terms of surgical removal and recurrence rates,[28,29,38] and only 1 study by

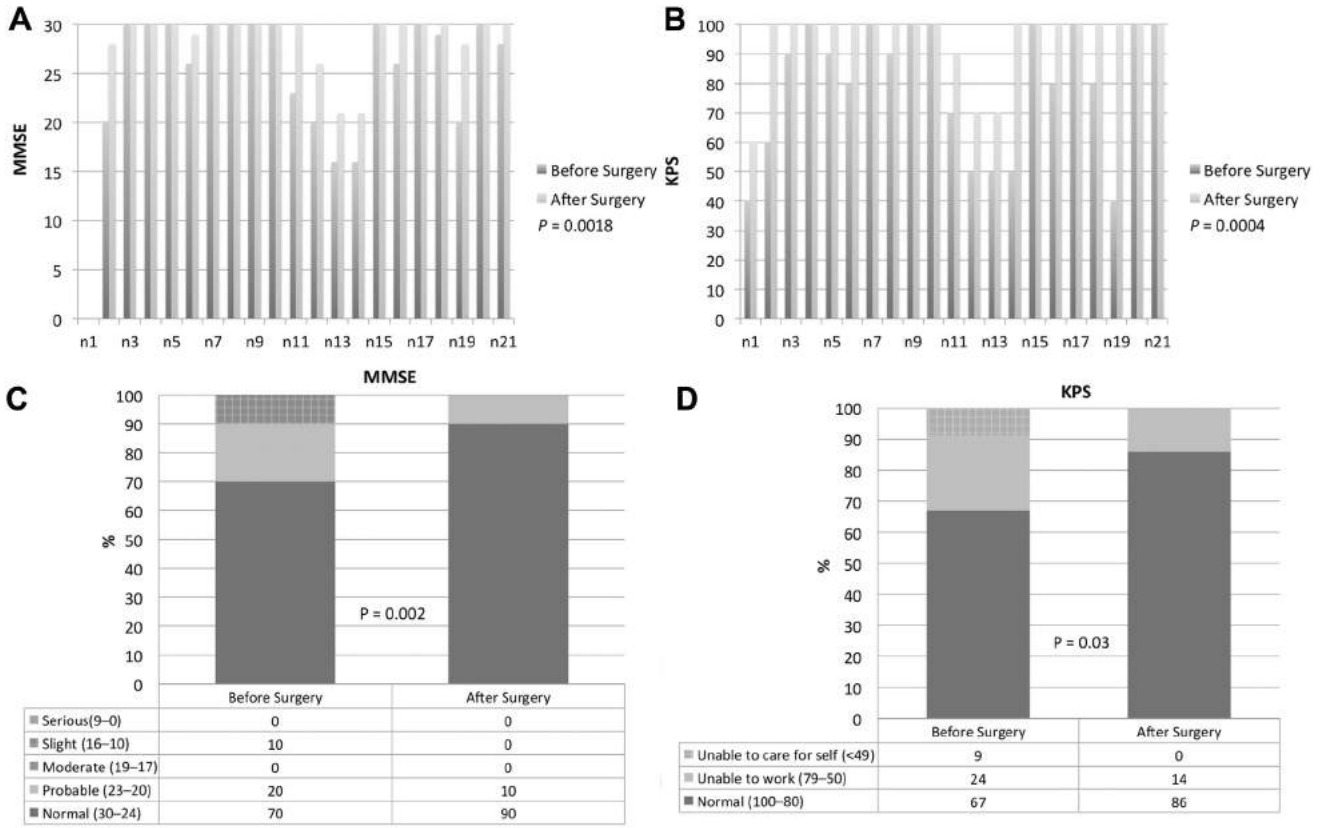

Figure 4. (**A**) Mini Mental State Examination (MMSE) score before and 12 months after surgery for each patient (paired t test was significant); (**B**) Karnofsky Performance Scale (KPS) score before and 12 months after surgery for each patient (paired *t* test was significant); (**C**) frequency of different classes of Mini Mental State Examination score before surgery; (**D**) frequency of different classes of Karnofsky Performance Scale score before surgery.

Pallini et al.[38] has reported a significant difference in favor of skull base techniques: SGI and II resection was achieved in all fronto-orbitobasal operations compared with 80% of bifrontal approaches and 81% of pterional approaches, but both SGI and II were a positive prognostic factor for longer overall survival. Conversely, Mukherjee et al.[39] have shown that complete versus incomplete (grades II–V) resection had a higher complication rate (50% vs. 23%; P = 0.16), including cerebrospinal fluid (CSF) leak, but no recurrence (0% vs. 25%; P = 0.07).

EEA may have some advantages, such as the direct tumor access avoiding any brain retraction, early tumor devascularization, and removal of involved bone and dura; however, the disadvantage is the difficulty of achieving SGI resection in tumors larger than 40 mm in maximum diameter.[11,14,15] Recently, in an EEA series, Koutourousiou et al.[14] reported SGI removal in 67% of OGMs, with 7% of recurrence during a mean follow-up of 32 months.

Another important matter of discussion is the complication rate in different types of approaches. TFSSA allows excellent exposure of the midline anterior cranial base with a direct route and a favorable working angle to the skull base, greatly reducing or avoiding the need of brain retraction, which may contribute to avoiding intraoperative and postoperative edema or contusion hemorrhages. The only cerebral hemorrhage that occurred in our series was located in the basal ganglia, caused by a coagulation disorder, and no brain retractor was used during surgery. The reported incidence of cerebral hemorrhage after surgery for OGMs varies between 0% and 13% in series adopting the bifrontal approach,[20,21,27,34,40] around 5% with the interhemispheric approach,[41] and ranges between 0% and 5% in series adopting the pterional approach.[22,23,25,36,42,43] When orbital osteotomies were added to standard craniotomies or in cases using the subcranial approach, this rate ranges between 0% and 10%.[2,5,6,29,37] In a series reported by Pallini et al.,[38] hemorrhages occurred in 13% of bifrontal approaches, in 5% of pterional approaches, and in 0% in bifrontal craniotomies with orbital osteotomies; brain swelling was reported in 17%, 19%, and 0% respectively, suggesting that skull base approaches allow a good tumor removal rate with a lower risk of life-threatening complications. Results of TFSSA are similar to those described earlier; nevertheless, this approach is less invasive in brain tissue.

Table 2. Literature Review of the Olfactory Groove Meningioma Surgical Series with Follow-Up Longer Than 5 Years: Surgical Outcome, Follow-Up Data, Recurrence, And Mortality

		GTR-MRI, n (%)				
Author, Year	Patients/Approach	Simpson Grade I and II, n (%)	Simpson Grade I and Simpson Grade II, n (%)	Mean Follow-Up	Recurrence After GTR, n (%)	Mortality, n (%)
Tomasello et al., 2011[25]	18 PT	17/18 (94)	NR	93 months	3/17 (18)	0
Bitter et al., 2013[36]	61 PT	60/61 (98)	NR	122 months	3/60 (5)	1 (2)
Tamaki et al., 1999[37]	5 BFON	4/5 (80)	I: 3/5 (60) II: 1/5 (20)	6 months—23 years	0	0
Obeid and Al-Mefty, 2003[6]	15 SO/U-BSF	14/15 (93)	NR	3.7 years	0	0
Spektor et al., 2005[9]	35 BF 9 USF 12 SB 18 PT 7 FOZ	72/81 (90)	NR	71 months	0/72 (0)	1 (1)
Bassiouni et al., 2007[28]	36 BF + 4 UF	56/56 (100)	I: 23/40 (57.5)	5.6 years	5/56 (9)	3 (5.4)
	13 PT + 3 SO		I: 1/16 (6)			
	Overall		I: 24/56 (43) II: 32/56 (57)			
Nakamura et al., 2007[29]	46 BF	93%	NR	5.3 years	6%	9%
	36 FL	91%			3% (NS)	0%
Pallini et al., 2015[38]	70 BSF	56 (80)	NR	89 months	13 (11)	4 (6)
	21 PT	17 (81)				0
	22 BSF + OS	22 (100)				0
	Overall	95/113 (84)				4 (3)
Present series	21 TFSSA	21/21 (100)	21/21 (100)	87 months	1/21 (4.8)	0

GTR, gross total tumor resection; MRI, magnetic resonance imaging; PT, pterional approach; NR, not reported; BFON, bilateral fronto-orbitonasal approach; SO, supraorbital approach; BSF, bilateral subfrontal approach; BF, bifrontal approach; U-BSF, unilateral or bilateral subfrontal approach; USF, unilateral subfrontal approach; SB, subcranial approach; FOZ, fronto-orbital-zygomatic approach; UF, unilateral frontal approach; FL, frontolateral approach; NS, not statistically significant; OS, orbitalosteotomy; TFSSA, transfrontal-sinus-subcranial approach.

In OGM surgery, another frequent complication is CSF rhinorrhea. TFSSA makes an easy and satisfactory cranial base repair possible, which is essential to prevent CSF leak and infections. We report no cases of CSF rhinorrhea or meningitis. The reported rate of CSF rhinorrhea in the literature ranges from 0% to 40%; in series using EEA and more aggressive subcranial or transbasal approaches, this complication is more frequently encountered; the meningitis rate is up to 6%, secondary to CSF leak or through direct contamination, which represents a serious complication, whereas surgical mortality is up to 20%, in the pertinent literature.[2,3,5-7,9,14,16,20,21,23-25,27-29,34,36-38,40-42,44-46]

TFSSA allows earlier coagulation of the anterior ethmoidal arteries on both sides within the orbit, obviating preoperative embolization, which is sometimes associated with a significant risk of visual loss.[30]

Changes in cognition and personality are the most common clinical manifestations in OGMs, ranging between 26% and 72% in reported cases; remarkable improvement of the cognitive status and attention functions after resection of OGMs has been reported in 22%—100% of patients.[3,5,6,10,14,23,27,28,36,41,43,44] TFSSA should allow a further improvement of impaired cognitive function with a good final cognitive status. In this series, the postoperative MMSE score improved significantly and 90% of patients had a normal score after surgery with no worsening in their cognitive functions. In our experience, this is the most remarkable advantage of TFSSA, keeping the postoperative quality of life at the highest possible level.

Visual loss is one of the most frequent onset symptoms, occurring in 21%—61% of cases, usually related to very large OGMs.[3,5,9,21,27-29,38,40] In this series, the rate of visual function improvement after surgery (87.5%) is comparable with those reported in the literature, ranging from 20% to 100%.[5,6,10,14,16,21,23,25,27-29,36,41,43]

Hyposmia/anosmia is generally present on preoperative examination in 43%—78% of patients[3,9,14,15,19,21,28,29,36,38,41,43] and only occasionally recovered after surgery.[5,28,30,47] In our series, the rate of functional olfaction preservation was 40% in all tumors and 57.1% in small tumors. Sense of smell preservation has been reported

in 10%–93% after surgery, depending on surgical approach, tumor size, and preoperative status.[5,21,23,25,28,35,40,41,43,44,46,47] Although the anatomic preservation of the olfactory nerves does not always mean a functional preservation, a significantly higher preservation rate was reported in patients who underwent a frontolateral approach (71.4%) compared with a bifrontal approach (36.8%).[47] The same investigators reported that olfactory preservation occurred more frequently in patients without preoperative olfactory dysfunction than in those presenting with olfactory dysfunction (84.6% vs. 40.7%; $P = 0.016$) and it was related to tumor size (78.6% in <4 cm vs. 42.3% in >4 cm; $P = 0.035$).

Limitations, Interpretation, and Generalizability

A potential pitfall affecting TFSSA, as with other anterior approaches, is the late exposure of optic nerves, internal carotid arteries, anterior cerebral arteries, and anterior communicating artery, which come into view at the final stages of tumor resection.[2,9,43,48] In most cases, the arachnoid is intact and creates a cleavage plane between the tumor and these structures. Infrequently, the arachnoid was not preserved with vessel encasement; in this case, the risk of vessel damage was high even if the tumors were approached laterally; a complementary treatment, such as intensity-modulated radiation therapy or radiosurgery, is effective and safest in achieving residual tumor control, suggesting that a less aggressive approach may be preferred.[49]

The main limitation of our study is the relatively small sample size and the lack of statistical analysis between different approaches, as pointed out by other previously published series. Inversely, our data underscore that the bone involvement in OGMs is a key point. Bony changes have been detected in only 33.3% of small meningiomas and none invaded the ethmoid. When dealing with larger tumors, hyperostosis and cranial base infiltration were detected in 85.7% of large OGMs and in all giant OGMs. MMSE and KPS correlate with tumor diameter. To achieve complete surgical resection in these bigger tumors, the dura and the bone have to be removed. TFSSA represents a less invasive skull base technique associated with a good outcome. The KPS score improved significantly: it was higher than 80 in 66.7% of patients preoperatively and in 85.7% after surgery. A good clinical outcome was achieved in most patients (95.2%), and the reported rate in the literature ranges from 75% to 95%.[2,3,7,9,16,25,27-29,34,38,40,42,46] Advantages in terms of low recurrence in SGI removal have still to be confirmed, but our results are encouraging.

The trend is to adopt the pterional route or other techniques, such as EEA or an endoscopic supraorbital approach, for small or medium OGMs, and to adopt the anterior bifrontal, transbasal, subcranial approaches, or the lateral fronto-orbitozygomatic approach and perhaps TFSSA for large or giant OGM.[2,3,9,14,18,38]

CONCLUSIONS

Given the high rate of complete tumor removal (100%), the relatively few recurrences (4.8%), low major morbidity (4.8%), and no surgery-related mortality, TFSSA seems to be a safe and effective surgical approach when dealing with OGMs. This approach is easy to perform, giving an early direct view of the lesion and early tumor devascularization and obviating brain retraction. Adopting TFSSA, the MMSE, KPS, and GOS scores increased, and visual function recovered in almost all patients. Based on these findings, TFSSA should be considered for the treatment of large and giant OGMs.

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