TUBERCULUM SELLAE MENINGIOMAS: MICROSURGICAL ANATOMY AND SURGICAL TECHNIQUE

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OBJECTIVE: Despite Cushing's accurate description of the anatomic origin of tuberculum sellae meningiomas, many subsequent authors have included tumors originating from the neighboring sella region in this classification. This has led to difficulty in evaluating the surgical results and consensus for an optimal surgical technique. We think this confusion has arisen from Cushing's description of these tumors under the heading "suprasellar meningiomas," which referred to their distinctive clinical symptoms and not their anatomic origin. We describe the microsurgical anatomy and tumor growth patterns to reemphasize the original classification of Cushing's tuberculum sellae meningiomas. Additionally, we describe our surgical approach, which decreases the risk of injury to anterior visual pathways and anterior cerebral circulation arteries.

METHODS: During a 19-year period, 23 patients with meningiomas arising from the tuberculum and diaphragma sellae underwent craniotomies at New York University Medical Center. The tumor size ranged from 2 to 5 cm. All patients presented with symptoms of visual dysfunction; 15 were asymmetrical. Magnetic resonance imaging with and without gadolinium differentiated these tumors from other suprasellar tumors with a high degree of accuracy. All patients underwent a pterional transsylvian approach.

RESULTS: Twenty patients had total tumor removal, and three had subtotal tumor removal. There was one regrowth in the subtotal tumor removal group. Patients were observed for a mean follow-up time of 9.3 years (range, 3.6–18.5 yr). Visual acuity improved in 55%, was unchanged in 26%, and worsened in 19% of patients. Two of the oldest patients died from pulmonary complications, resulting in a mortality rate of 8.7%.

CONCLUSION: We think that tuberculum and diaphragma sellae meningiomas are anatomically indistinguishable and should be termed *tuberculum sellae meningioma*. A pterional craniotomy with microsurgical dissection of the sylvian fissure allows access to these tumors with minimal neurological and ophthalmological morbidity.

KEY WORDS: Meningioma, Microsurgical anatomy, Pterional craniotomy, Tuberculum sellae, Visual acuity

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The first case of a tuberculum sellae meningioma was reported by Steward (27) in 1899 as an incidental autopsy finding. Cushing performed the first complete removal of a meningioma in this location in 1916. In 1938, Cushing and Eisenhardt (7) operated on 24 cases of tuberculum sellae meningiomas and proposed a four-stage classification according to size. They used the term *suprasellar chiasmal syndrome* (6, 17) on the basis of the clinical presentation and also to differentiate this tumor from pituitary tumors, craniopharyngiomas, gliomas, and other diseases. However, this term fails to denote the anatomic origin from the dura at the tuberculum-diaphragma of the sella turcica. After this original series, many reports were published regarding suprasellar meningiomas, which include tumors arising from different locations (2, 3, 5, 14, 18, 23, 25, 28): the anterior clinoid, optic foramen, olfactory groove, planum sphenoidale, and medial sphenoid ridge. There have been few reports concerning only tuberculum sellae meningiomas (8, 10, 12, 15, 20, 22, 29). Some authors have distinguished between diaphragma and tuberculum as two separate categories of tumor origin (19). We think that for critical evaluation of surgical results and outcome, accurate classification on the basis of the anatomy of

these tumors is essential. In this report, 23 cases of tuberculum sellae meningiomas are reviewed with attention to their microsurgical anatomy, technical aspects of surgery, and patients' postoperative visual recovery.

PATIENTS AND METHODS

Patient Population

Between January 1983 and December 2001, 23 patients with tuberculum sellae meningiomas underwent craniotomies performed by the senior author (VB) at New York University Medical Center. All of the tumors were located at the tuberculum and diaphragma sellae dura with extension either anteriorly to the planum sphenoidale or laterally to the carotid cisterns. Clinical and neuro-ophthalmological examinations, operative reports, imaging studies, and videotapes from these cases were reviewed retrospectively. The patients included 8 men and 15 women ranging in age from 40 to 73 years (mean, 57.7 yr). *Table 1* lists each patient's age and sex, duration of symptoms, ophthalmological findings, tumor size, operative approach, and extent of tumor removal. Visual failure was the most common initial symptom and was present in all patients.

TABLE 1. Clinical summary of 23 patients with tuberculum sellae meningioma[a]

Patient no.	Age (yr)/sex	Duration (mo)	Preoperative VA		Postoperative VA		Craniotomy	Size (cm)	Resection	Complication
			Right	Left	Right	Left				
1	72/M	120	20/40	20/60	ND	ND	L	4 × 4 × 3	Partial	Death (POD 6)
2	53/F	12	20/25	CF	20/15	HM	R	3 × 3 × 3	Total	None
3	63/M	12	20/25	20/50	20/20	20/30	L	3 × 3 × 2	Total	None
4	48/M	3	20/30	NLP	20/25	NLP	L	3 × 2 × 2	Total	None
5	56/M	36	NLP	20/30	NLP	20/25	R	2 × 2 × 2	Total	None
6	57/F	9	20/20	20/25	20/25	20/25	R	4 × 4 × 3	Total	None
7	63/F	84	CF	20/25	LP	20/25	R	3 × 3 × 3	Total	None
8	49/M	3	20/100	20/400	20/25	20/20	R	2 × 3 × 4	Total	None
9	40/M	3	20/15	20/70	20/25	20/20	L	3 × 2 × 2	Partial	None
10	71/F	2	20/20	20/400	20/70	20/70	L	2 × 2 × 3	Total	None
11	50/F	0.5	HM	NLP	20/40	NLP	R	5 × 4 × 3	Total	Transient DI
12	46/M	12	20/20	20/40	20/20	20/40	L	3 × 2 × 2	Total	None
13	68/F	6	20/60	20/30	20/30	20/25	R	2 × 2 × 2	Total	None
14	72/F	6	20/30	20/50	ND	ND	L	4 × 3 × 2	Total	Death (POD 10)
15	64/F	8	20/80	20/60	20/50	20/30	R	3 × 3 × 3	Total	None
16	46/F	24	20/40	20/50	20/30	20/60	R	3 × 3 × 3	Partial	None
17	47/F	6	20/20	20/20	20/20	20/40	L	4 × 3 × 2	Total	None
18	56/F	5	20/30	20/20	20/30	20/20	R	2 × 2 × 2	Total	None
19	51/F	1	20/30	LP	20/20	NLP	L	4 × 3 × 3	Total	None
20	68/F	2	CF	20/400	CF	20/100	R	3 × 4 × 3	Total	None
21	63/M	12	CF	20/80	20/200	20/50	L	4 × 3 × 3	Total	None
22	51/F	8	20/40	20/50	20/25	20/30	L	2 × 2 × 2	Total	None
23	73/F	10	CF	20/400	20/200	20/80	R	4 × 3 × 2	Total	None

[a] VA, visual acuity; ND, not done; L, left; POD, postoperative day; CF, counts fingers; HM, hand motion; R, right; NLP, no light perception; LP, light perception; DI, diabetes insipidus.

Fifteen patients presented with unilateral and seven with bilateral visual acuity deterioration. One patient had normal vision as revealed by examination. Eleven patients presented with severely decreased visual acuity (>20/400). Visual field defects were present in 17 patients: 10 had unilateral temporal anopia, 4 had quadrantanopia, and only 3 had classic bitemporal hemianopsia. Six patients had normal visual fields as revealed by neuro-ophthalmological testing. Headaches were uncommon and were present in only 22% of patients. All patients had normal endocrine function and were otherwise neurologically intact.

At presentation, the duration of symptoms ranged from 2 weeks to 10 years (mean, 16.7 mo). Patients with acute visual acuity deterioration sought medical attention earlier than those with a visual field deficit.

Surgical Technique

Before surgery, corticosteroids, anticonvulsants, and perioperative broad spectrum antibiotics were administered. Early in this series, a lumbar drain was inserted to minimize brain retraction. Recently, however, intraoperative removal of cerebrospinal fluid (CSF) from the sylvian and carotid cisterns has obviated the need for lumbar drainage. All tumors were approached via a frontotemporal (pterional) craniotomy. The patients were positioned supine with the head rotated 15 degrees away from the side of the larger tumor extension. In all cases, the larger tumor extension corresponded clinically with the side of the most compromised visual function. In patients with strictly midline tumors, the approach was from the nondominant side. The craniotomy at the frontal base was extended close to the frontal sinus to enhance the anterior view of the chiasm and the opposite optic nerve. The greater sphenoid wing and the orbital roof excrescence were drilled before dural opening. Under microscopic observation, the sylvian fissure arachnoid was then opened widely in a distal to proximal direction. A self-retaining retractor placed underneath the frontal lobe provided adequate exposure to enable the removal of the majority of tumors. The olfactory nerves on both sides were preserved anatomically in all but one patient, in whom the ipsilateral nerve was disrupted. This exposure allowed for visualization of the ipsilateral optic nerve as soon as the arachnoid of the carotid cistern was opened. If the optic nerve was covered by tumor, the midline ridge of the planum sphenoidale was used as an anatomic landmark for spatial orientation. The tumor was first gutted in the midline at the tuberculum sellae or planum sphenoidale (if present) with low-intensity bipolar cautery, and thereafter the tumor was removed from under the chiasmatic cistern (the subdural space) in a contralateral to ipsilateral direction. This helped in identification of the optic nerve and carotid arteries if they were covered by tumor.

The operation was conducted according to the following steps. The optic nerve most compressed by the largest tumor extension was identified. No attempt was made to remove tumor from underneath this nerve, which was under significant tension. Next, the contralateral optic nerve was identified and tumor was removed from under this optic nerve and the medial side of the contralateral carotid artery. Tumor was removed from underneath the optic chiasm in a contralateral to ipsilateral direction and then from underneath the ipsilateral optic nerve and the carotid artery (*Fig. 1*). Finally, tumor was dissected from the pituitary stalk and from the interpeduncular cistern.

In six patients, tumor extended under the optic nerve into the optic canal. In these patients, the optic canal was unroofed with a 2-mm carbide drill and the tumor was removed with blunt microinstruments. Piecemeal removal allowed preservation of most of the arachnoid of the carotid and chiasmatic cisterns. The tumor originated consistently from the dura of both the tuberculum and diaphragma sellae. Tumor extended onto the planum in 14 patients and the lesser wing of the sphenoid in 2 patients. No tumor invaded the lateral wall of the cavernous sinus, dura of the dorsum sellae, or upper clivus. In one patient, the tumor had extended into the pituitary fossa underneath the diaphragma. This patient had undergone a transsphenoidal biopsy and aborted transcranial procedure at another institution before referral to our center.

RESULTS

Tumor Removal

Gross total tumor excision was achieved in 20 cases, and subtotal resection was performed in 3 cases. The first patient in this series had undergone a known subtotal resection of tumor. In the second patient, residual tumor was not visualized at the time of operation, but postoperative magnetic resonance imaging (MRI) demonstrated a small amount of tumor within the medial wall of the contralateral cavernous sinus. A third patient had residual tumor in the sella turcica. The dural attachment at the tuberculum sellae was not removed in any patients; however, the meningeal layer was thoroughly coagulated with bipolar cautery.

Visual Outcome

Postoperative visual outcome analysis was performed by a neuro-ophthalmologist for each eye in 21 patients postoperatively, for a total of 42 examinations. The two patients who died were excluded, because no formal postoperative examinations had been performed. Gross postoperative ophthalmological testing in these two patients had demonstrated stable visual acuity. Visual acuity improved in 55%, remained unchanged in 26%, and worsened in 19% of patients (*Fig. 2*). If the visual acuity improved, it did so within the first postoperative week and continued to improve or remain stable during the follow-up period. Visual field deficits also improved after surgery. Eleven patients had documented improvement from their preoperative deficit in their visual fields.

Follow-up

All 21 surviving patients were followed up regularly by the neurosurgery and ophthalmology services. The follow-up period varied from 3.6 to 18.5 years (mean, 9.3 yr). No patients were lost to follow-up. The three patients with residual tumor have undergone annual MRI examinations, which have documented one

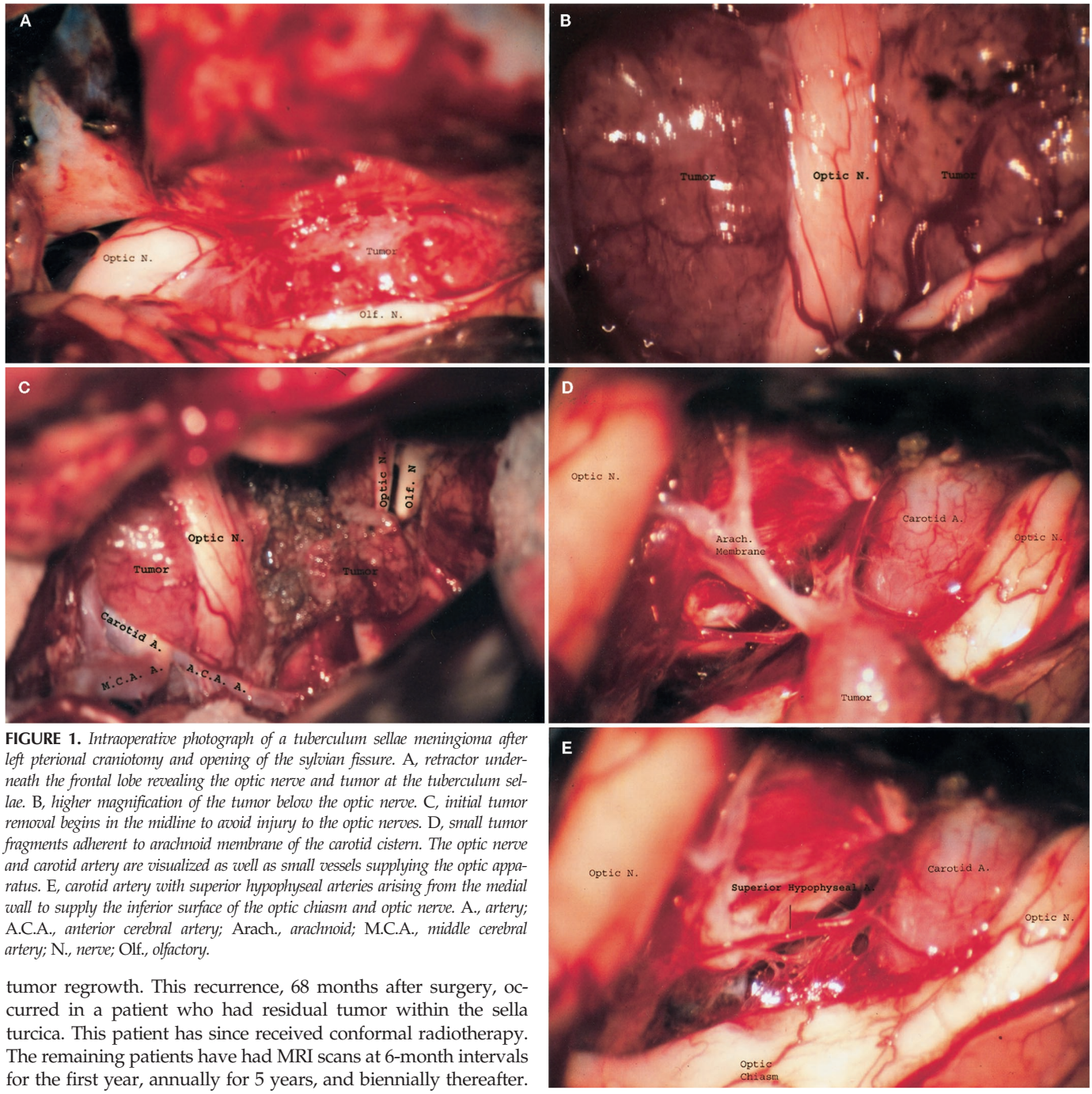

FIGURE 1. *Intraoperative photograph of a tuberculum sellae meningioma after left pterional craniotomy and opening of the sylvian fissure.* A, *retractor underneath the frontal lobe revealing the optic nerve and tumor at the tuberculum sellae.* B, *higher magnification of the tumor below the optic nerve.* C, *initial tumor removal begins in the midline to avoid injury to the optic nerves.* D, *small tumor fragments adherent to arachnoid membrane of the carotid cistern. The optic nerve and carotid artery are visualized as well as small vessels supplying the optic apparatus.* E, *carotid artery with superior hypophyseal arteries arising from the medial wall to supply the inferior surface of the optic chiasm and optic nerve.* A., *artery;* A.C.A., *anterior cerebral artery;* Arach., *arachnoid;* M.C.A., *middle cerebral artery;* N., *nerve;* Olf., *olfactory.*

tumor regrowth. This recurrence, 68 months after surgery, occurred in a patient who had residual tumor within the sella turcica. This patient has since received conformal radiotherapy. The remaining patients have had MRI scans at 6-month intervals for the first year, annually for 5 years, and biennially thereafter.

Mortality and Morbidity

There were two deaths (8.7%) in this series. The first patient died on postoperative Day 6 from a pulmonary infection, which progressed to septicemia. The second patient died on postoperative Day 10 from aspiration pneumonia, which progressed to multisystem organ failure. These two patients were the oldest patients in the series. Aside from these two deaths, there was one complication in the remaining 21 patients: one patient had transient diabetes insipidus, which resolved within 4 days after surgery. None of the patients whose tumors were approached via the dominant hemisphere had speech dysfunction. There were no CSF leaks, seizures, anosmia, or pituitary dysfunction.

DISCUSSION

Tuberculum sellae meningiomas comprise 5 to 10% of intracranial meningiomas. The mean age at discovery is the fourth decade, with predominance observed in women.

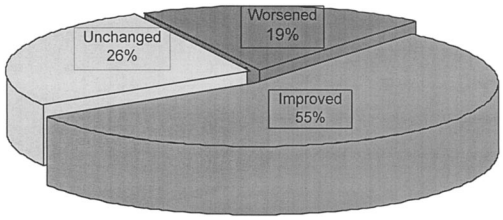

FIGURE 2. *Pie chart illustrating outcome of visual acuity after surgery in 21 patients.*

Holmes and Sargeant (17) first described the "chiasmal syndrome" as a primary optic atrophy with bitemporal field defect in adult patients who had tumors located at the tuberculum sellae. Cushing and Eisenhardt (7) classified these tumors into four stages according to their size and chiasmal deformation: I, initial stage; II, probably presymptomatic; III, early stage of syndrome, still surgically favorable (10–18 g); and IV, surgically unfavorable (>20 g). However, much confusion exists in the literature regarding these tumors. Many authors have discussed the management of suprasellar tumors and associated visual function, but the literature is sparse regarding tuberculum sellae meningiomas (3, 5, 7, 8, 10, 13, 15, 20, 23) (*Table 2*). In a review of the literature, there is no comprehensive report of the clinical presentation, surgical anatomy, extent of tumor removal, and visual outcome for tumors arising from the tuberculum sellae.

Anatomy and Classification

Cushing and Eisenhardt (7) classified meningiomas by dural and bony sites of origin on the basis of surgical and postmortem findings. With three-dimensional imaging techniques and superselective angiography, a more accurate understanding of the anatomy of these tumors and their classification currently is possible.

In 1930, Cushing (6) stated that tuberculum sellae meningiomas "arise or appear to arise from the tuberculum sellae and sulcus chiasmatis" (6). In 1938, however, he called them suprasellar meningiomas causing the "chiasmal syndrome" (7). He stated this term to differentiate meningiomas from other suprasellar lesions, such as pituitary adenomas, craniopharyngiomas, chiasmal gliomas, aneurysms, and chordomas, for which they might clinically be mistaken. In most subsequent reports of these tumors, less strict attention to the tuberculum sellae site of origin and more emphasis on the descriptive "suprasellar" terminology resulted in the inclusion of meningiomas arising from the olfactory groove, planum sphenoidale, and medial sphenoid ridge locations with tuberculum sellae tumors. In discussing reports on the experience of Vincent (16) and Alajouanine et al. (1), Cushing thought that some of their "suprasellar meningiomas" weighing 60 to 120 g resembled olfactory groove or medial sphenoid ridge tumors, both of which may overlap the tuberculum-diaphragma sellae. "Such tumors impair olfactory perception and tend to depress rather than to elevate the chiasm which could scarcely straddle a tumor of such magnitude without permanent blindness" (7, p 242). The critical observation of chiasmal elevation by tuberculum tumors was found in all of our patients at surgery. This is the key to the accurate classification of these tumors.

TABLE 2. Operative results in various studies of tuberculum sellae meningiomas[a]

Series (ref. no.)	No. of cases	Surgical approach	Complete resection (%)	Mortality (%)	Visual outcome (%)		
					Improved	Unchanged	Worse
Cushing and Eisenhardt, 1938 (7)	24	Lateral or transfrontal	54	21	53[b]	27	20
Grant and Hedges, 1956 (13)	30	18 right transfrontal, 8 left transfrontal, 4 bifrontal	12	20	50	5	45
Kunicki and Uhl, 1968 (20)	12	NA	67	67		NA	
Grisoli et al., 1986 (15)	28	Pterional	93	4	55	38	7
Andrews and Wilson, 1988 (3)	11	Unilateral subfrontal	72	NA	73	9	18
Gokalp et al., 1993 (10)	88	5 bifrontal, 9 frontotemporal, 36 subfrontal, 38 pterional	67	18	53.5	27.5	19
Ojemann et al., 1995 (23)	18	Unilateral subfrontal	44	NA	67	23	11
Fahlbusch and Schott, 2002 (8)	47	Pterional	98	0	80		20
Present study	23	Pterional	87	8.7	55	26	19

[a] NA, not available.
[b] Visual analysis for 15 patients.

We think that the growth pattern of meningiomas arising from the tuberculum or diaphragma sellae is dictated by neighboring anatomic structures.

In order of importance, the following structures act as barriers confining tumor growth at the tuberculum and diaphragma sellae area: laterally, the internal carotid and posterior communicating arteries and arachnoid envelope of the carotid cistern; anteriorly, the optic nerves and their arachnoid pouch; posteriorly, the pituitary stalk, infundibulum, and Liliequist's membrane; and superiorly, the optic chiasm and its arachnoid investment, the lamina terminalis, the A1 segment of the anterior cerebral arteries, and the anterior communicating artery. Consequently, the only route for tumor spread is anteriorly over the planum, over the optic nerves, and above the chiasm around the anterior cerebral artery complex.

The growth over the planum may be the result of either an anatomic defect in the arachnoid of the chiasmatic cistern at the chiasmatic sulcus or a postfixed chiasm. These predisposing anatomic circumstances may allow the tumor to spread over the planum and one or both optic nerves. As the tumor enlarges, it may envelop the anterior cerebral and communicating arteries. Correlation of the preoperative MRI scans with intraoperative observations demonstrates that the tumor may grow laterally through the space between the optic nerve and the superior aspect of the carotid artery or, in some cases, laterally around the posterior communicating artery. None of our 23 patients had a tumor that grew posteriorly on the dura of the dorsum sellae and upper clivus. These observations on the pattern of growth of these tumors give credence to the well-known fact that meningiomas grow along the path of least resistance.

Clinical Presentation

The diagnosis and treatment of tuberculum sellae meningiomas remain difficult. Similar to the description in Cushing and Eisenhardt's monograph (7), in the initial and presymptomatic stages, these tumors present with visual dysfunction or headaches. Headache was uncommon (22%) in our series. The location of headache was not diagnostically helpful in many of the cases. All patients presented with visual dysfunction in one eye (68%) or both eyes (32%). Eleven patients presented with a severe visual deficit (visual acuity $>20/400$). Visual field defects were present in 74% of the patients, but only three patients had classic bitemporal hemianopsia.

Radiographic Investigation

The imaging studies, which include computed tomographic scans, cerebral angiography, and MRI, are critical in preoperative planning for tuberculum sellae meningiomas. Computed tomographic scans obtained in 16 patients before the advent of MRI revealed a suprasellar location with homogeneously enhancing tumor; bony hyperostosis was noted in eight cases. MRI with its multiplanar sequences is the radiographic imaging study of choice for tuberculum sellae meningiomas. These images clearly delineate the three-dimensional extent of tumor and its relationship to the cavernous sinus, optic chiasm, hypothalamus, and major cerebral arteries. The images delineate extension into the sellae, cavernous sinus, and other neighboring regions. Meningiomas are isointense on T1-weighted sequences and hypointense on T2-weighted sequences (*Fig. 3*). However, MRI without gadolinium does not exclude a pituitary adenoma (26). After administration of gadolinium, meningiomas reveal significant homogeneous enhancement, whereas pituitary adenomas reveal only slight and inconsistent enhancement (29). Other distinguishing features are a dural-based tail and a suprasellar epicenter. Kinjo et al. (19) concur that these characteristics also differentiate tuberculum sellae meningiomas from pituitary adenomas. However, we do not think that diaphragma sellae tumors can be differentiated from tuberculum sellae meningiomas.

Microsurgical Anatomy

The tuberculum sellae is a slight bony elevation that separates the anterior roof of the pituitary fossa from the prechiasmal sulcus. Because of the relatively small dimensions of the sella, the dural attachment of these tumors can extend anteriorly to the sphenoid limbus and planum sphenoidale or posteriorly to involve the diaphragma sellae. The diaphragma sellae stretches from the region of the tuberculum sellae to the upper border of the posterior clinoid process. Its average length is 8 mm (range, 5–13 mm) and width is 11 mm (range, 6–15 mm) (21). This explains why a tumor smaller than 1.5 cm does not cause clinical symptoms unless it originates in the optic foramen.

As the meningioma grows, the arachnoid of the floor of the chiasmatic cistern is pushed up and stretched over the tumor. With continued growth, the tumor encroaches upon the adjacent structures (carotid artery, lamina terminalis, and interpeduncular cistern) and becomes involved with various neighboring structures. This unique characteristic of the arachnoid membrane and the continuous flow of CSF provide a barrier between tumor and neural tissue.

Because the optic nerves are fixed at the optic foramen, with continued tumor growth, they can be angulated and further compressed at this site. The optic nerves may be asymmetrically enveloped by the tumor. The internal carotid arteries are displaced laterally but to a lesser extent than the optic nerves. The tumor may insinuate itself between the optic nerve and carotid artery and actually encase the artery at times, yet the vessel is still covered by a displaced arachnoid layer. The anterior cerebral arteries, which are dorsal to the optic chiasm, are stretched and may become embedded by tumors larger than 3.5 cm in size. Posteriorly, the tumor may extend behind the sella turcica into the interpeduncular cistern, displacing the pituitary stalk, but the tumor does not adhere to the dura of the upper clivus or dorsum sellae because of this arachnoid membrane. The tumor also may extend anteriorly onto the planum sphenoidale. Tuberculum sellae meningiomas, which elevate the anterior visual pathways, are distinguished from anterior cranial fossa tumors because the latter tumors depress the optic nerves and chiasm with continued growth. Likewise,

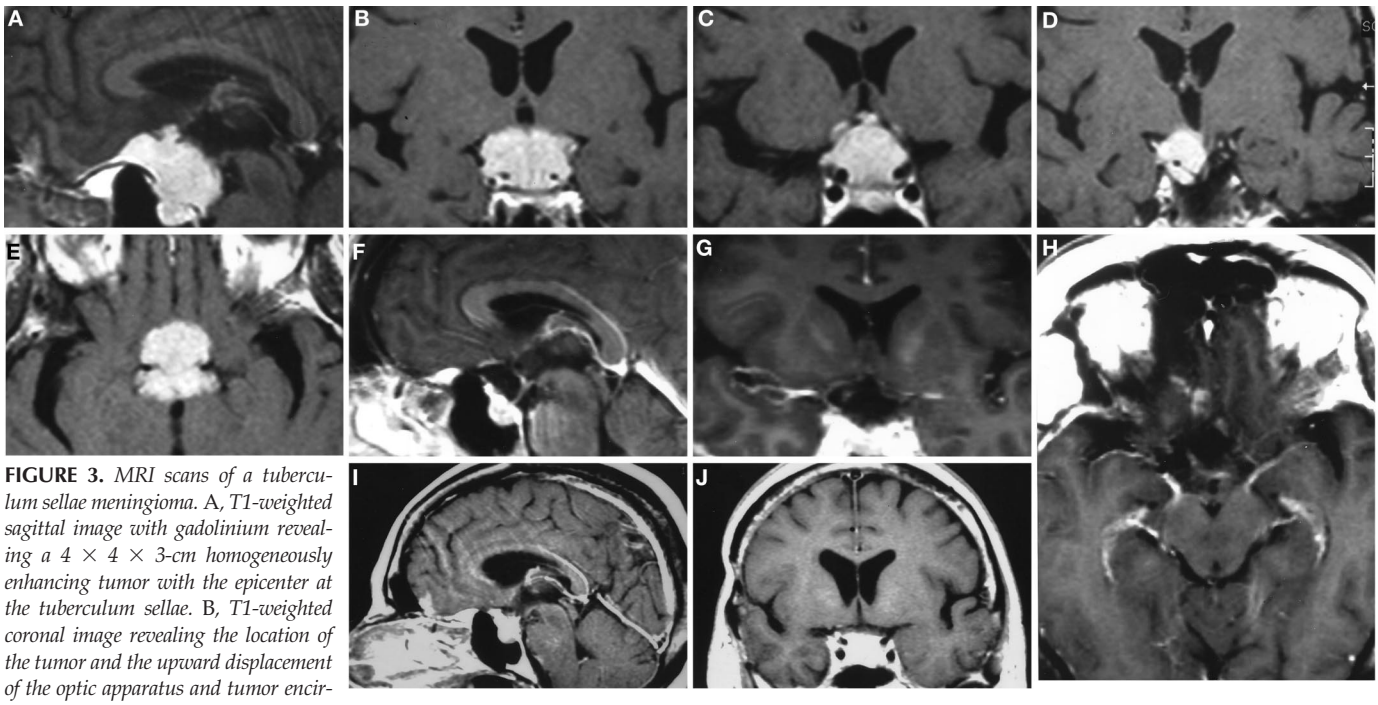

FIGURE 3. *MRI scans of a tuberculum sellae meningioma.* A, *T1-weighted sagittal image with gadolinium revealing a 4 × 4 × 3-cm homogeneously enhancing tumor with the epicenter at the tuberculum sellae.* B, *T1-weighted coronal image revealing the location of the tumor and the upward displacement of the optic apparatus and tumor encircling the carotid arteries.* C, *T1-weighted coronal image revealing the tumor extension superior to the anterior cerebral artery complex.* D, *coronal image revealing the posterior extension of the tumor to the basilar artery and encasement of the posterior communicating artery.* E, *T1-weighted axial image revealing the tumor enveloping the anterior cerebral arteries.* F, *sagittal image 48 hours after surgery showing gross total resection. The infundibulum and pituitary gland are preserved.* G, *coronal image 48 hours after surgery showing the resection bed and the anterior circulation vessels.* H, *axial image 48 hours after surgery showing the suprasellar region devoid of tumor.* I *and* J, *T1-weighted sagittal* (I) *and coronal* (J) *images obtained 4 years after surgery showing no recurrent tumor.*

olfactory groove meningiomas depress these visual structures. Anterior clinoid and medial sphenoid meningiomas displace the optic nerve, chiasm, and tract medially.

The key to preserving visual function is to minimize direct manipulation or trauma to the optic nerves and avoid injury to the blood supply of the optic apparatus (4, 8, 9, 11, 24). Initial debulking of the tumor should start from within the center, where no vital structures are present. The arachnoid plane is then delineated, starting at the contralateral optic nerve and working to the undersurface of the optic chiasm and then along the ipsilateral nerve. With this technique, the surgeon remains within the subdural space as much as possible, minimizing direct injury to the optic nerves. The inferior surface of anterior visual pathways (optic nerve and optic chiasm) receive their blood supply from two to three small arteries (the superior hypophyseal arteries), which arise from the medial wall of the internal carotid artery (21). During resection of the meningioma, small vessels observed in the stretched arachnoid layer should not be coagulated. By preserving these vessels, there is a better chance for visual function improvement. In our study, these vessels were preserved in 21 contralateral and 19 ipsilateral arteries. In 16 patients, the anterior communicating artery and A1 portion of the anterior cerebral arteries were encircled by tumor. The tumor could be removed without injury to these vessels in all cases. By use of this technique, visual acuity has remained stable or improved in 81% of patients in this series.

Tuberculum sellae meningiomas may be resected through several approaches: bifrontal, unilateral frontal, and pterional. The pterional approach, with generous removal of the sphenoid ridge and wide dissection of the sylvian fissure, allows access to the suprasellar region with minimal brain retraction. This approach has two advantages: it minimizes injury to the olfactory nerves, and the risk of CSF leakage or infection from frontal sinus transgression is minimal. The only disadvantage of this approach is that the undersurface of the ipsilateral optic nerve and chiasm are not as well visualized as in the subfrontal approach. For this reason, the pterional craniotomy is performed on the same side as the more compromised visual function.

Complications and Outcome

The mortality rate for surgical resection of tuberculum sellae meningiomas is limited; analysis of several series reveals a rate of 0 to 67%. The higher rates for the suprasellar tumors were reported in the earliest series. The recurrence rate for these tumors varies from 0 to 25%. Jane and McKissock (18) were the first to note the influence of tumor size on surgical outcome for suprasellar tumors. They reported a mortality rate of 42% in 32 cases in which the tumor was larger than 3 cm; there were no deaths in 17 patients with tumors smaller than 3 cm. This observation is not supported by our series, however; the two deaths in our study resulted from pulmo-

nary complications unrelated to tumor size. Complete removal was accomplished in all but three tumors. There has been one regrowth of residual tumor within the sella during the follow-up period.

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COMMENTS

The authors present the experience of the senior surgeon (VB) with meningiomas in the tuberculum sellae, which is a relatively uncommon location for meningiomas. As the authors state, the literature is somewhat sparse regarding this location of meningioma. I think that this lack of previous reports speaks to the uncommon nature of the tuberculum and diaphragma sellae as an origin point for meningiomas. These lesions are certainly very challenging because of the surrounding anatomic structures. In general, they do not present after they have reached a tremendous size, but they pose some particular difficulties that the authors elucidate in this article.

I think that the reader should take some important technical points from this article. First, I agree completely with the authors regarding their not recommending preoperative embolization. In these tumors, I have found preoperative embolization to be completely unnecessary because of their small size. This is in addition to the technical difficulties that embolization presents in terms of the arteries that would need to be catheterized. Certainly, when dealing with a patient with a tumor in this location, embolization should not enter into the preoperative considerations. In terms of the technical aspects of surgery, I would also emphasize the importance of preserving the arachnoid plane over the superior and posterior aspects of the tumor. This is the key to the preservation of perforating arteries to the optic system as well as the preservation of the pituitary stalk. Particular attention must be paid to preserving this arachnoidal plane to avoid visual complications. I have also found it helpful in these cases to remove the anterior clinoid process and unroof the ipsilateral optic canal extradurally. This maneuver has the theoretical advantage of lengthening the optic nerve and reducing the chance of damaging the nerve during manipulation of the tumor. The falciform ligament and edge of the optic canal potentially present a hard edge that the optic nerve can be pressed against during manipulation of the tumor. This serves to compress the small vessels on the surface of the nerve, as well as the nerve fibers, which could result in worsened visual function on the ipsilateral side. I do not have a large number of patients to compare with the authors' to indicate that this is a definite benefit, although I do think that it is helpful in my hands.

Another technical point that may be of benefit in terms of a tumor that extends superiorly significantly above the level of the tuberculum is the incorporation of an orbitofrontal type of craniotomy. Removal of the orbital rim in conjunction with the frontotemporal craniotomy adds the advantage of a more

inferosuperior viewing trajectory with reduced brain retraction. In the rare tumor that has significant superior extension, I think that this would be helpful.

It is clear from the senior author's (VB's) results that he has achieved a very high level of expertise in treating meningiomas in this location. I think that his results should set the standard for future comparisons of variance in surgical technique.

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The authors describe their experience with tuberculum sellae meningiomas. They assert that their preferred technique is to approach these lesions through a frontotemporal pterional craniotomy. They gain additional access to the tumor by smoothing over the orbital roof and removing the greater wing of the sphenoid. They open the sylvian fissure in a proximal to distal direction, and they remove the tumor after first decompressing it starting at the contralateral optic nerve and working their way across the chiasm toward the ipsilateral optic nerve and the stalk.

My technique for the removal of these tumors is similar to that described in a recent report (1). Specifically, I tend to perform more of a cranial base dissection in terms of an additional orbitoclinoidal dissection performed extradurally, which leads me to the immediate vicinity of the tumor. This allows the right optic nerve to be mobilized gently, if necessary, during the dissection of the tumor. I also emphasize the importance of recognizing that meningiomas in general, and tuberculum sellae meningiomas in particular, are extra-arachnoid lesions that displace the arachnoid as they grow. Thus, the plane of dissection should be between the tumor surface and the arachnoid membrane covering it rather than between the arachnoid and the surrounding subarachnoid neurovascular structures. My preferred instrument for decompressing the tumor is the ultrasonic cavitating aspirator armed with a precision tip. Also, I am not in favor of separating the tumor base from the dural blood supply until after the tumor has been decompressed. If the tumor base is detached from the dural blood supply before tumor decompression, it may be difficult to control bleeding, especially if a hematoma were to form behind the still taut tumor with the possibility of significant neurological complications. The surgical progression is usually from the ipsilateral side across the chiasm to the contralateral optic nerve and the carotid artery. It seems to me that the reason why I am able to proceed in this fashion is that the craniotomy extends to the midline, which provides better visual access to the tumor tucked beneath the ipsilateral optic nerve.

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The authors report their experience with the surgical removal of tuberculum sellae meningiomas in 23 cases accumulated during a 14-year span. They emphasize the microsurgical anatomy and discuss the optimal microsurgical technique to use. Because these tumors primarily affect vision and do so from the early stage of their growth, the goal of surgical management is to preserve and possibly improve vision, starting with the better eye. I completely agree with the authors that the pterional approach, with the opening of the sylvian fissure, allows for optimal exposure of the region. In this area, the surgeon, after proper identification of the neurovascular structures involved, can decide on the best surgical strategy with which to achieve removal of the tumor and consequent freeing of the optic nerves and chiasm. Avoiding additional surgical injury to these structures is imperative. The authors' suggestions regarding the use of this microsurgical technique to minimize the risk of any worsening of vision and for preserving the pituitary stalk as well as the arteries involved with the tumors are valuable.

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In this article, Jallo and Benjamin describe a retrospective experience with tuberculum sellae meningiomas. Several aspects of the article make the information that it provides Level 3 data. The variable use of imaging to assess the degree of resection, the retrospective analysis, and the small number of patients limit its application. Two important points are made here, however. The first is that it is very important to preserve the blood supply to the optic nerves to preserve the patient's vision. This may lead to definite residual tumor, and this is exactly why radiosurgery may not be possible—that is, because of the proximity to the optic nerve and chasm. Second, the authors emphasize the importance of minimal trauma to the anterior cerebral artery. These tumors are rare, and Jallo and Benjamin have done neurosurgery a great service by writing this report.

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