THE MICROSURGICAL NUANCES OF RESECTING TUBERCULUM SELLAE MENINGIOMAS

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ONLINE DIGITAL VIDEO

In a recent article, our experience and knowledge of the clinical picture, microsurgical anatomy, and long-term surgical outcome of resecting tuberculum sellae meningiomas was described in detail. We now present our surgical technique in a pictorial and video format for the benefit of neurosurgeons in training, as well as for general critique. Attention is given to the details of surgery: patient positioning, surgical approaches, technique of tumor removal, and postoperative care.

KEY WORDS: Brain tumor, Meningioma, Sella turcica, Surgical nuances

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The removal of tuberculum sellae meningiomas may be associated with significant operative morbidity because of the tumor's entanglement with vital suprasellar and parasellar structures, including the anterior visual pathways, pituitary stalk, oculomotor nerves, and arteries of the anterior circulation (2–5). Proficiency in resecting these lesions has a steep learning curve, with the majority of poor outcomes most likely to occur early in a surgeon's career. The purpose of this article is to describe precisely the operative nuances used during the resection of tuberculum sellae meningiomas in an effort to inform young neurosurgeons for the purpose of self-education, as well as for general critique from those with experience resecting these complex growths. The operative video and *Figures 1* and *2* are included as focal points of this communication.

SELECTION OF A SURGICAL APPROACH

There are three approaches used to resect tuberculum sellae meningiomas: 1) bicoronal subfrontal (1), 2) oblique subfrontal (8), and 3) pterional transsylvian (5). The advantage of the bicoronal approach is that it provides a wide and direct view of both optic nerves, as well as internal carotid and anterior cerebral arteries. However, the bicoronal approach has some disadvantages, including opening the frontal sinus with the risk of cerebrospinal fluid leakage and meningitis, olfactory nerve damage, and possible cortical injury of the frontal lobes from retraction, and it is the longest distance to the sellar region of the three approaches. The oblique subfrontal approach has few advantages, but several disadvantages. It is a longer approach than the pterional transsylvian, has a surgical view often obstructed by a prominent orbital roof, requires excessive frontal lobe retraction, and provides a limited view under the ipsilateral optic nerve and carotid cistern unless the sylvian fissure is opened. We use the pterional transsylvian approach because it provides both a frontolateral view between the optic nerves, as well as a lateral view through the carotid cistern; preserves the olfactory nerves; and, with removal of the greater wing of the sphenoid bone, provides the shortest distance to the tuberculum sellae (11).

Generally, the craniotomy flap is made on the side of the nondominant hemisphere. If the tumor is significantly eccentric toward the optic nerve and carotid artery on one side, we then approach the lesion from the ipsilateral side. If one eye is blind or nearly blind, the approach is from the amblyopic side because this method permits optimal exposure for decompression of the less involved optic nerve. One disadvantage of the pterional approach is that removal of tumor located underneath the ipsilateral optic nerve can be difficult without some manipulation of this structure. However, patients usually have asymmetrical visual deficits before surgery, and by approaching the tumor from the side with the worse

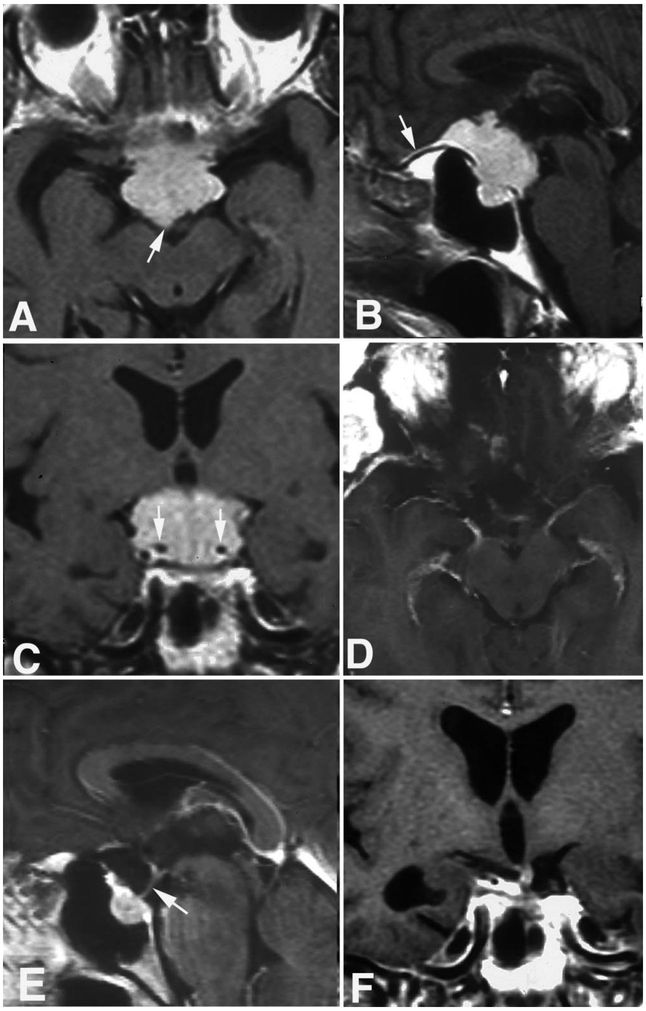

FIGURE 1. *Magnetic resonance imaging scans with gadolinium in a patient with a 4 × 4 × 3-cm tuberculum sellae meningioma. Representative axial* (A), *sagittal* (B), *and coronal* (C) *images obtained before surgery demonstrate the tumor compressing the optic apparatus, engulfing intracranial vessels* (C, arrows), *extending into the sella, and compressing the interpeduncular cistern* (A, arrow). *A dural tail can be identified on the sagittal image extending anteriorly over the planum sphenoidale* (B, arrow). *This patient underwent a right pterional craniotomy and microsurgical resection of her tumor. Postoperative axial* (D), *sagittal* (E), *and coronal* (F) *images with gadolinium confirmed a gross total resection. Preservation of the pituitary stalk* (E, arrow) *and gland can be seen. This patient has remained recurrence-free for 4 years, as documented with serial magnetic resonance image scans.*

optic nerve function, new postoperative visual loss is minimized.

POSITIONING FOR SPATIAL ORIENTATION

The patient is placed supine on the operating table with the body flexed so that the head is 30 degrees above the level of the heart to facilitate venous drainage, which reduces brain

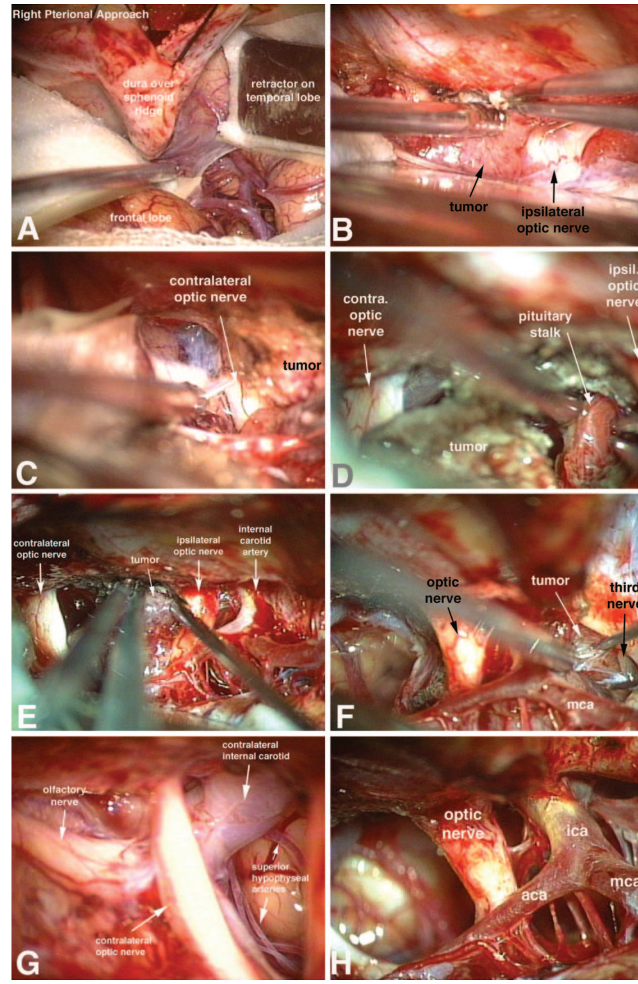

FIGURE 2. *Serial intraoperative photomicrographs of a tuberculum sellae meningioma being resected via a right pterional approach.* A, *after craniotomy, the dura is opened in a curvilinear fashion and is draped over the sphenoid ridge. The sylvian fissure is split widely, and before the tumor resection, a retractor is placed on both the frontal and temporal lobes. A piece of Penrose drain covered with a cottonoid is placed under the retractor to protect the cortical surface.* B, *early in the tumor resection, the ipsilateral optic nerve is uncovered. Tumor underneath this nerve is left untouched, to be removed later in the procedure.* C, *after the anterior portion of the tumor is resected, the contralateral optic nerve also is identified. After its identification, tumor then is removed from both above and below this nerve, exposing the contralateral internal carotid artery and its medial branches.* D, *as soon as the contralateral optic nerve is decompressed fully, the tumor is removed from along the chiasm and then deep in the midline, exposing the pituitary stalk that is displaced posteriorly by the tumor.* E, *at this stage, the tumor has been detached from its origin, debulked, and removed from around the contralateral optic nerve. Now, using a bipolar forceps and suction tip, tumor is removed from underneath the ipsilateral optic nerve and internal carotid artery via the interoptic space.* F, *tumor is dissected free from between the optic nerve and internal carotid and from between the internal carotid and oculomotor nerve.* G, *view of the region surrounding the contralateral optic nerve after resection. The contralateral internal carotid artery, olfactory nerve, and superior hypophyseal arteries are preserved.* H, *view of the region surrounding the ipsilateral optic nerve after resection. The ipsilateral internal carotid artery* (ica), *anterior cerebral artery* (aca), *and middle cerebral artery* (mca), *along with their lenticulostriate branches, are preserved. Although not seen in this postoperative image, the ipsilateral olfactory nerve and pituitary stalk were not damaged during the exposure and tumor resection (see video at web site).*

fullness. The head is rotated 35 degrees away from the side of approach to bring the lesser wing of the sphenoid ridge into a vertical position (11). In elderly patients with limited mobility of the cervical spine because of spondylosis, a small shoulder roll may be used to help rotate the head. This vertical orientation of the sphenoid ridge establishes a reference for spatial orientation during the microscopic dissection of tumor from potentially distorted or obscured intracranial structures. This nuance is especially important when the anterior clinoid and optic nerves are covered by a large tumor. In such cases, a consistently positioned sphenoid ridge directs the surgeon toward the midline, helping to localize the ipsilateral anterior clinoid and optic nerve. The angle between the lesser wing and midline sagittal plane in adults is approximately 60 degrees (6). To allow the frontal lobe to fall away from the anterior cranial fossa after opening the arachnoid of the sylvian fissure, which minimizes frontal lobe retraction while maximizing the exposure of the cranial base, the head is extended approximately 25 degrees. As soon as it is properly positioned, the cranium is immobilized with a three-pin fixation device. The patient's chest, pelvis, and extremities are secured to the operating table with belts or tape so that the bed may be turned side to side during surgery without risk of the patient moving.

CEREBROSPINAL FLUID DRAINAGE AND BRAIN RETRACTION

Initially, a lumbar drain was used during surgery to withdraw cerebrospinal fluid for brain relaxation. However with further experience, we found this to be unnecessary because adequate brain relaxation could be obtained by cerebrospinal fluid drainage from the sylvian fissure early in the operation.

After the craniotomy and wide opening of the sylvian fissure arachnoid is completed, one brain retractor is placed under the frontal lobe; if necessary, a second retractor may be placed on the temporal lobe for larger tumors. To protect the cerebral cortex and to minimize pial injury from cottonoid adherence, a single layer piece of Penrose drain under each retractor is placed directly on the brain, which is then padded with a cottonoid. Although the retractors are fixed with mild pressure on the frontal and temporal lobes, their main function is to cover and protect the cortex from inadvertent damage during these long operations. With proper patient positioning, cerebrospinal fluid drainage, and sylvian fissure dissection, these retractors only keep the brain in place, thereby not causing retractor injury.

ESSENTIALS OF INSTRUMENTATION USE (*see video at web site*)

After a pterional craniotomy is completed in the standard fashion (11) and before opening the dura, a variable-speed, hand-controlled, pneumatic drill with a large 6-mm cutting carbide burr is used to remove the greater wing of the sphenoid bone along with any large bony prominences on the orbital roof. As soon as the dura is opened, the operating microscope is used for the remainder of the intracranial procedure. In general, only three instruments are used for splitting the sylvian fissure and removal of the tumor: 0.5-mm microbipolar forceps, Brackmann-type suction tips (i.e., with side perforations), and microscissors. Bipolar forceps, both straight and angled, are used to coagulate and shrink the tumor away from adjacent neurovascular structures. These forceps also are used to dissect and tease the tumor away from the cisternal arachnoid, which covers normal arteries and nerves. To remove tumor situated underneath the ipsilateral optic nerve or internal carotid artery, a down-angled bipolar may be used to minimize the manipulation of these two structures. During coagulation, a constant slow irrigation of Ringer's lactate solution (we do not use saline irrigation intradurally because we believe it irritates neural tissue) in the field prevents sticking of the bipolar to the tumor and limits coagulation debris from forming on the tips. To be most effective when coagulating tissue, the bipolar tips should not be squeezed firmly together. A useful dissection technique is to coagulate the tumor as it is simultaneously pulled away from normal structures, which often prevents it from retracting back into place as soon as the tumor is released.

Five- to 7-gauge Brackmann-type suctions are used to remove blood and cerebrospinal fluid in the surgical field, as well as to retract and dissect the tumor. The multiple small holes near the tip limit accidental suction and damage to normal parasellar structures and also prevent complete occlusion of the suction when the tip is applied to the tumor's surface. In some cases, when the tumor is soft and devascularized with bipolar coagulation, the suction may be used, with higher pressure, to aspirate the tumor.

Open and closed tips of the microscissors are used intermittently to remove pieces of tumor and to cut arachnoid strands from normal structures. As the resection proceeds, the internal portion of the tumor gradually is debulked using circular microdissectors and cup forceps to remove small to moderately sized portions of the tumor. However, after the tumor is devascularized and debulked, the surrounding arachnoid should be dissected away carefully from the tumor's perimeter, using coagulation sparingly to avoid injury to small perforating arteries within the arachnoid that are not feeding the tumor.

STAGES OF SURGICAL RESECTION (*see video at web site*)

In all patients with true tuberculum meningiomas, as soon as the medial limit of the sylvian fissure is opened and the carotid cistern is inspected, the lateral aspect of the tumor is seen. For tumors larger than 3 cm, the ipsilateral optic nerve invariably is covered by an extension of tumor between the two optic nerves in the epiarachnoid ("subdural") space. This portion of the tumor can be brushed away easily with a cottonoid from the superior surface of the ipsilateral optic nerve. As soon as the ipsilateral optic nerve is uncovered, attention then is directed to exposing the olfactory nerve for its preservation; the midline ridge behind the cribriform plate also is identified, which orients the surgeon to the location of the sella and the normal structures inside the tumor mass. The tumor then is coagulated and disconnected from its attachment to the planum and tuberculum sellae at the midline using bipolar coagulation and microscissors. At this time, only the ipsilateral optic nerve is identified. Tumor underneath the ipsilateral optic nerve is not removed at this point but instead is resected during the late stages of the procedure. Tumor removal then is continued in the midline with piecemeal resection until the medial aspect of the contralateral optic nerve is seen. As soon as both optic nerves are identified, tumor debulking may proceed more safely.

Next, in the area between the two optic nerves, tumor is removed from around the contralateral optic nerve, exposing the contralateral carotid artery. Here the arachnoid of the chiasmatic and carotid cisterns can be preserved carefully because these membranes are on the farthest side of the meningioma. It is in this location that three to four anterior hypophyseal arteries are seen and preserved. With additional tumor removed, the anterior and inferior edge of the chiasm is identified and decompressed. In large tumors, the anterior communicating complex may be enveloped by tumor located dorsal to the chiasm. The layers of arachnoid of the chiasmatic and lamina terminalis cisterns are dissected, and the arteries are freed. As the tumor resection proceeds in the depth between the optic nerves inferior to the chiasm, the pituitary stalk eventually is identified at the posterior limit of the tumor and is preserved. This latter structure usually is displaced posteriorly and, in larger tumors, also may be enveloped. The posterior margin of the tumor is removed from the hypophyseal arteries, posterior arachnoid layers of the chiasmatic cistern, and Liliequist's membrane, deep in the surgical exposure where the tip of the basilar artery may be seen. High-power magnification is used, and the surgeon avoids injury to small perforators. During the initial decompression, a 2- to 3-mm layer of tumor should be cauterized and left at the dural attachment, which prevents troublesome bleeding that may occur when dura is stripped from the bone of the tuberculum sellae and planum sphenoidale.

At this stage, residual tumor is located under the ipsilateral optic nerve and medial to the internal carotid artery. Because most of the tumor already has been removed, the arachnoid-tumor interface in this region becomes more relaxed, which facilitates dissection. The corridor used to resect the residual tumor in this area can alternate either from medially between the optic nerves with an angled bipolar forceps or laterally between the ipsilateral optic nerve and carotid artery. For larger meningiomas, tumor also may need to be resected between the carotid artery and the oculomotor nerve, as well as from around the posterior communicating and posterior cerebral arteries. Rotating the operating table so that the ipsilateral optic nerve moves away from midline often is useful at this stage of the operation to help provide a better view of any tumor behind it. The tumor is removed in a piecemeal fashion, often using a gentle push-pull technique whereby tumor is detached from its arachnoid trabeculae through the optic-carotid space and then is removed with angled bipolar forceps between the optic nerves.

The final stage of tumor removal consists of inspecting the undersurface of the ipsilateral optic nerve, where it enters the optic canal's dural sleeve. If a small nodule of residual tumor is found, it can be removed with minimal manipulation of the optic nerve using small, cupped microdissectors. Larger extensions into the optic foramen require drilling of the anterior clinoid and optic canal after excising the overlying dura. We use a variable-speed pneumatic drill with hand control and a 2- or 3-mm cutting carbide burr. With slow revolutions, the bone is shaved away from the dura overlying the optic canal. As soon as it is unroofed, this dura is opened and residual tumor located under the optic nerve is removed. Diamond burrs are not used because they are slow, require more pressure, and produce heat.

Immediately after each operation, one should create a drawing that documents the tumor's growth pattern, extent of tumor removal, and vital structures involved. This information not only becomes part of the patient's surgical record but also serves as an educational tool, especially when used in conjunction with operative video footage, for the surgeon-in-training (*Fig. 3*).

PRESERVATION OF VASCULAR ELEMENTS (*see video at web site*)

Besides limiting manipulation of the optic nerves and major intracranial vessels, meticulous preservation of vascular elements during tumor resection is paramount for optimal visual, hormonal, and neurological outcomes. Damage to small superior hypophyseal branches from the internal carotid artery and small perforators from the posterior communicating artery must be avoided carefully.

As meningiomas grow, adjacent arachnoid cisterns become compressed and then obliterated from tumor compression. The arachnoid layers remain intact but become stretched around the arteries and nerves adjacent to the tumor. Although the cisterns subsequently collapse from progressive tumor compression, cerebrospinal fluid pulsations continue to occur in these potential arachnoid planes around the tumor. However, with long-standing compression, cerebrospinal fluid flow may cease, causing the arachnoid layers to fuse together and scar. As soon as this occurs, tumor may recruit neovessels from adjacent arteries. This situation rarely is seen in tuberculum sellae meningiomas because clinical symptoms usually occur before the tumor is large enough to completely occlude the relatively large chiasmatic and carotid cisterns. Furthermore, because meningiomas do not have a tumor capsule, they readily expand in the line of least resistance and often insinuate into nearby crevices, making their removal more difficult (2, 7).

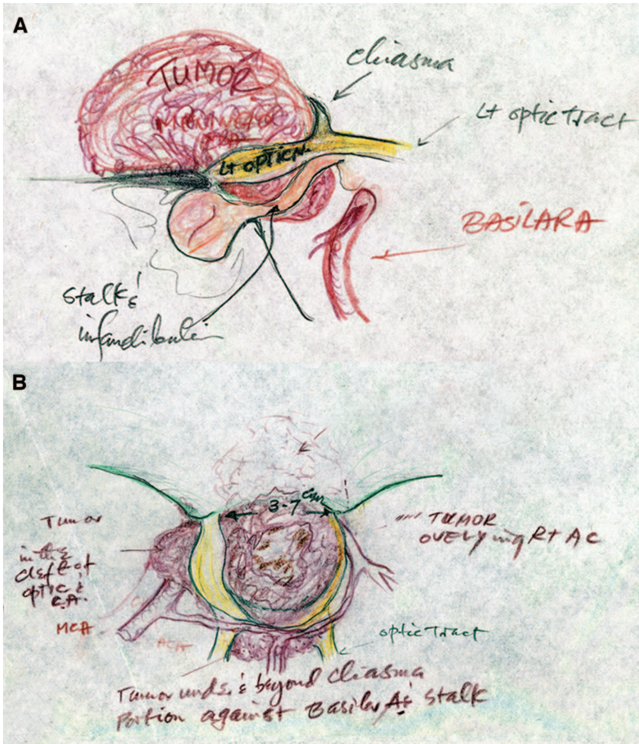

FIGURE 3. *Example of an immediate postoperative drawing. The tumor growth pattern and involvement of vital intracranial neurovascular structures are depicted. The surgeon reviews these drawings along with operative videos from each patient for critical self-assessment and optimization of surgical techniques.* A, *lateral view;* B, *superior frontal view.*

Taking advantage of this pathological growth pattern, the surgeon can preserve the small arteries located around the tumor within the arachnoid layers. To do so, one must pull away tumor from the arachnoid as much as possible to preserve these delicate vessels. As mentioned above, when cerebrospinal fluid flow is present, the arachnoid is minimally adherent to the tumor and therefore can be readily separated.

MANAGING THE DURAL ATTACHMENT AND HYPEROSTOTIC BONE

The tumor's origin from the tuberculum sellae should be thoroughly inspected after completion of the intracranial tumor resection. Any hyperostotic bone should be removed with an appropriately sized cutting burr. If the ethmoid sinus is entered inadvertently, the defect is filled with a piece of temporalis muscle and autologous fibrin glue. A margin of dura surrounding the tumor attachment, along with any residual tumor tissue, should be resected and/or thoroughly coagulated. These maneuvers help to minimize tumor recurrence (9, 10). Osseous bleeding is controlled with small pieces of bone wax or bipolar cautery.

POSTOPERATIVE CARE

Patients are given high-dose intravenous corticosteroids immediately before surgery and then for 5 days after surgery to minimize optic nerve and brain edema that may occur from manipulation and retraction during surgery. The corticosteroids then are tapered slowly. Perioperative anticonvulsants, antibiotics, and venous thromboembolism prophylaxis also are prescribed. For patients with large tumors who undergo long operations, the endotracheal tube is kept in place until the patient is fully awake and following commands to protect the patient from possible aspiration or respiratory compromise. The patient's fluid balance and electrolytes are monitored closely for at least 48 hours after surgery. From manipulation of the pituitary stalk, iatrogenic diabetes insipidus may occur, but this usually is transient. Neuro-ophthalmology and endocrine consultations also are performed routinely before and after surgery.

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COMMENTS

Benjamin and Russell clearly demonstrate the microsurgical approach to the removal of a tuberculum sellae meningioma using a frontotemporal craniotomy centered on the pterion. The major points about isolation of the tumor from the optic nerves and optic chiasm and pituitary stalk and the devascularization of the tumor by dealing with the basal dura are well done and beautifully illustrated in the video.

It should be recognized that there are some surgeons who would have approached this lesion with a more subfrontal craniotomy, and I certainly think that is a valid alternative to the approach illustrated here. We have been using an extended transsphenoidal approach to deal with some tumors of the planum sphenoidale and the tuberculum sellae and, with the right type of tumor, have had extraordinarily satisfactory results with a minimally invasive procedure using a transsphenoidal extended exposure and the endoscope and other adjuncts to ensure satisfactory removal (1, 3–5). We have treated six patients using this method, and a recent report from Dan Kelly (2) at the University of California at Los Angeles has added several additional cases. Thus far, we have not had any recurrences of the tumors, and our enthusiasm for this approach remains significant.

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In this well-written and well-demonstrated report, Benjamin and Russell describe their technique of the pterional transsylvian approach for tuberculum sellae meningiomas. We agree with the authors that the pterional transsylvian trajectory has a number of advantages over the standard bifrontal craniotomy when accessing these tumors. Early release of cerebrospinal fluid from the basal cisterns allows for brain relaxation and minimizes brain retraction, early identification of the internal carotid artery and its branches protects these vessels, early exposure of the optic nerves and chiasm provides protection of the visual system, and the ability to dissect the anterior cerebral artery and its branches from a lateral approach allows maximal protection of these crucial vessels (1). We do disagree with the authors regarding the use of self-retaining brain retractors. In the video provided, the authors show the use of relatively large frontal and temporal retractors, which we do not believe is necessary in this approach, provided that wide splitting of the proximal sylvian fissure is accomplished.

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Benjamin and Russell present their experience with tuberculum sellae meningiomas. They present three surgical approaches to resect tuberculum sellae meningiomas: the bicoronal subfrontal, the oblique subfrontal, and the pterional-transsylvian. They recommend and describe the pterional-transsylvian approach for these lesions in the central cranial base. The article is well written, and the surgical technique is precisely described. Also, the surgical video accompanying this article is well prepared. We respect each surgeon's own preferences, strategies, tactics, and surgical techniques. However, we have some technical points regarding which we do not agree with the authors (1–3).

We preferred a supraorbital approach, removing the orbital rim, to the small to moderate-sized tuberculum sellae meningiomas with bicoronal skin incision. A large or giant tumor is approached through a bifrontal flap. The patient's head is kept straight to facilitate the surgeon's orientation, and it is hyperextended to allow the frontal lobes to fall backward. Removing the orbital rim can allow a low basal access and working below the frontal lobe without excessive retraction. This approach allows direct access and shortens the distance to the tumor and gives wider exposure of the tumor, bilateral internal carotid arteries, and optic nerves, as well as the pituitary stalk, especially when dealing with a diaphragma sellae meningioma, which is more challenging, and the supraorbital approach is more advantageous.

Opening the frontal sinus during the craniotomy does not necessarily lead to cerebrospinal fluid leak and infectious complications as long as precautions are taken. These are total exenteration of the mucosa and packing of the sinus with a piece of temporal muscle or fat. It is important that all instruments used in handling the sinus are disposed of and that the surgical team is redressed. At the end of the operation, the defect in the anterior fossa after tumor removal, as well as the opened frontal sinus, should be closed in double layers with a vascularized pericranial flap to prevent cerebrospinal fluid leak.

We like to attack the base of the tumor first for devascularization. Then, the tumor can be debulked with suction, the ultrasonic aspirator, bipolar coagulation, and microscissors. The optic apparatus and the cerebral vessels are mostly separated by an arachnoidal membrane, which provides a plane of dissection and allows total removal of tumor. In almost every case, the Lilliequist membrane is intact, and we should keep it intact. We have to keep in mind that vital arterial perforators might be displaced or encased by the tumor. Therefore, no vessel should be sacrificed under the assumption of its being a tumor feeder until its course is fully ascertained. In particular, preservation of the branches from the A1 and internal carotid artery to the optic apparatus is critical to prevent postoperative visual problems.

When the tumor extends into the optic canal, the roof of the optic canal is drilled away with the diamond bit of a high-speed air drill, and the dural fold is then opened along the optic nerve. The tumor tissue around the optic nerve has to be removed with particular attention to preserving the ophthalmic and central retinal artery. We like to use saline irrigation especially during bipolar coagulation or drilling to prevent thermal injury to neurovascular structures.

We agree with the authors that the best treatment of these tumors is total surgical removal, including tumor, involved dura, and hyperostotic bone, with preservation of the olfactory and optic nerves and pituitary stalk.

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