

## VARIATIONS ON THE STANDARD TRANSSPHENOIDAL APPROACH TO THE SELLAR REGION, WITH EMPHASIS ON THE EXTENDED APPROACHES AND PARASELLAR APPROACHES: SURGICAL EXPERIENCE IN 105 CASES

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Received, October 16, 2003.

Accepted, February 24, 2004.

**OBJECTIVE:** The traditional boundaries of the transsphenoidal approach may be expanded to include the region from the cribriform plate of the anterior cranial base to the inferior clivus in the anteroposterior plane, and laterally to expose the cavernous cranial nerves and the optic canal. We review our combined experience with these variations on the transsphenoidal approach to various lesions of the sellar and parasellar region.

**METHODS:** From 1982 to 2003, we used the extended and parasellar transsphenoidal approaches in 105 patients presenting with a variety of lesions of the parasellar region. This study specifically reviews the breadth of pathological lesions operated and the complications associated with the approaches.

**RESULTS:** Variations of the standard transsphenoidal approach have been used in the following series: 30 cases of pituitary adenomas extending laterally to involve the cavernous sinus, 27 craniopharyngiomas, 11 tuberculoma/diaphragma sellae meningiomas, 10 sphenoid sinus mucocoeles, 18 clivus chordomas, 4 cases of carcinoma of the sphenoid sinus, 2 cases of breast carcinoma metastatic to the sella, and 3 cases of monostotic fibrous dysplasia involving the clivus. There was no mortality in the series. Permanent neurological complications included one case of monocular blindness, one case of permanent diabetes insipidus, and two permanent cavernous cranial neuropathies. There were four cases of internal carotid artery hemorrhage, one of which required ligation of the cervical internal carotid artery and resulted in hemiparesis. The incidence of postoperative cerebrospinal fluid fistulae was 6% (6 of 105 cases).

**CONCLUSION:** These modifications of the standard transsphenoidal approach are useful for lesions within the boundaries noted above, they offer excellent alternatives to transcranial approaches for these lesions, and they avoid prolonged exposure time and brain retraction. Technical details are discussed and illustrative cases presented.

**KEY WORDS:** Chordoma, Craniopharyngioma, Intracranial neoplasm, Meningioma, Pituitary adenoma, Sella turcica, Transsphenoidal craniotomy

*Neurosurgery* 55:539-550, 2004

DOI: 10.1227/01.NEU.0000134287.19377.A2

www.neurosurgery-online.com

Since repopularization of the transsphenoidal approach by Guiot and Thibaut (17) and Hardy and Wigser (19–21), most surgeons have adopted this technique as the primary method for the removal of pituitary adenomas. With the development of modern microinstrumentation and the use of the operating microscope, transsphenoidal surgery has proven to be a safe and effective method of approaching the sella (3). The increase in popu-

larity of this technique also may be attributed in part to the well-recognized inadequacy of the subfrontal approach to removal of the intrasellar component of the tumor (6–8, 19, 20, 45).

During the past 2 decades, numerous innovative methods of exposing other regions of the cranial base have been described. In this regard, we and others have extended the exposure via the transsphenoidal approach to gain added exposure of the cranial base for

lesions of the parasellar and clival region (10, 22, 24a, 27, 30, 36, 38). The present article reviews the application and experience with these variations on the standard transsphenoidal approach in 105 consecutive cases during the past 20 years at our institutions. The review focuses on the nature of pathological lesions addressed and the complications we experienced.

## PATIENTS AND METHODS

### Patient Population

From 1982 through July 2003, 105 extended and parasellar transsphenoidal procedures were performed by the senior authors (WTC, MHW, RIA, TF) at our respective institutions (The University of Utah University Hospital, Salt Lake City, UT; New York Medical College, Valhalla, NY; The University of Southern California Teaching Hospitals [LAC+USC Medical Center, USC University Hospital], Los Angeles, CA; Mitsui Memorial Hospital, Tokyo, Japan; and the Carolina Neuroscience Institute, Raleigh, NC). Patients were included in this series if a transnasal, transsphenoidal approach was performed for a lesion that extended beyond the anterior, posterior, or lateral boundaries of the sella. Patients harboring pituitary macroadenomas with primary vertical extent from the sella, in whom a standard transsphenoidal-transsellar exposure would enable adequate decompression and removal, were specifically excluded. The patients' ages ranged from 13 to 76 years (mean, 33.5 yr). There were 50 males and 55 females. *Table 1* summarizes the operated lesions.

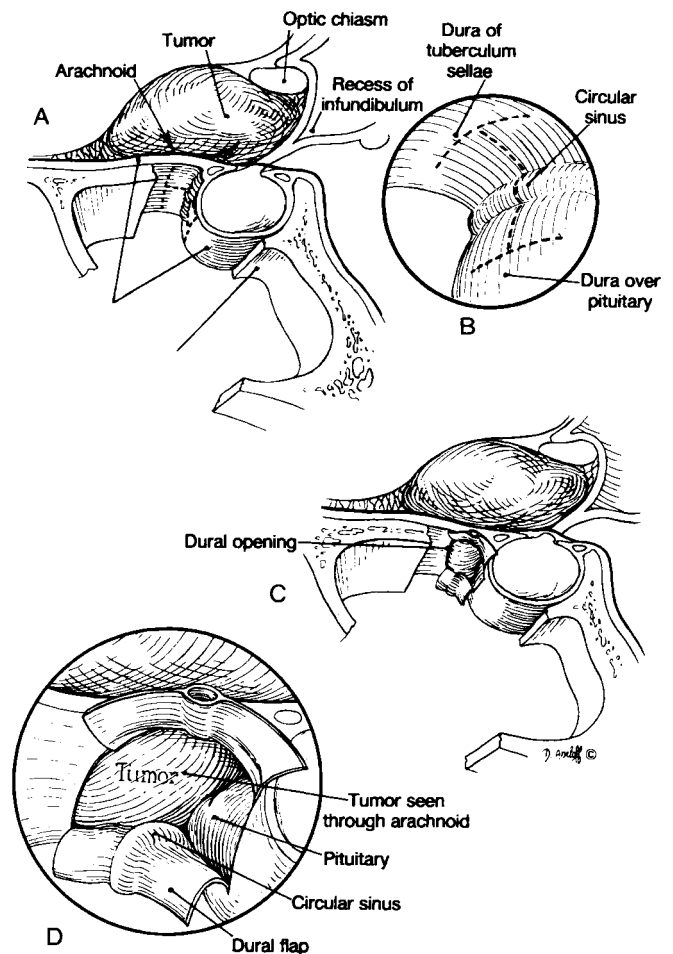
**TABLE 1. Summary of anatomic location and histological characteristics of lesions resected via variations of the transsphenoidal approach (extended and parasellar approaches)**

Location and histological characteristics	No. of cases
Anterior cranial base	
<i>Tuberculum/diaphragma sellae meningioma</i>	11
Sellar/parasellar region	
<i>Pituitary adenoma with cavernous extension</i>	30
<i>Sellar/suprasellar craniopharyngioma</i>	27
<i>Sphenoid mucocele</i>	10
<i>Sphenoid sinus carcinoma</i>	4
<i>Breast adenocarcinoma metastatic to sella</i>	2
Clivus	
<i>Chordoma</i>	18
<i>Monostotic fibrous dysplasia</i>	3
<b>Total</b>	<b>105</b>

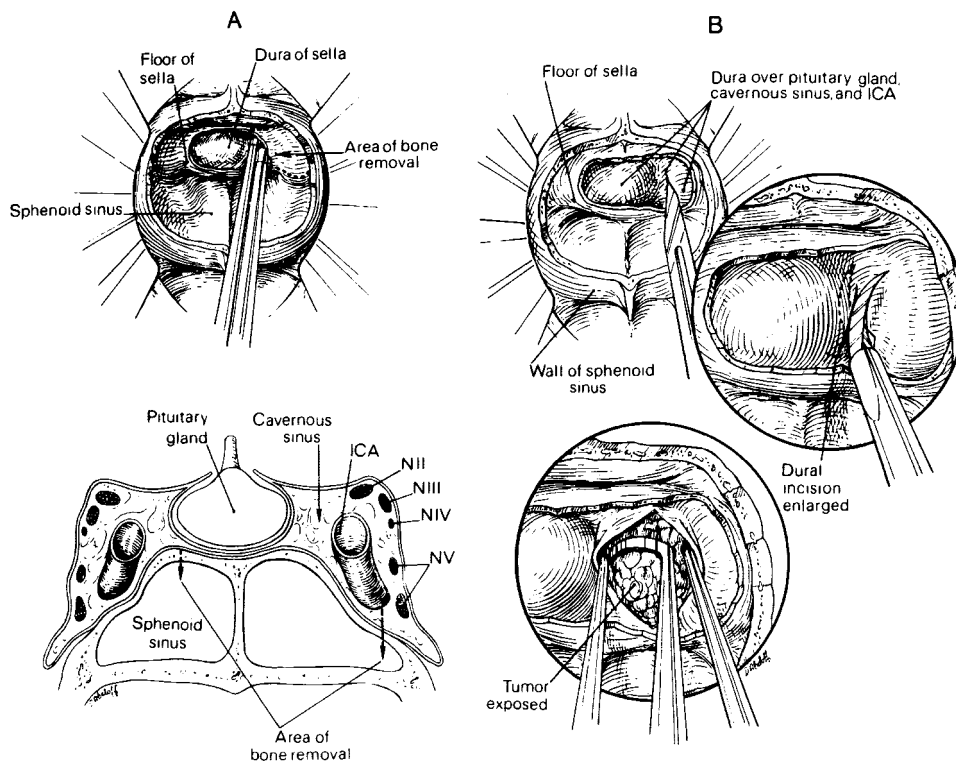
## OPERATIVE TECHNIQUE

### Patient Positioning and Exposure of the Sella

The patient is placed supine on the operating table with the head elevated approximately 15 degrees on a horseshoe headrest. This is preferred to rigid pin fixation, which limits intraoperative manipulation of the patient's head to improve visualization. A standard transeptal approach to the sphenoid sinus is performed as described previously (10, 46); the lateral aspects of the pyriform aperture are then enlarged with a high-speed diamond drill (Midas Rex, Fort Worth, TX) or rongeur. This enables additional lateral exposure after place-



**FIGURE 1.** Illustration showing exposure of the anterior cranial base. A purely suprasellar tumor may be approached by extending the bone resection anteriorly to include the tuberculum sellae, thus exposing the dura mater lying anterior to the circular sinus. An incision is made in the dura mater anteriorly and inferiorly to the circular sinus (A and B). The sinus is coagulated and then divided (C) to gain a direct view of the suprasellar cistern (D) without disturbing the pituitary gland (from, Couldwell WT, Weiss MH: *Transnasal transsphenoidal approach*, in Apuzzo MLJ (ed): *Surgery of the Third Ventricle*. Baltimore, Williams & Wilkins, 1998, ed 2, pp 553–574 [10]).



**FIGURE 2.** Illustration showing inferolateral exposure of the cavernous sinus. A, upper, the cavernous sinus area is exposed after extending the standard bony removal in a lateral direction, up to and including the carotid groove. A, lower, coronal view of the anatomic relationships delineating the lateral extent of bone removal relative to the positions of the internal carotid artery and cranial nerves. B, upper, after removal of the bone overlying the cavernous sinus, the dura is opened first by penetration with a no. 11 blade. B, middle, the dural incision is then extended with curved alligator microscissors. B, lower, removal of the intracavernous portion of the tumor is performed with a micro-ring curette (from, Couldwell WT, Weiss MH: *Transnasal transsphenoidal approach*, in Apuzzo MLJ (ed): *Surgery of the Third Ventricle*. Baltimore, Williams & Wilkins, 1998, ed 2, pp 553–574 [10]).

ment of a large bivalve speculum (a companion high-power spreader may be used to place the speculum). More recently, an endonasal approach has been used (37). The sphenoid sinus is then exposed in the usual fashion and all mucosa is everted. Specialized microinstruments, such as curved and angled alligator microscissors, a long monopolar coagulator with a malleable tip, and malleable-tip micro-ring curettes facilitate resection at the lateral extremes of the exposure. In addition, long, narrow bipolar forceps with up- or down-angled fine tips are used.

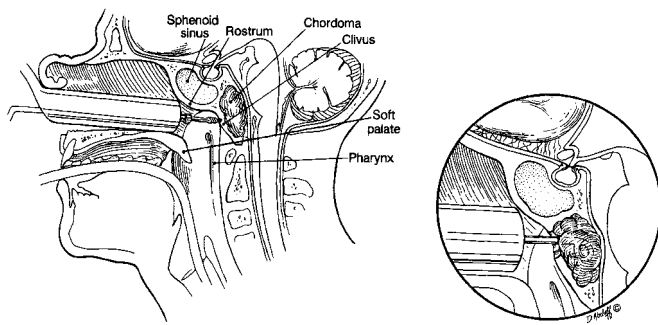
**Exposure of the Anterior Cranial Base (Extended Transsphenoidal Craniotomy)**

Access to the anterior cranial base is facilitated by slight extension of the patient’s head and manipulation of the speculum to point more superiorly (10). The bone of the tuberculum sellae is removed by first removing a small amount of bone over the anterior sellar wall to expose the anterior circular sinus and then extending this bony removal rostrally with microrongeurs (Fig. 1). In the case of meningioma removal, the

bone may be hyperostotic and require use of a high-speed drill. Bony removal in this location also yields additional exposure of the suprasellar region. The surgeon must remain cognizant of the position of the circular sinus, which demarcates the anterior extension of the sella, the anterior communicating artery complex superiorly, the ethmoid sinuses anteriorly, and the optic nerves superolaterally. After tumor removal, the dural defect must be repaired carefully. We prefer to use abdominal fascia or fascia lata and fat for this purpose. The fat is placed in the bony opening of the cranial base, followed by fascia to cover the dural defect. Lactosorb (Walter Lorenz Surgical, Inc., Jacksonville, FL) absorbable plate or mesh (100 mm × 100 mm; 1.5 mm thickness) has been used more recently and is tailored to size to repair the cranial base defect. This is buttressed in place and supported by packing the sphenoid sinus region with fat followed by packing of the nasopharynx as described previously (10, 46). For large cranial base defects, lumbar drainage is used for 4 days postoperatively.

**Inferolateral Exposure of the Cavernous Sinus**

The lateral extent of the lesion may be anticipated by carefully reviewing the preoperative coronal magnetic resonance imaging (MRI) scans. Particularly, the relationship of the cavernous carotid arteries to the lesion is essential for surgical planning. Before proceeding with the approach for lesions extending into the cavernous sinus, it is our practice to include the ipsilateral neck in the prepared field, in the event of significant carotid artery hemorrhage that may not be controlled by local hemostatic maneuvers. After exposure of the dura overlying the sella, the bone overlying the cavernous sinus, including that overlying the carotid grooves, is removed carefully (Fig. 2A). This results in limitation of the lateral extent of the exposure by the cavernous cranial nerves. The dura medial to the C3 portion of the internal carotid artery is incised with a no. 11 blade and opened with angled alligator microscissors (Fig. 2B). Tumor removal is then performed judiciously with micro-ring curettes. Venous bleeding that is encountered is controlled by gentle packing with Surgicel oxidized cellulose (Ethicon, Inc., Somerville, NJ) to avoid compressive cavernous cranial neuropathies.



**FIGURE 3.** Illustration showing inferior exposure of the clivus. Exposure of the clivus is facilitated by slight flexion of the patient's head and repositioning of the nasal self-retaining retractor to point inferiorly. The upper clivus lies directly posterior to the sphenoid sinus, but additional exposure of the middle and lower clivus requires a more inferior angle of the retractor. If the tumor has failed to erode the ventral clival bone, this may be performed with a high-speed drill (inset) (from, Couldwell WT, Weiss MH: Transnasal transsphenoidal approach, in Apuzzo MLJ (ed): *Surgery of the Third Ventricle*. Baltimore, Williams & Wilkins, 1998, ed 2, pp 553–574 [10]).

**Inferior Exposure of the Clivus**

Exposure of the clivus is facilitated by slight flexion of the patient's head and repositioning of the nasal self-retaining retractor to point inferiorly (10). The upper clivus lies directly posterior to the sphenoid sinus, but additional exposure to the mid and lower clivus requires more inferior exposure. The posterior wall and floor of the sphenoid sinus can be removed with conventional rongeurs or a high-speed drill (Fig. 3). In a patient with chordoma, the tumor may actually erode through the ventral cortical bone of the clivus, and care must be taken not to perforate the posterior fossa dura. Fortunately, most of the lesions in this region are extradural or extra-arachnoidal in nature, reducing the potential for cerebrospinal fluid (CSF) leakage and injury to the basilar artery. Repair of the dural

defect adjacent to the clivus is problematic at best, but careful grafting and packing, as outlined above, with the use of post-operative continuous lumbar drainage will suffice in most cases.

**RESULTS**

By use of the techniques described above, the following lesions were operated during a 20-year period (Table 1): 30 pituitary adenomas involving the cavernous sinus (19 prolactinomas, 5 nonfunctional adenomas, 4 growth-hormone secreting tumors, and 2 adrenocorticotropic hormone-producing tumors), 27 craniopharyngiomas, 11 tuberculum/diaphragma sellae meningiomas, 18 clivus chordomas, 10 sphenoid sinus mucocoeles, 4 carcinomas of the sphenoid sinus, 2 breast carcinomas metastatic to the sella, and 3 monostotic fibrous dysplasias involving the clivus.

All lesions were studied preoperatively with computed tomography and/or MRI; in the early case collection period, computed tomography was the modality of choice. Angiography with balloon occlusion was performed when planned dissection of the cavernous sinus was to be performed.

Among the various tumors, gross total resection was achieved in 7 of the 11 meningiomas, 12 of the 18 chordomas, 18 of the 30 pituitary adenomas, and 20 of the 27 craniopharyngiomas. Four of the completely resected craniopharyngiomas have recurred to date (mean follow-up, 10.2 yr). None of the carcinomas was resected completely, and all patients with carcinomas were treated with postoperative radiotherapy.

Complications related to surgery are listed in Table 2. There were a total of 15 complications (14%) among the 105 patients. Postoperative CSF fistulae were noted in 6 (5.7%) of 105 patients. Treatment for these six patients consisted of lumbar drainage in one patient and repairing the cranial base defect and repacking the sphenoid sinus in the remaining five patients. No further recurrence of CSF was encountered. Perma-

**TABLE 2. Complications related to resection via variations of the transsphenoidal approach\***

Complication	No. of cases
Cerebrospinal fluid fistula	6 (3 pituitary tumors, 2 craniopharyngiomas, 1 chordoma)
Monocular blindness	1 (meningioma)
Internal carotid hemorrhage	4 (3 chordomas, 1 pituitary adenoma)
Hemiparesis (secondary to ICA ligation)	1 (chordoma)
Sixth nerve palsy	1 (chordoma)
Partial third nerve palsy	1 (chordoma)
Permanent diabetes insipidus	1 (craniopharyngioma)
Total	15

\* ICA, internal carotid artery. A total of 105 patients underwent treatment for lesions as listed in Table 1.

nent neurological complications included one case of monocular blindness, one case of permanent diabetes insipidus, one permanent sixth nerve palsy, one partial third nerve palsy, and four cases of carotid artery hemorrhage, one of which required ligation of the cervical internal carotid artery and resulted in hemiparesis. The case of monocular blindness was thought, in retrospect, to have resulted from use of the monopolar cautery in proximity to the optic canal. There was no mortality in the series.

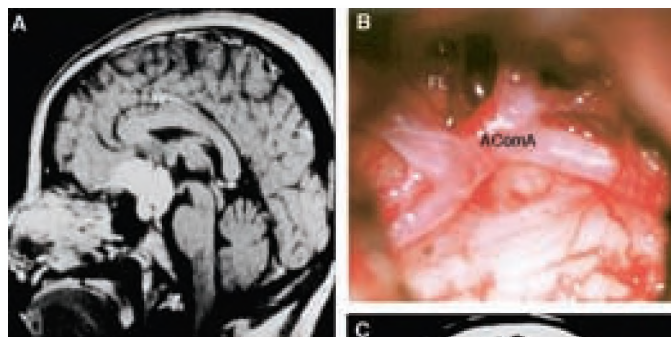
## ILLUSTRATIVE CASES

### Patient 1: Tuberculum Sellae Meningioma

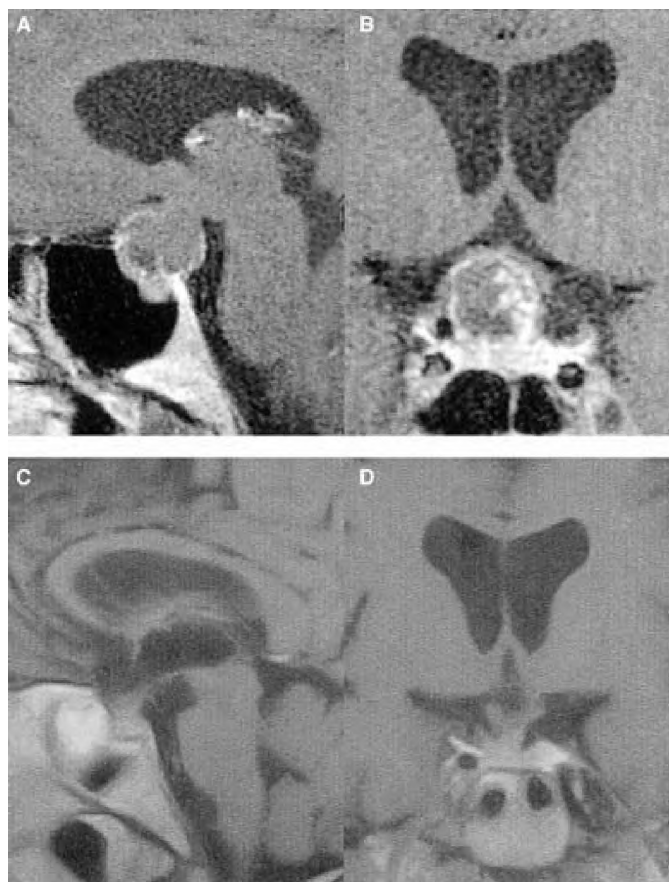
A 36-year-old woman presented with bilateral progressive visual loss. MRI revealed a suprasellar lesion based on the tuberculum sellae that enhanced avidly after gadolinium administration (Fig. 4A). The lesion was removed via the extended transsphenoidal approach with complete resection of the tumor. An intraoperative image (Fig. 4B) displayed the anterior communicating artery complex. A postoperative computed tomographic scan (Fig. 4C) revealed complete radiographic removal of the lesion with fat packing in the sphenoid sinus. The patient's vision improved postoperatively.

### Patient 2: Suprasellar Craniopharyngioma

A 56-year-old man presented with rapid visual loss and headaches. Physical examination revealed severe loss of vision (20/1000) in his right eye associated with a temporal field deficit. Pituitary endocrine studies were unremarkable. An extended transsphenoidal resection was undertaken, and gross total resection was achieved (Fig. 5). Post-



**FIGURE 4.** Patient 1, a 36-year-old woman with progressive visual loss secondary to tuberculum sellae meningioma. A, sagittal MRI scan showing a meningioma arising from the tuberculum sellae. Via an extended transsphenoidal approach with removal of the bone of the tuberculum sellae, the meningioma was removed with its dural attachment. B, intraoperative image showing the anterior communicating artery complex. FL, frontal lobe; ACoMA, anterior communicating artery. C, axial postoperative computed tomographic scan showing tumor removal with fat graft in the region.

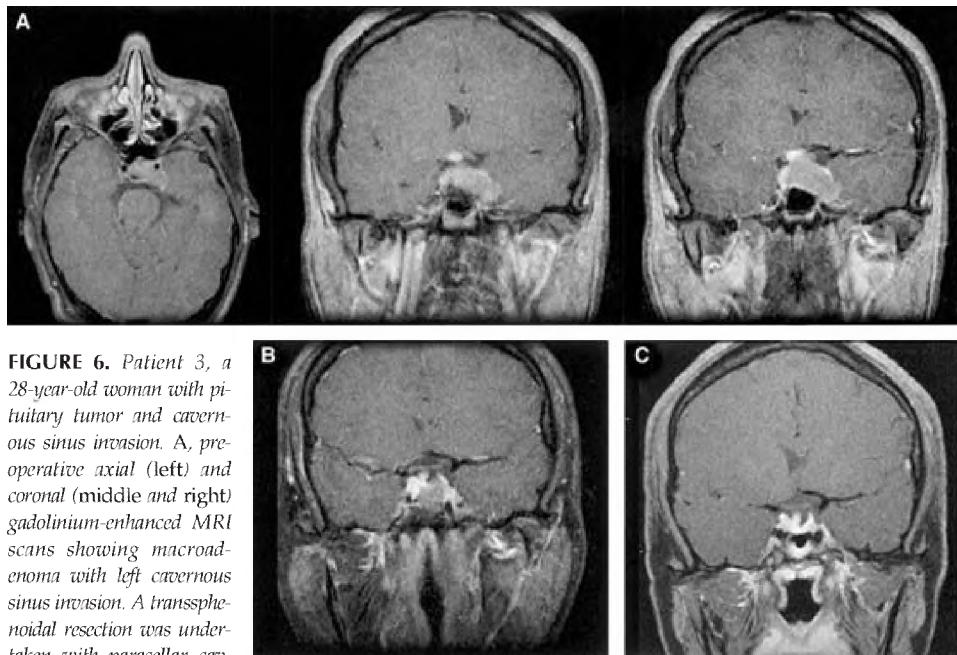


**FIGURE 5.** Patient 2, a 56-year-old man with visual loss and headache secondary to suprasellar craniopharyngioma. Preoperative sagittal (A) and coronal (B) MRI scans with gadolinium enhancement showing a suprasellar partially cystic lesion above a normal sella producing chiasmatal compression. An extended transsphenoidal approach was performed with removal of the bone of the tuberculum sellae. Complete resection of tumor was achieved. C and D, postoperative MRI scans more than 1 year later showing no residual or recurrent lesion.

operatively, vision improved in his right eye. Follow-up MRI has revealed no evidence of recurrence during 12 months of follow-up.

### Patient 3: Pituitary Adenoma with Cavernous Sinus Extension

A 28-year-old woman presented with enlarging hands and feet during a 2-year period and amenorrhea that she had experienced for the past 8 months. Endocrinological evaluation revealed clinical acromegaly, with elevated insulin-like growth factor 1 (650 ng/ml) and fasting growth hormone levels. MRI of the pituitary revealed a 2.0 × 2.8-cm macroadenoma of the pituitary with obvious cavernous sinus invasion (Fig. 6). A transsphenoidal approach was performed with exposure of the cavernous carotid artery. The tumor was resected with endoscopic assistance. The postoperative course was unremarkable. Postoperative Day 1 fasting growth hormone level was 2 ng/ml, and insulin-like growth factor 1 level decreased to 297 ng/ml 2 months after surgery. MRI scans obtained immediately after surgery and 9 months postoperatively revealed no residual or recurrent tumor. The patient has been followed for more than 1 year with no evidence of recurrence of her disease.



**FIGURE 6.** Patient 3, a 28-year-old woman with pituitary tumor and cavernous sinus invasion. A, pre-operative axial (left) and coronal (middle and right) gadolinium-enhanced MRI scans showing macroadenoma with left cavernous sinus invasion. A transsphenoidal resection was undertaken with parasellar cavernous sinus exposure of the carotid artery. Aggressive endoscopic-aided resection of the lesion was undertaken. B, immediate postoperative and C, 9-month postoperative MRI scans showing no additional tumor.

**Patient 4: Clivus Chordoma Demonstrating Limits of Inferior Exposure via the Transsphenoidal Approach**

This 24-year-old man presented with a history of progressive neck pain, diplopia, nasal obstruction, and difficulty swallowing. Physical examination was notable for a left abducens palsy and bilateral tongue weakness. MRI scans revealed a massive lesion involving the complete clivus, eroding the occipital condyles bilaterally and extending to C2 (Fig. 7. A and B). Posterior occipital cervical fusion was performed to stabilize the upper cervical spine and occiput (Fig. 7C). Via an endonasal transsphenoidal route, the upper two-thirds of the lesion was removed. The patient’s symptomatic nasal obstruction improved, as did his swallowing, which was thought to be secondary to brainstem compression. Imaging studies demonstrated resection of the lesion in the upper and mid clivus, decompression of the brainstem, and residual tumor inferiorly that was resected ultimately via the transoral corridor (Fig. 7D). The abducens palsy improved postoperatively. This case illustrates the limitation of the inferior exposure of the transsphenoidal approach.

**DISCUSSION**

**Historical Perspective**

In 1905, Krause (31) introduced the frontal transcranial approach to the sella; this technique has provided the basis on which the majority of subsequent variations of transcranial approaches to this region have been developed. Shortly thereafter, Schloffer (42), an Austrian rhinologist, recommended use of a transsphenoidal route as an alternate and presumably safer approach to the sella turcica and its contents. In 1907, he reported the first successful removal of a pituitary tumor via the transsphenoidal approach (43). The technique of sphenoid sinus exposure subsequently underwent a number of modifications by interested surgeons, the culmination of

which was the 1910 description by Halstead (18) of the sublabial gingival incision for the initial stage of sphenoid sinus exposure. After initial disappointments at transcranial efforts, Cushing (13) embraced the transsphenoidal approach. He described a technique that combined a number of suggestions that had been made by previous authors (18, 23, 26) and used the sublabial incision described by Halstead. Cushing also adopted the technique of submucous dissection of the nasal septum promulgated by Eiselberg and Kocher and used the headlight described by Kanavel to enable better visualization in the depths of the operative field during surgery. Using the transnasal/transsphenoidal approach during the 15-year period from 1910 to 1925, Cushing operated on 231 pituitary tumors with a reported mortality of 5.6%. This represented the best efforts at surgical exposure and access to the pituitary at the time. Although the sella also has been

approached transthemoidally (5) and transantrally (2), the transnasal transsphenoidal route has become the preferred method for removal of intrasellar masses. A brief history of the evolution of transsphenoidal techniques has been published recently (36).

Although the transsphenoidal approach has been advocated primarily for access to sellar lesions, in recent years, these indications have been extended by some authors to include lesions of the upper clivus (33, 46). Several authors have suggested use of the transsphenoidal approach to access lesions of the parasellar region (10, 27–30, 35, 38, 41, 45); the initial report of such a case occurred when Cushing removed two meningiomas of the anterior clinoid via the transnasal, transsphenoidal route (14). On the basis of the elegant anatomic descriptions published by Fujii et al. (16), we have applied these anatomic principles to maximize direct visualization of the tuberculum sellae, cavernous sinus, and the entire clivus.

**Anatomic Limitations of the Variations on the Transsphenoidal Approach**

The anatomic limits of the transsphenoidal approach are primarily defined 1) superiorly by the posterior cribriform region, 2) laterally by the cavernous sinus and carotid arteries, and 3) inferiorly on the basis of the inferior mobility of the retractor and extent of visualization of the clivus, usually to the region of the cervicoclival junction (Patient 4). If the lateral extent of the lesion exceeds that of the transsphenoidal approach, the transmaxillary route may supplement lateral ex-



**FIGURE 7.** Patient 4, a 24-year-old man with extensive clivus chordoma presenting with a history of progressive neck pain, diplopia, and nasal obstruction. Preoperative T1-weighted sagittal (A) and axial (B) MRI scans with contrast enhancement showing the presence of a large tumor involving the entire clivus. The lesion was eroding the occipital condyles bilaterally and extending to C2. C, x-ray showing initial posterior occipital-cervical fusion. D, sagittal image obtained 2 days later, when an endonasal transsphenoidal approach was used to remove the majority of the clival lesion. Dotted line shows the inferior extent of tumor removal and represents the delineation of the fat graft and residual tumor. The extent of visualization transnasally is determined by the hard palate, which limits the extent of retractor placement inferiorly. Residual tumor is located in the region of C1–C2 and the condyles. Subsequently, the patient underwent a transoral approach with supplementation by a LeFort I osteotomy to enable removal of the inferolateral residual tumor.

posure (12, 15, 39, 40). As with suprasellar exposure (44), the extent of exposure obtained in all directions may be enhanced with the application of endoscopic visualization (1, 4, 25, 34, 47). More recently, we have routinely used endoscopy as an adjunct for visualization beyond the limits of standard microsurgical visualization.

### Indications for the Use of These Variations on the Transsphenoidal Approach

These variations on the transsphenoidal approach have been used for a variety of pathological lesions in this series. For patients in whom one would prefer to avoid prolonged surgery, such as elderly patients and those with medical comorbidities, the transsphenoidal approach provides an espe-

cially attractive alternative. Furthermore, brain retraction is avoided with the approach.

Early in the series, sophisticated imaging studies were not available, and some of the meningiomas in the series were approached transsphenoidally under the preoperative diagnosis of nonfunctional pituitary macroadenoma. After noting that such tumors could be removed transsphenoidally, these methodologies were applied to several tumors later in the series, when a preoperative radiographic diagnosis of meningioma was possible. We advocate this approach for very well-selected small (2–3 cm) meningiomas of the midline tuberculum sellae/planum sphenoidale region that may be accessed completely by the more extensive bone removal described above. The approach enables early devascularization of the tumor at its base and removal of the tumor beneath the chiasm and optic nerves with no manipulation of the neural structures.

The patients with sphenoid mucocoeles and carcinomas in this series all presented with visual loss. The focal nature of the carcinoma lesion (all with preoperative unknown primary) as revealed by imaging studies precluded a definite preoperative diagnosis, and again, nonfunctional pituitary adenomas with inferior extension into the sphenoid sinus could not be excluded. Through this approach, the diagnosis was made and the optic apparatus was decompressed. All patients with carcinomas were treated with postoperative radiotherapy. However, we would not advocate a primary transsphenoidal resection for known carcinomatous processes, except in patients presenting with rapid visual loss (9, 24) or because of subsequent failure of radiation or chemotherapy. If there is suspicion of such a lesion, an endoscopic biopsy may be performed before more definitive therapy is planned.

Laws (32) reported the merits of the transsphenoidal route in the removal of craniopharyngiomas previously. In patients with craniopharyngiomas in the present series, the additional bony exposure provided improved visualization of the suprasellar portions of these tumors. This reduced the amount of blind curettage in that region. Cystic tumors were particularly amenable to drainage and removal by this approach. It is important to note that the transsphenoidal approach was used in craniopharyngiomas with both an intrasellar and suprasellar component, without significant lateral extension. We prefer to use a standard transcranial approach (subfrontal or pterional) if the tumor is located entirely suprasellar.

With respect to the pituitary adenomas operated in the series, additional lateral exposure enabled removal of tumor within the confines of the cavernous sinus proper. With the maximum lateral exposure outlined above, the carotid grooves are unroofed, exposing the C3 portion of the internal carotid; the cavernous sinus is entered by opening the dura just medial to the carotid artery. With the development of this particular technique, we think that more complete resection of adenomas may be achieved, reducing the need for blind curettage of tumor performed by reaching into the cavernous sinus via the sella. It is important to note that early in this series, i.e., 15 to 20 years ago, large prolactinomas were treated

with surgical resection as a component of multi-therapy. However, with the efficacy of current well-tolerated medical therapy (especially cabergoline), indication for surgical resection of macroprolactinoma has been reduced to the rare tumor that fails to respond to medical therapy. More recently, the indications for cavernous dissection in the setting of a pituitary tumor have been further reduced with the increased application of radiosurgical techniques. We now prefer to use planned adjuvant radiosurgery for residual tumor in the cavernous sinus to avoid potential cranial neuropathy. In such instances, hypophysopexy (transposition of the pituitary with interposition of fat graft between the cavernous sinus and gland) may be performed to enable treatment of known residual tumor in the cavernous sinus and preserve pituitary function in the face of planned radiosurgery (11).

As clivus chordomas are primarily extradural and midline in location, the extended transsphenoidal approach is well suited to approaching the majority of these lesions without significant lateral extension. We approach chordomas at any level of the clivus via a transsphenoidal exposure, which enables associated sinus extension of the lesion to be removed with ease. Chordomas with significant lateral component may require a more lateral approach for their removal, and those with extension below the inferior clivus level are approached via a transoral route (Patient 4).

### Risks Associated with These Variations of the Transsphenoidal Approach

Review of the results of the present series indicates that serious complications from the use of the extended and parasellar transsphenoidal approaches are uncommon. The most significant complications include the development of CSF fistulae and vascular injury to the cavernous carotid artery.

The risk of CSF leakage may be reduced by careful dural grafting and nasal packing techniques with adjuvant use of postoperative CSF drainage. The grafting method used at the University of Southern California has been published previously (10, 46). More recently, we have used bioabsorbable plating systems to fortify the closure of the cranial base and to anchor the fascia graft opposed to the dural opening. This may be molded with gentle heat to conform to cover the cranial base defect. The sphenoid sinus is then packed with fat behind the cranial base dural graft and plate. Before closing, the anesthetist is asked to perform a Valsalva maneuver to assess the functional integrity of the graft. If there is no CSF leakage around the graft, the retractor is removed, and the posterior nasal packs (nasal tampons) are placed against the sphenoidal opening. In the unusual case of a postoperative leak after removal of the nasal packing (2–3 d), the decision to return to the operating room for formal repacking is made early to avoid meningitis. If postoperative lumbar CSF drainage is used, the drain is left in place for approximately 4 days, and head position is maintained at a modest 10 to 15 degrees to decrease the incidence of pneumocephalus.

Carotid artery injury occurred in four cases in the present series. When open dissection of the cavernous sinus is anticipated, a carotid balloon occlusion test should be contemplated, as carotid hemorrhage is a risk with exposure or tumor removal in the area. If hemorrhage occurs, it is usually controllable through packing with harvested fascia. Failure to stop this hemorrhage by packing with fascia and Surgical may necessitate ligation of the artery in its cervical portion. If intraoperative carotid rupture occurs, immediate postoperative angiography is performed to exclude the presence of a false aneurysm, which may result in delayed, fulminant epistaxis, a potentially life-threatening condition. If a pseudoaneurysm is noted, endovascular techniques are used to obliterate the lesion or ligate the carotid after a successful appropriate balloon occlusion test. If no aneurysm is noted on the immediate postoperative study, delayed (7–10 d) angiography is performed to exclude the occurrence of an aneurysm occurring in a delayed fashion.

It is notable that the majority of the serious complications (vascular injuries and permanent cranial nerve palsies) noted in this series occurred during the 1st decade of use of these approach variations. We suspect the reasons for this are multifactorial, but they include increased experience (learning curve) and improved MRI, which can reveal important tumor and vascular/nerve relationships to aid in surgical planning.

### CONCLUSION

The development of cranial base approaches facilitates exposure of basal lesions by the removal of osseous structures to minimize brain retraction. The described variations of the transsphenoidal approach provide safe alternatives when attempting to access lesions involving the tuberculum sellae, suprasellar region, cavernous sinus, and clivus. The transsphenoidal route is best used for midline lesions that lack significant lateral extension. With appropriate patient selection, microinstrumentation, and familiarity of the regional microanatomy, complications can be minimized.

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## Acknowledgments

We acknowledge the superb editorial assistance of Kristin Kraus. We have no financial interest in any of the equipment or products described herein.

## COMMENTS

This reviewer has always believed that transsphenoidal surgery is an important part of cranial base surgery. This article certainly demonstrates that and offers our readers a real stimulus to the use of this highly versatile approach for a wide variety of lesions affecting different parts of the anterior cranial base. Their results have been outstanding. Their technical variations have been highly successful, and the suggestions offered for variations on the standard transsphenoidal approach are carefully and intelligently described. We have become more and more enthusiastic about the extended transsphenoidal cranial base approach for midline suprasellar tumors such as craniopharyngiomas. The trajectory and the view are in most cases excellent for the safe and effective removal of these difficult lesions that often arise behind the optic chiasm, where they are extremely difficult to expose effectively through standard transcranial approaches. It makes great sense to try to remove midline lesions through a midline approach, and this, along with a number of other methods of

dealing with challenging lesions, is elegantly demonstrated in this article.

**Edward R. Laws, Jr.**  
Charlottesville, Virginia

**T**his is a combined series of 105 patients who underwent an extended transsphenoidal approach for a variety of sellar and suprasellar lesions at three different institutions. The authors describe their surgical technique as it pertains to removal of a variety of lesions that extend beyond the sellar confines and the immediate suprasellar space. Specifically, they describe the technique for removal of tumors that extend anteriorly over the planum, posteriorly behind the clivus, and laterally into the cavernous sinus. They further describe their results, and they discuss their complications. Among the complications listed, internal carotid artery injury and hemorrhage in four patients looms as probably the most significant one. In addition, they also list a 6% incidence of postoperative cerebrospinal fluid fistulas. Clearly, the authors bring to our attention that these complications occur with a higher incidence in conjunction with this approach, compared with the standard transsphenoidal microsurgical or endoscopic approach.

Our own experience with this procedure extends over 12 cases of pituitary adenomas. The indication for the extended transsphenoidal approach was an anterior extension of the tumor over the planum, significant tumor extension into the interpeduncular cistern, predominant supradiaphragmatic tumor position in conjunction with a relatively narrow diaphragma sellae, and a relative narrowing of the diaphragma sellae in three patients who at operation were found to have tumors of an unusual hard, rubbery, tough consistency. We did not use this approach for purely supradiaphragmatic lesions and in the presence of a normal diaphragma sellae. Consequently, we have not used this approach for suprasellar craniopharyngiomas, meningiomas, etc.

Our technique is similar to that of the authors. However, we feel reasonably strongly that the use of intracranial navigation with computer stereotactic guidance adds significantly to the safety of the operation. The intracranial navigation offers not only a vertical orientation but also, more importantly, a horizontal orientation as to the position of the carotid arteries, optic nerves, etc. After accessing the sphenoid sinus via an endonasal microsurgical approach, the entire anterior and inferior sella walls of the planum and clivus as well as both carotid tubercles are exposed. This is followed by a standard exposure of the entire anterior and partially inferior sella dura from one cavernous sinus region to the other and from the sella floor to the planum. At this juncture, we prefer to drill out the planum using a microsurgical drill armed with a diamond drill bit, beginning with a 3-mm drill and finishing with a 1- or 2-mm drill. Both coarse and fine diamond drills are used in this regard. Intermittent spot checks are made with the navigational probe as to the position of the carotid arteries and the optic nerves so as not to extend the drilling too far laterally. It is not necessary to remove more than 6 to 7 mm of

the posterior planum in this manner. The final drilling is performed between the planum and the sella, that is to say, at the level of the tuberculum sellae, which is thinned out and finally removed with the use of a fine, thin-lipped 1-mm rongeur. By now, the entire dura from the sellar floor to the mid planum is exposed. We then proceed to open the sella dura in the standard manner. This is performed up to the dura of the circular sinus. With this accomplished, the planum dura is opened next. Finally, the circular sinus is coagulated and divided. Again, spot checks are made with the navigational probe as to the position of the carotid arteries and the optic nerves. By now, the lesion is usually very nicely exposed to begin tumor resection. The tumor is first decompressed in the sella before the suprasellar portion is decompressed as well. The slackened tumor surface is then separated from the dura of the sella floor, the cavernous sinuses, and superiorly from the reflections of the arachnoid membrane working alternately from both sides until the dome of the tumor can be retrieved from beneath the superiorly displaced arachnoid. In the process, it is almost inevitable that the arachnoid membrane will be opened, especially anteriorly over the planum, where the arachnoid is usually much thinner and more vulnerable compared with the suprasellar arachnoid. In patients with pituitary tumors, the surgeon should adhere to the anatomic concept that the tumor is always beneath the arachnoid regardless of its size. Consequently, recognition of the arachnoid membrane as such during the tumor's dissection in the suprasellar space is critical for the safe outcome of the operation. Our closure is identical to that described by the authors. Instead of a mesh, we have also used at times a thin layer of an iliac allograft that is wedged into the sella opening so as to hold the fascia-fat graft in place. We also use biological fibrin glue to seal off the entire construct. In patients in whom there was evidence of a significant cerebrospinal fluid leak, a lumbar subarachnoid catheter is inserted for a period of approximately 3 to 4 days. We have not had any mortality, incidents of carotid artery injuries, loss of vision, or diplopia. We did have one case of meningitis.

Among several questions that come to mind, the foremost would seem to be whether this approach should be used for purely suprasellar lesions in the presence of a normal sella. I personally am not comfortable recommending this approach to my patients under these circumstances. This is not to say that a select group of very experienced pituitary surgeons should not use this approach as described in this report. Clearly, the extended transsphenoidal approach can be associated with a significant morbidity. I suppose it would probably be safer during the learning curve if neurosurgeons endeavoring to become facile with this procedure were to first apply this approach to the removal of pituitary that seems less amenable to a meaningful resection using the standard transsphenoidal approach before considering resection of purely suprasellar lesions in the face of a completely normal sella.

**Ivan S. Ciric**  
Evanston, Illinois

The authors of this article represent a heterogeneous group of very experienced surgeons, some of them with a special concern for the transsphenoidal approach. One of the senior authors (MHW) is commonly recognized as a pioneer of the extended transsphenoidal approaches (5). Their contribution and their experience on a large number of selected patients is without any doubt very interesting.

We agree with most of the points they outline (i.e., no rigid pin head fixation, preferred endonasal approach rather than sublabial [4, 6], early devascularization in meningioma at its base, etc.) and with the indications they give for the extended approaches. In any case, we would like to make some comments.

Since 1997, we have been using a pure endoscopic endonasal transsphenoidal approach, which has proved to be less traumatic and very effective in the removal of a great variety of lesions via a transsphenoidal route (3), with a low complication rate (1). Time is needed to acquire a specific endoscopic skill to be able to use the endoscope alone in an extended transsphenoidal approach with confidence (learning curve). In our opinion, the endoscope is superior to the microscope in providing a wider and closer vision, which can be very helpful in these cases. The occasional use of the endoscope in the course of a microsurgical approach, in which an excellent but restricted visual field is available, offers the surgeon a wider look only from time to time and to perform a frequently necessary blind curettage, particularly in remote corners. Conversely, the microsurgical procedure has its advantages in terms of tridimensional vision, of easier maneuverability with both hands (which can be very useful in cases of intraoperative complications), and in the phase of reconstruction of the cranial base defect.

To reduce the risk of carotid injuries, it is very useful to adopt a regular intraoperative control of the internal carotid artery by means of a microdoppler probe. This permits a rather safe exposure of the medial and even of the lateral segment of the intracavernous internal carotid artery (2). This should not allow us to be too aggressive or to take too many risks, always keeping in mind the modern attitudes that take into consideration the new pharmacological agents and radiosurgical techniques, as the authors clearly state.

**Paolo Cappabianca**  
Naples, Italy

- Zada G, Kelly DF, Cohan P, Wang C, Swerdloff R: The endonasal transsphenoidal approach for pituitary adenomas and other sellar lesions: An assessment of efficacy, safety and patient impressions. *J Neurosurg* 98:350-358, 2003.

A group of experienced pituitary surgeons from several institutions retrospectively assembled this compilation of cases over a period of 20 years during which the transsphenoidal approach was used to treat lesions outside the margins of the sella. The analysis clearly demonstrates the usefulness of the extended transsphenoidal approach in treating a variety of lesions that have traditionally required craniotomy or more extensive cranial base approaches to the clivus, cavernous sinuses, and frontal base. It is difficult to gather more specific information from this article, because the analysis involves a variety of lesions treated by different techniques over a long interval of time. For example, advances in surgical navigation, intraoperative imaging, endoscopy, and adjunctive therapies such as radiosurgery have markedly changed the indications, objectives, and technical aspects of these approaches in recent years. Nevertheless, this article should raise the awareness of neurosurgeons to the broad usefulness and potential benefits of transnasal, transsphenoidal approaches to intradural and extradural lesions situated along the anterior ventral cranial base. Further advances in instrumentation may solve some of the current limitations for this approach and enable these operations to become routine.

**Marc R. Mayberg**  
Cleveland, Ohio

In this article, Couldwell et al. describe their 20-year experience with an extended transsphenoidal approach for a number of lesions, including pituitary adenomas, meningiomas, craniopharyngiomas, sphenoid sinus mucoceles, clival chordomas, carcinomas, and fibrous dysplasia. It is the compilation of the results of several experienced surgeons at several institutions. As they point out, this is not a single approach per se but rather an extension of the more routine standard transsphenoidal exposure (either sublabial or endonasal) to lesions that are not confined to the sella turcica proper. This is an important concept and a strategy that has been described by others. As the authors rightly point out, this type of surgery can be associated with significant risks, including carotid artery injury, which was seen in nearly 4% of their patient population. A comfort level at repairing the resultant cranial base defects is a must, given the potential for cerebrospinal fluid leakage. The results presented here are impressive, and the complications are understandable. Clearly, this attests to this group's technical expertise and comfort in this location. This is not the type of surgery that will be undertaken by the average neurosurgeon, nor should it be.

With the introduction of other noninvasive adjuvant modalities, such as stereotactic radiosurgery, one can ask whether such an approach would be still indicated in many of the patients presented in this article. There is no question that the concept of acceptable morbidity has changed during the past

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decade. We agree with the authors that in certain cases, especially pituitary adenomas, a less intrusive primary surgery might be more in the patient's best interest. In the same way, we have an obligation to show that chasing a meningioma into the medial cavernous sinus truly justifies the inherent real risk of vascular and cranial nerve injury. It is critical that in the

future, the results are analyzed in terms of outcome rather than just surgical feasibility.

Wesley A. King  
Kalmon D. Post  
New York, New York



Anatomic plate from Sir Charles Bell's series of engravings depicting neural-related limb anatomy (1803). This drawing illustrates the course of the sciatic nerve. (See pages 561, 568, and 601 for more plates from this series.) Inset shows the frontispiece of Bell's *An Exposition of the Natural System of the Nerves of the Human Body* (1825), published shortly after he became the first professor of anatomy and surgery at the Royal College of Surgeons in London. He was known for his clear and elegant prose, of which this text is exemplary.

