

## The extended direct endonasal transsphenoidal approach for nonadenomatous suprasellar tumors

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**Object.** The extended transsphenoidal approach, which requires a bone and dural opening through the tuberculum sellae and posterior planum sphenoidale, is increasingly used for the treatment of nonadenomatous suprasellar tumors. The authors present their experiences in using the direct endonasal approach in patients with nonadenomatous suprasellar tumors.

**Methods.** Surgery was performed with the aid of an operating microscope and angled endoscopes were used to assess the completeness of resection. Bone and dural defects were repaired using abdominal fat, collagen sponge, titanium mesh, and, in most cases, lumbar drainage of cerebrospinal fluid (CSF).

Twenty-six procedures for tumor removal were performed in 24 patients (ages 9–79 years), including two repeated operations for residual tumor. Gross-total removal could be accomplished in only 46% of patients, with near-gross-total removal or better in 74% of 23 patients (five of eight with craniopharyngiomas, six of seven with meningiomas, five of six with Rathke cleft cysts, and one of two with a dermoid or epidermoid cyst); a patient with a lymphoma only underwent biopsy. Of 13 patients with tumor-related visual loss, 85% improved postoperatively. The complications that occurred included five patients (21%) with postoperative CSF leaks, one patient (4%) with bacterial meningitis; five patients (21%) with new endocrinopathy; and two patients (8%) who needed to undergo repeated operations to downsize suprasellar fat grafts. The only permanent neurological deficit was anosmia in one patient; there were no intracranial vascular injuries.

**Conclusions.** The direct endonasal skull-base approach provides an effective minimally invasive means for resecting or debulking nonadenomatous suprasellar tumors that have traditionally been approached through a sublabial or transcranial route. Procedures in the supraglandular space can be performed effectively with excellent visualization of the optic apparatus while preserving pituitary function in most cases. The major challenge remains developing consistently effective techniques to prevent postoperative CSF leaks.

**KEY WORDS** • extended transsphenoidal surgery • endonasal approach • suprasellar tumor • meningioma • craniopharyngioma • Rathke cleft cyst

THE transsphenoidal route has been the favored approach for resection of most intrasellar tumors for longer than three decades.<sup>46,48</sup> For many nonadenomatous suprasellar tumors, however, the transcranial route, taken either by performing a pterional or subfrontal approach, has continued to be used by a majority of neurosurgeons. More recently, a modification of the transsphenoidal approach that allows additional exposure of the suprasellar space has been followed for various pathological conditions such as tuberculum sellae meningiomas, craniopharyngiomas, and supraglandular Rathke cleft cysts.<sup>15,20,29,34–36,38,39,43,51,61</sup> Termed the extended transsphenoidal approach and originally described by Weiss<sup>61</sup> in 1987, this approach requires removal of additional bone along the tuberculum sellae and the posterior planum sphenoidale with subsequent opening of the dura mater above the diaphragma sellae. This route allows excellent midline access and visibility to the suprasellar space while obviating brain retraction. The

technique does require a large opening in the dura mater over the tuberculum sellae and the posterior planum sphenoidale and typically results in large intraoperative CSF leaks, which necessitate precise and effective dural closure to prevent a postoperative CSF fistula and meningitis.

In all early reports of this technique, with the exception of those by de Divitiis, et al.<sup>15</sup> and Jho and Ha,<sup>34</sup> who used an endonasal endoscopic approach, the technique is described in conjunction with a sublabial or transcolumellar (transseptal) endonasal route. We recently reported our experience with the extended transsphenoidal approach in which we used a direct endonasal route for three patients with tuberculum sellae meningiomas.<sup>12</sup> This more minimally invasive transsphenoidal approach was originally described by Griffith and Veerapen<sup>23</sup> in 1987 and is being increasingly used for sellar lesions. Our report and those by others<sup>20,35</sup> on the extended approach have been technical notes or small case series in which the largest included 14 patients. Here we present our initial experience with the extended direct endonasal transsphenoidal route in 24 patients with suprasellar nonadenomatous lesions. Attention is focused on tumor removal rates, visual recovery, technical complications, and postoperative neuroendocrine function.

*Abbreviations used in this paper:* CA = carotid artery; CSF = cerebrospinal fluid; DI = diabetes insipidus; MR = magnetic resonance.

## Extended direct endonasal transsphenoidal approach

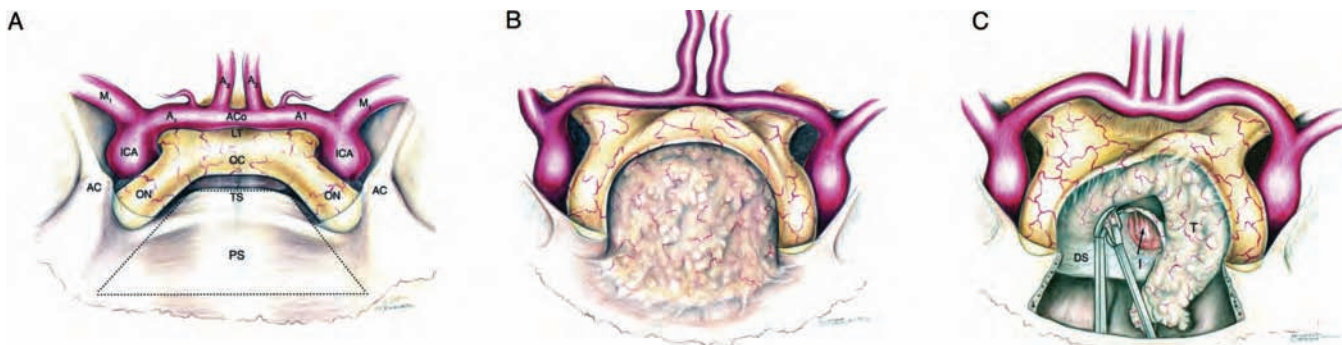


FIG. 1. Illustrations of the extended approach, from the vantage point of the frontal fossa, demonstrating the extent of bone and dura removed along the posterior planum sphenoidale and the tuberculum sellae (A); a typical tuberculum sellae meningioma extending outward along the proximal planum sphenoidale and causing chiasmal elevation (B); and transsphenoidal resection of a meningioma showing the need for sharp dissection and grasping forceps to help define the arachnoid planes between the tumor and optic apparatus (C). Dotted lines indicate the border of area of bone resection required for the extended approach. A<sub>1</sub> = first segment of anterior cerebral artery; A<sub>2</sub> = second segment of anterior cerebral artery; AC = anterior clinoid process; DS = diaphragma sellae; I = infundibulum; ICA = internal CA; LT = lamina terminalis; M<sub>1</sub> = first segment of middle cerebral artery; OC = optic chiasm; ON = optic nerve; PS = planum sphenoidale; T = tumor; TS = tuberculum sellae.

### Clinical Material and Methods

#### Patient Population

All patients who had undergone an extended transsphenoidal approach via the direct endonasal approach for tumor removal and who participated in at least 3 months of follow-up review were identified since we began using this technique in June 2000. Patients with a diagnosis of pituitary adenoma were excluded from this analysis. The Institutional Review Board of the University of California at Los Angeles approved the retrospective review and analysis of the patient data.

#### Surgical Technique

The direct endonasal approach, as described previously, was used in all cases by using the operating microscope and endoscope to guide tumor removal.<sup>23,64</sup> Surgical navigation was used in all cases; in 21 cases this included only fluoroscopy, whereas more recently computerized surgical navigation (BrainLab VectorVision cranial; Westchester, IL) was used in eight cases. In two cases surgery was performed in an operating-MR imaging suite for intraoperative assessment of completeness of tumor removal.

**Endonasal Approach to the Planum.** The nostril chosen for the approach was based on the location of the tumor. For tumors projecting more to one side, the contralateral nostril was used, given that a greater contralateral sellar and suprasellar exposure is provided than an ipsilateral exposure. Briefly, the initial approach through the nostril was performed using a hand-held speculum, which was then replaced by a thin, modified Hardy speculum (Aesculap, Tuttlingen, Germany, or Mizuho-America, Beverly, MA). The Hardy speculum was placed facing the sphenoid bone and angled more superiorly than one would for a sellar lesion, aiming toward the junction of the tuberculum sellae and the planum sphenoidale. After the sphenoid sinus had been opened widely, the face of the sella turcica was removed. The extent of the bone removal was lengthened anteriorly through the tuberculum sellae and proximal planum sphenoidale

by using a Kerrison bone punch and/or a transsphenoidal drill (MicroMax; Anspach, Palm Beach Gardens, FL). The removal of the planum sphenoidale is limited laterally by the optic canals (Fig. 1). During this bone removal, care must be taken to avoid placing the Kerrison bone punch or the drill lateral to the medial border of the optic canals, which could potentially injure an optic nerve. Based on cadaveric dissections performed using this approach by Jho and Ha<sup>34</sup> and by Rhoton's group<sup>21,50</sup> the medial edges of the optic canals at their most posterior extent (at the level of the intracranial opening of the optic canal) are 14 to 18 mm apart on average. Immediately inferior to the optic canals, the width-limiting structures are the cavernous CAs and their initial intracranial portions, which on average are 13.9 to 17 mm apart.<sup>21,34,50</sup>

**Difficulties Encountered With Exposure.** Using the direct endonasal approach, the greatest exposure difficulties are encountered in trying to establish adequate visualization of the posterior planum and the ipsilateral intra- and suprasellar spaces. Regarding exposure of the posterior planum, if a difficulty is encountered in establishing a sufficient cephalad trajectory of the speculum, the speculum can be rotated 15 to 30° in either direction until a more stable fit is established in the appropriate trajectory. Additional removal of the sphenoid keel and the mucosa overlying it superiorly will extend the visible field toward the sphenoid roof even if the speculum remains aimed in a somewhat lower trajectory. One or two cottonoids can also be placed inferiorly beneath the speculum blades to help bolster its position in a more cephalad trajectory to prevent slippage in an inferior direction. A final alternative to achieving sufficient cephalad exposure is to wedge the distal end of the speculum blades within the bony edges of the sphenoidotomy. This maneuver, however, is generally not recommended, given the potential risk of fracturing the skull base through the optic canals with forceful opening of the speculum.<sup>5</sup>

Regarding ipsilateral exposure, adequate bone removal of the ipsilateral sphenoid bone, the face of the sella turcica, and the lateral tuberculum sellae and planum is essential.

TABLE 1  
Surgical indications in 24 patients undergoing  
extended transsphenoidal procedures

Pathological Diagnosis	No. of Patients	Max Tumor Diameter (mm)
craniopharyngioma	8	30–60
meningioma	7	15–30
Rathke cleft cyst	6	7–10
dermoid cyst	1	11
epidermoid tumor	1	66
non-Hodgkin lymphoma, metastasis	1	20

Image guidance can be very helpful to determine how much additional bone can be removed in these areas. Additionally, the micro-Doppler probe, as noted below, can be used to define the location of the cavernous CAs. If the artery is not audible with a given exposure, more bone can often be removed laterally. Because the approach superiorly is rather narrow and limited laterally by the optic canals and the CAs (averaging 15–16 mm), however, both the ipsilateral and contralateral ends of this exposure have generally been adequate.

**Dural Opening and Tumor Removal.** After adequate bone removal, the micro-Doppler probe was used to locate the cavernous CA before opening the dura mater to demarcate the safe lateral limit of the sellar opening. Depending on the nature and exact location of the tumor, the initial dural opening was either made in the sellar dura and then extended above and through the diaphragma sellae or only above the diaphragma sellae. When the dural opening was extended across the diaphragma sellae, bleeding from the superior circular sinus (also known as the anterior intercavernous sinus) was controlled using Gelfoam and bipolar cautery.

Tumor removal proceeded in the supraglandular space with care being taken to respect the arachnoid planes laterally and superiorly and to avoid injury to the pituitary gland, which in most cases was located inferiorly and posteriorly with respect to the tumor. Given the rubbery, fibrous, and/or partially calcified nature of many tumors in this series, particularly meningiomas and craniopharyngiomas, sharp dissection using curved and straight microscissors along the arachnoid planes and within the tumor cavity itself was often required for removal. An effort was made in every case to identify the pituitary stalk and its site of insertion to the pituitary gland early in the dissection and to avoid traction on the stalk during tumor removal. In some cases, an anterior-superior incision was made in the anterior pituitary gland to facilitate exposure directly above the gland and to minimize traction on the gland and the pituitary stalk. When the tumor or cyst lining remained densely adherent to the stalk or optic chiasm despite attempts to remove them with sharp dissection, these remnants were left in the hopes of preserving pituitary function and avoiding new visual deficits. Angled 30 or 45° 4-mm rigid endoscopes (Karl Storz, Tuttlingen, Germany) were used to assess the completeness of tumor removal and to help determine the tumor-neurovascular relationships.

Following tumor removal, the bone or dural defects were repaired in all but one case by using an abdominal fat graft placed in the suprasellar space followed by a collagen sponge (Helistat; Integra Life-Sciences Corp., Plainsboro,

TABLE 2  
Completeness of resection by tumor type

Pathological Diagnosis	Extent of Resection		
	Gross-Total	Near-Gross Total	Subtotal
craniopharyngioma	1	4	3
meningioma	4	2	1
Rathke cleft cyst	5	0	1
dermoid cyst	1	0	0
epidermoid tumor	0	0	1
non-Hodgkin lymphoma	0	0	1*
total	11 (46%)	6 (25%)	7 (29%)

\* This patient underwent biopsy only.

NJ) and a titanium mesh buttress (MicroMesh 0.2 mm, Styker-Leibinger, Kalamazoo, MI), which was wedged in the epidural space. Additional fat was typically placed in the sphenoid sinus. Tissue glue was used inconsistently (five cases). In most cases, lumbar CSF drainage was also used for 2 to 3 days. Nasal packing was placed for 24 to 48 hours in the first five patients in the series but not in the subsequent 19 patients. A prophylactic intravenous antibiotic agent (cefazolin) was administered for 24 hours after surgery or until the lumbar drain was removed.

#### Outcome Analysis

Tumor characteristics of size, suprasellar extension, and cavernous sinus invasion were noted based on MR imaging reports. Pituitary function was assessed by measurement of pre- and postoperative levels of morning serum cortisol and adrenocorticotropic hormone as well as levels of free thyroxine, thyroid-stimulating hormone, growth hormone, insulin-like growth factor-I, free and/or bioavailable testosterone, and urine specific gravity. Serum sodium levels obtained on postoperative Days 4 through 7 were reviewed to assess whether patients experienced delayed hyponatremia. Clinic notes were reviewed for pre- and postoperative visual status (results of both visual acuity and visual field tests) and new hormone replacement. Complication rates were determined by examining operative and postoperative notes. Complete tumor removal was defined as no residual or recurrent tumor demonstrated on the latest postoperative MR image. Tumor removal was further categorized as gross-total removal if no tumor could be seen intraoperatively and on the immediate and 3-month postoperative MR images, near-gross-total removal if small (< 5 mm) tumor fragments remained, or subtotal removal if larger fragments remained.

## Results

#### Study Population

Over a 4-year period, 24 patients (median age 45 years [range 9–79 years]; 13 female and 11 male patients) underwent 26 procedures for tumor removal. Diagnoses included eight craniopharyngiomas, seven tuberculum sellae meningiomas, six Rathke cleft cysts, one suprasellar dermoid cyst, one extensive suprasellar/retrosellar/prepontine epidermoid tumor, and one metastatic non-Hodgkin B-cell lymphoma.

## Extended direct endonasal transsphenoidal approach

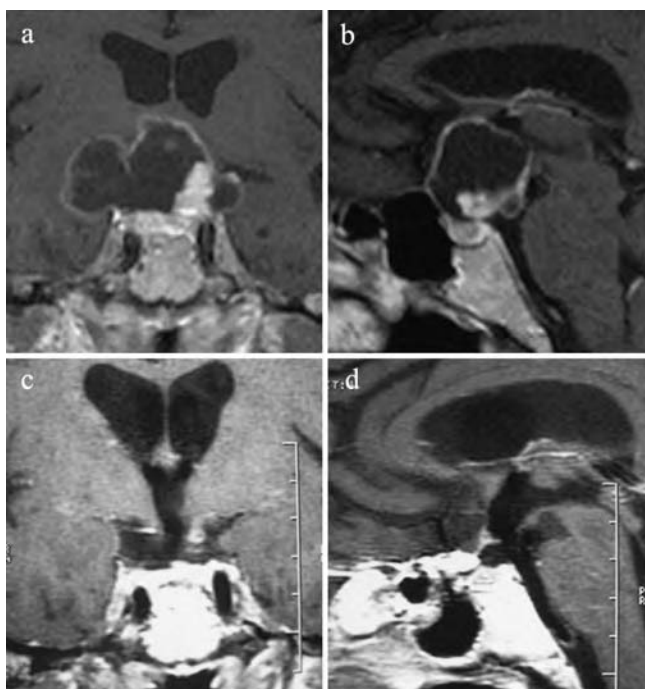


FIG. 2. Preoperative (a and b) and 9-month postoperative (c and d) contrast-enhanced MR images obtained in a 79-year-old man with bitemporal visual loss, failure of pituitary function, and decreased mental status caused by a large cystic craniopharyngioma. A subtotal resection was accomplished followed by fractionated stereotactic radiotherapy (performed using a linear accelerator), which was completed by 4 months after surgery. The patient's mental status and vision normalized, and he has panhypopituitarism.

Three of the patients with tuberculum sellae meningiomas were previously described by Cook, et al.,<sup>12</sup> in a technical note. Two patients, both with craniopharyngiomas, underwent early repeated operations for residual tumor left at the initial surgery. Six patients (25%) had undergone surgery previously at other institutions; four were craniotomies and two were sublabial transsphenoidal procedures. The maximal tumor diameter ranged from 7 to 66 mm (median 20 mm); 62% of patients harbored tumors that were 20 mm or greater in maximal dimension (Table 1).

### Tumor Removal Rates

Based on MR images obtained 3 months postoperatively, gross-total tumor removal was accomplished in 11 (46%) of 24 patients (Table 2). Of the 23 patients in whom total removal was the goal, a gross-total or a near-gross-total removal was achieved in 17 (74%).

### Patients With Craniopharyngiomas

In only one (12.5%) of eight patients harboring a craniopharyngioma was tumor removal complete; in four patients near-gross-total removal was accomplished and in three subtotal removal was obtained (median follow-up period 7 months; range 3–28 months). All seven patients in whom tumor removal was incomplete had harbored large tumors with a mean maximal diameter of 37 mm, including two who had undergone a prior craniotomy. Of these seven pa-

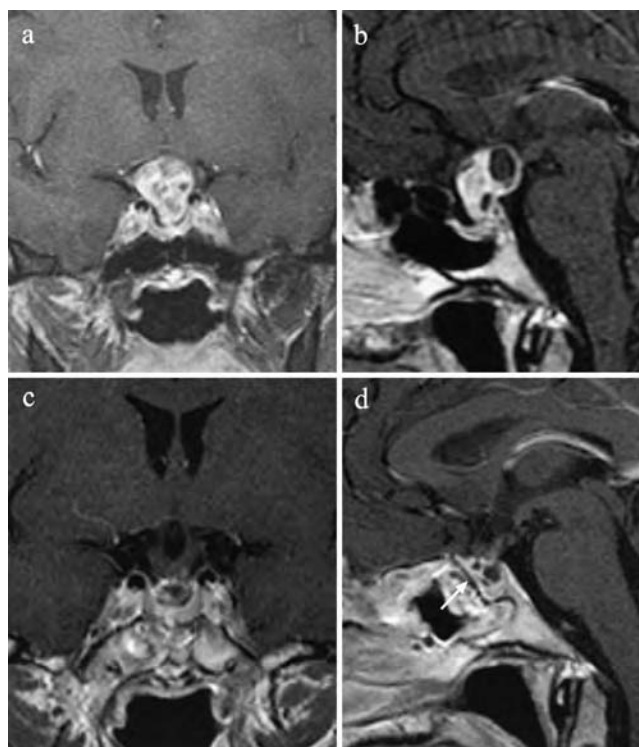


FIG. 3. Preoperative (a and b) and 3-month postoperative (c and d) contrast-enhanced MR images obtained in a 42-year-old woman with bitemporal visual loss and failure of pituitary function due to a craniopharyngioma. A near-gross total resection was achieved, leaving a minute tumor fragment attached to the pituitary stalk. The patient experienced panhypopituitarism after surgery and normalization of vision. Arrow indicates a signal void representing the titanium mesh skull base reconstruction.

tients, the four in whom near-gross total removal had been accomplished all had minute tumor fragments densely attached to either the optic chiasm (two patients) or the pituitary stalk (two patients) that were intentionally left behind. The three patients in whom subtotal removal was obtained included a 9-year-old girl who had a maximal 60-mm-diameter tumor with a large component invading the left cavernous sinus and a tumor cyst extending into the left temporal lobe. Another patient in whom a subtotal removal had been accomplished was a 79-year-old man with a 40-mm tumor (Fig. 2). Of the seven patients in whom removal was incomplete (except one who was lost to follow up 6 months after surgery), five were eventually treated with fractionated stereotactic radiotherapy with a linear accelerator (Novalis Shaped Beam Surgery; BrainLAB, Inc., Westchester, IL) and one is being followed with serial MR images to monitor for recurrence (Fig. 3).

### Patients With Meningiomas

Four (57%) of seven patients with meningiomas underwent complete removal (median follow-up duration 12.5 months; range 3–18 months). Of the three patients in whom incomplete removal was obtained, in two there was near-gross-total removal with at least 95% tumor extirpation and in one who had undergone a prior craniotomy, there was

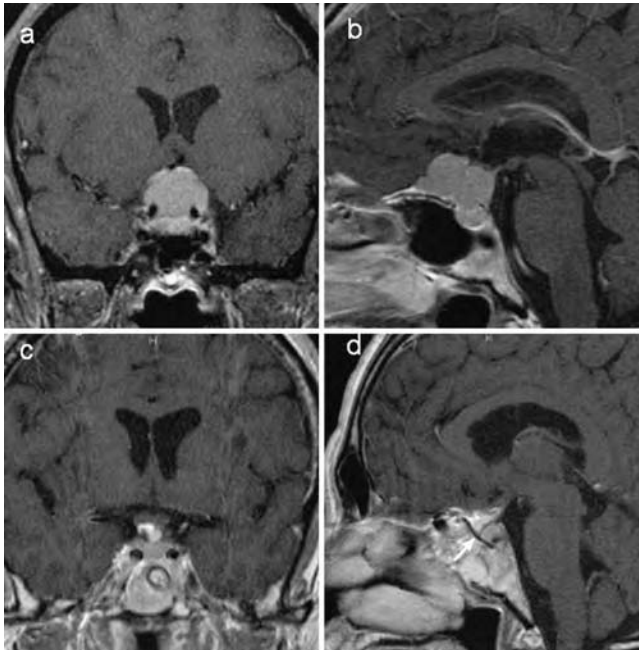


FIG. 4. Preoperative (a and b) and 6-month postoperative (c and d) contrast-enhanced MR images obtained in a 59-year-old man with decreased visual acuity and a bitemporal visual field defect due to a tuberculum sellae and planum sphenoidale meningioma. A gross-total resection was achieved. The patient's vision has returned to normal and he has normal pituitary function. *Arrow* indicates a signal void representing the titanium mesh skull base reconstruction.

tumor debulking with approximately 70% tumor removal (Fig. 4).

*Patients With Rathke Cleft Cysts*

Five (83%) of six patients with suprasellar Rathke cleft

TABLE 3  
*Complications of surgery in 24 patients*

Complication	No. of Patients (%)
surgical/technical	
CSF leak, total	5 (21)
meningioma	3
craniopharyngioma	1
epidermoid tumor	1
meningitis	1 (4)
fat graft too large	2 (8)
delayed epistaxis	2 (8)
anosmia	1 (4)
transient worsening of 3rd cranial nerve palsy	1 (4)
vascular injury	0
visual acuity/field deterioration	0
persistent neurological deficit	0
endocrinopathy	
permanent DI, total	4 (17)
craniopharyngioma	3
Rathke cyst	1
transient DI	2 (8)
failure or worsening of anterior pituitary functions	2 (8)
any new permanent endocrinopathy*	5 (21)

\* Includes new DI and/or new failures in anterior pituitary function.

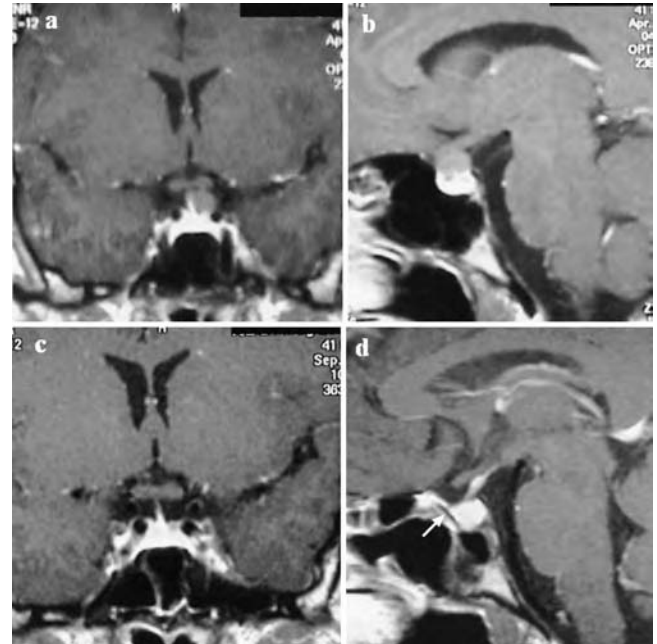


FIG. 5. Preoperative (a and b) and 1-year postoperative (c and d) contrast-enhanced MR images obtained in a 41-year-old woman with visual loss and amenorrhea due to a suprasellar Rathke cleft cyst that was adherent to the pituitary stalk. A total resection was achieved, the patient's vision returned to normal, and normal menses resumed. *Arrow* indicates a signal void due to the titanium mesh skull-base reconstruction.

cysts underwent complete cyst removal (median follow-up duration 9 months, range 3–13 months; Fig. 5). The one patient with a subtotal removal had dense adhesions of the cyst capsule to the pituitary stalk.

*Patients With Other Tumor Types*

One patient with a dermoid cyst (duration of follow up 30 months) underwent complete removal of the lesion. One patient with a 66 × 55-mm suprasellar and retroclival epidermoid tumor (duration of follow up 4 months) underwent tumor debulking through a combined suprasellar–transclival approach with a significant decrease in mass effect on the brainstem. A 75-year-old man with a suprasellar non-Hodgkin B-cell lymphoma underwent biopsy only for diagnosis before initiation of chemotherapy; that patient subsequently died approximately 2 months after surgery from systemic disease progression.

*Neurological Outcome and Complications*

Preoperatively, 13 patients experienced new tumor-related visual loss. Of these, 11 (85%) noted significant visual improvement after surgery. No patients had a decrease in visual fields or visual acuity following surgery. The patient with the large epidermoid tumor had transient worsening of a preexisting third cranial nerve palsy, which resolved 3 months after surgery. There were no other neurological complications except anosmia in one patient after the removal of a meningioma.

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TABLE 4  
*Endocrinological outcome after surgery*

Function	Craniopharyngioma (8 patients)	Rathke Cyst (6 patients)	Meningioma (7 patients)	Other (3 patients)	Total (24 patients)
loss of function*					
loss of 1 ant axis	0	0	1	0	1 (4%)
loss of 2 ant axes	1	0	0	0	1 (4%)
permanent DI	3	1	0	0	4 (17%)
gain of function					
gain of 1 ant axis	0	2	0	0	2 (8%)

\* One patient with a craniopharyngioma and preexisting growth hormone and gonadal deficiencies experienced complete failure of anterior pituitary function and DI after surgery.

### *Cerebrospinal Fluid Leaks, Meningitis, and Other Technical Complications*

Five patients (21%), including three with tuberculum sellae meningiomas, one with a craniopharyngioma, and one with an epidermoid tumor, experienced postoperative CSF leaks that required treatment. All had large dural and diaphragmatic defects that had been created at the original surgery. Two patients, both of whom had a tuberculum sellae meningioma, received successful treatment for their CSF leaks with 48 hours of lumbar CSF diversion, which had not been placed at the time of their original surgery. Three patients (12.5%) underwent a repeated operation to repair the CSF leak, including two patients who required a second operation for CSF leak repair. The patient with the epidermoid tumor also experienced severe bacterial meningitis that resolved after a repeated operation and a course of antibiotic therapy. His CSF leak closure was effectively treated on the second attempt with a combination of fascia lata, abdominal fat, titanium mesh, tissue glue, and lumbar CSF diversion.

Two patients with meningiomas who were treated relatively early in the series received excessively generous intrasellar and suprasellar abdominal fat grafts, which caused compression of the optical chiasm as seen on postoperative MR images. Both patients were taken back to the operating room for fat graft revision, which in one case led to a new CSF leak as described earlier. Both patients ultimately attained complete improvement in their preoperative visual statuses (Table 3).

### *Endocrinological Complications*

Five patients (21%) experienced new endocrinopathy including four (17%) with persistent DI and two (8%) with failure of anterior pituitary function (Table 4). Four of these five patients had preexisting anterior pituitary hormone failure in at least two axes. One of these patients who had preoperative gonadal failure and growth hormone deficiency later experienced complete failure of anterior pituitary function and new DI despite anatomical stalk preservation at surgery. Two patients had transient DI lasting less than 4 days in each case. One patient had transient delayed hyponatremia that was successfully treated with fluid restriction and salt supplementation.

### *Other Complications*

Two patients had delayed epistaxis 3 weeks after sur-

gery, which resolved spontaneously in one patient. Both patients had normal cerebral angiograms but were treated with empirical internal maxillary artery embolization without sequelae for presumed bleeding from one of the sphenopalatine arteries. Three patients who had persistent nasal congestion longer than 10 days after surgery were treated presumptively for sinusitis with a 10-day course of oral antibiotics. In two of these patients, the symptoms resolved; in the third, despite initial resolution, persistent complaints 1 year after surgery prompted additional antibiotic treatment and endoscopic sinus surgery with subsequent symptom resolution.

### *Overall Results*

In total, 11 (46%) of 24 patients experienced postoperative complications including five patients (21%) with CSF leaks (one with meningitis), two requiring repeated operations to decrease fat graft size, two with delayed epistaxis, and five (21%) with new pituitary hormone failure. Nevertheless, there were no intracranial vascular injuries, no deaths, and no persistent neurological deficits, except anosmia in one patient. All 24 patients ultimately had excellent functional recoveries.

## Discussion

### *Advantages, Disadvantages, and Limits of the Extended Transsphenoidal Approach*

With the introduction of the extended transsphenoidal skull base approach, wherein the bone of the tuberculum sellae and the posterior planum sphenoidale between the optic canals is removed, suprasellar lesions that have traditionally been approached transcranially, such as tuberculum sellae meningiomas and craniopharyngiomas, have been increasingly removed transsphenoidally.<sup>15,20,29,35,36,38,39,43,51,61</sup> Provided that the chiasm is not prefixed by the tumor and located directly between the sphenoid sinus and tumor, or that a functional pituitary gland is not directly impeding the transsphenoidal route, the most obvious and significant advantages of this approach are the following: 1) brain retraction is obviated; 2) direct manipulation of the optic apparatus is minimized; and 3) early identification of the pituitary gland and the infundibulum increases the likelihood of preserving pituitary function. Furthermore, by using this approach, because these lesions generally displace the optic apparatus away from the surgeon, tumor removal can begin

immediately on opening the dura mater, resulting in prompt chiasm decompression. This early decompression likely allows the removal of any tumor adherent to the optic apparatus and/or its arachnoidal and vascular connections to be performed with less risk of visual worsening.

Originally described by Hirsch in 1910<sup>46,48</sup> and later popularized by Griffiths and Veerapen,<sup>23</sup> the direct endonasal approach for removal of sellar and suprasellar lesions has been shown to be comparable to the traditional sublabial route in efficacy and neuroendocrine complication rates.<sup>64</sup> This approach requires minimal nasal mucosal dissection, resulting in fewer sinonasal complications and a more rapid and less painful rhinological recovery than the sublabial approach.<sup>3,64</sup> The major disadvantage of the direct endonasal route is the relatively restricted and slightly off-midline working channel.<sup>14</sup> This problem has been largely overcome by several technical innovations including the use of low-profile microdissection instruments and cutting blades, use of the micro-Doppler probe to localize the CAs and other intracranial vessels before opening the dura mater, use of angled endoscopes for more panoramic cephalad and lateral visualization beyond the tunnel vision of the microscope, and the use of intraoperative surgical navigation to confirm surgical trajectory and key landmarks.<sup>12</sup>

Even with such adjuncts, the direct endonasal approach—and all transsphenoidal approaches to some degree—provide limited parasellar exposure, particularly for lesions that extend far superiorly or far laterally into the perimesencephalic cisterns. Although endoscopic visualization is helpful for assessing the anatomical relationships in these far reaches of the exposure, safe tumor removal from these locations remains problematic because the endoscope itself limits the working space within the speculum for effective maneuverability of other instruments. Yet, without the endoscope, the risk of neurovascular injury from “blind grabs” of tumor in these areas is high. Consequently, we settled for incomplete tumor removal when adequate access and visualization were not possible. This conservative approach is reflected in the fact that there were no serious neurological or intracranial vascular injuries in this series. Given that most of these tumors, such as craniopharyngiomas and meningiomas, are radiosensitive (control rates of 58–100%), this approach appears prudent.<sup>1,9,10,16,41,53,54,56,59</sup>

#### *Tumor Removal Rates Compared With Prior Series*

In this series, complete tumor removal was accomplished in only 46% of patients and complete or near complete removal was achieved in 74% of the 23 patients in whom total removal was the ideal goal. For patients with craniopharyngiomas, gross-total or near-gross-total removal was accomplished in five of eight patients. Clearly, in the three other patients, complete removal by any approach was not a realistic goal given the size and invasive nature of the tumors. Previous reports on patients who have undergone transsphenoidal surgery for craniopharyngioma have documented gross-total-removal rates ranging from 7 to 86%.<sup>6,18,24,25,28,42,44,47,60,63</sup> In many of these series, however, the transsphenoidal route was only used for craniopharyngiomas that were largely cystic and/or intrasellar.

For patients with tuberculum sellae meningiomas, complete resection was possible in four (57%) of seven patients and near-gross-total removal in two of the remaining three

patients. In earlier series, complete tumor removal rates have ranged from 45 to 98% for transcranial routes<sup>19,20,22</sup> and from 25 to 100% for the extended transsphenoidal approach.<sup>12,29,32–35</sup> As we recently described, these tumors pose challenges to removal via an extended approach because of their firm or rubbery texture and wide dural attachment along the planum and tuberculum sellae.<sup>12</sup> Our initial experience, however, indicates that such midline suprasellar meningiomas that are 3 cm or less in diameter can be effectively removed through an endonasal approach with an excellent outcome particularly in visual status and preservation of hormone function. For meningiomas that extend into the optic canals superiorly and laterally, the transsphenoidal route will likely not allow safe and complete removal given inadequate visualization. Even with the use of a transcranial approach and adequate visualization of the optic canals, however, total tumor removal may still not be possible in some patients because of dense tumor adherent to the nerves. In such instances, subtotal removal and stereotactic radiotherapy may provide the safest treatment option.

For patients with Rathke cleft cysts, complete resection was achieved in 83%. Most previous reports on supraglandular Rathke cleft cysts have been small case reports describing removal via a transcranial route.<sup>4,7,30,49,52,62</sup> Given the location of these lesions, the extended transsphenoidal approach appears to be ideal for their removal with a relatively low risk of new endocrinopathy, as seen in our small series.

#### *Complication Rates Compared With Previous Series*

*Transcranial Approach.* The brain retraction and manipulation of neurovascular structures that are generally required for all frontal or pterional approaches to the suprasellar space have been associated with a variety of postoperative problems and provide one of the strongest rationales for selecting the extended transsphenoidal approach.<sup>65</sup> By using a transcranial route, complications may include neuropsychological deficits in up to a third of patients,<sup>8,27</sup> as well as new visual loss, vascular injuries, and endocrinopathy.<sup>2,17,19,22,26,27,55,57,58,60,63</sup>

*Visual Recovery and Deterioration.* In our series, 85% of patients with preoperative visual loss experienced normalization of vision or significant improvement after surgery and no patient experienced worsening of visual function. Visual deterioration after transcranial removal of craniopharyngiomas and suprasellar meningiomas ranges from 2 to 30%<sup>17,27,60,63</sup> and 0 to 20%,<sup>19,22,31</sup> respectively. In the Yaşargil, et al.,<sup>63</sup> series of aggressive surgical resection of craniopharyngiomas, approximately 15% of all patients experienced worsening of visual field function. In recent transcranial series of patients with tuberculum sellae meningiomas described by Fahlbusch and Schott<sup>19</sup> and Goel and colleagues,<sup>22</sup> vision improved in 80 and 70%, respectively, and worsened in 20 and 10%, respectively. The results of our series compare favorably with those obtained using the transcranial approach and further support the notion that approaching these lesions transsphenoidally, from below the chiasm, may pose a lower risk of postoperative visual deterioration. Other authors of reports of extended transsphenoidal approaches for a variety of lesions have reported a 0 to 17% rate of visual deterioration, which is comparable with our results.<sup>29,32,35</sup>

*Vascular Injuries.* Cavernous carotid, supraclinoid carot-

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id, anterior cerebral, and basilar artery injuries are dreaded but rare complications of transsphenoidal and transcranial procedures.<sup>27,57,58,63</sup> A preliminary report of the extended transsphenoidal approach for meningiomas by Jane, et al.,<sup>32</sup> reported no vascular injuries. According to previous reports on the transsphenoidal approach, vascular injuries occur in approximately 0.4 to 1.4% of cases depending on the experience of the surgeon.<sup>11,45</sup> In our series there were no intracranial vascular injuries, which we attribute to the following: 1) routine use of the micro-Doppler probe before dural opening; 2) use of microscissors and microblades only when direct vision is possible; and 3) sharp dissection of arachnoid-tumor planes to avoid excessive vessel traction.

**New Endocrinopathy.** New permanent endocrinological disturbances occurred in 21% of patients in this series with new DI occurring in 17% and new failure in anterior pituitary function in 8%. Preservation of pituitary function is challenging in patients with craniopharyngiomas, especially those in whom anterior pituitary function has already failed, as was the case in three of the four patients in our series with new DI.<sup>42</sup> Although the rate of endocrinopathy appears to be related to the aggressiveness of resection for craniopharyngioma, literature on the transcranial approach indicates that as many as 75 to 80% of patients with aggressive resection and 38% with partial resection will have new postoperative endocrine deficiencies that are not limited only to DI.<sup>26,55</sup> In contrast, for patients with suprasellar meningiomas and Rathke cleft cysts in this series, the extended transsphenoidal route allowed preservation of pituitary function in the great majority of patients. Only one patient with a meningioma who had a prior craniotomy, hypothyroidism, and hypogonadism experienced new adrenal insufficiency after surgery; additionally, one patient with a Rathke cleft cyst experienced new DI.

**Cerebrospinal Fluid Leaks and Related Complications.** The most common technical complication in our series was a postoperative CSF leak occurring in 21% of patients, with resultant meningitis in one patient. In two patients with suprasellar meningiomas, overconfidence about the initial repair, which was made using fat, collagen, and titanium mesh, led to the initial omission of lumbar drain CSF diversion. This decision proved to be a poor one because both of these patients experienced postoperative CSF rhinorrhea that ultimately resolved with 48 hours of lumbar CSF drainage. Relatively high CSF leak rates, ranging from 0 to 50%, have been previously associated with the extended transsphenoidal route.<sup>13,32,37,40</sup> Our method involving placement of a suprasellar fat graft proved to be problematic in two patients who received grafts that caused chiasmal compression. This complication illustrates the careful balance required between the prevention of a postoperative CSF leak and the creation of a new mass effect from the repair itself. Fortunately, in both cases, downsizing the fat graft restored normal visual function. Recently Kitano and Taneda<sup>40</sup> described a subdural double-layer patch graft composed of fascia lata and Gore-Tex, which is held in place by tacking sutures and has a failure rate of only 9%. Clearly, the optimal repair method for these skull-base defects remains to be defined. Although most would probably trade a higher risk of a CSF leak for a decrease in the risk of brain retraction injuries, new visual loss, and endocrinopathy, which may be more common after craniotomy, more effective strategies

to prevent CSF leaks are needed if the transsphenoidal approach is to become the primary route for removing suprasellar tumors.

## Conclusions

The direct endonasal extended transsphenoidal approach performed with the operating microscope provides a minimally invasive route to remove nonadenomatous suprasellar tumors such as tuberculoma sellae meningiomas, craniopharyngiomas, and supraglandular Rathke cleft cysts. When augmented with the panoramic visualization provided by angled endoscopes, it affords an excellent view of the pituitary gland, infundibulum, diaphragma sellae, vascular structures, and optic apparatus, and allows relatively safe removal of these tumors. The direct endonasal approach appears comparable to the sublabial and transcranial routes in efficacy, overall safety, and rate of recovery. The primary concern and goal for the future remains the development of more reliable cranial base reconstruction methods to prevent a postoperative CSF leak. Certainly, the overall complication rate in this series is relatively high. Nevertheless, this patient series represents a work in progress toward achieving safer, more effective minimally invasive removal of these challenging suprasellar lesions.

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