

THE ENDONASAL MICROSCOPIC APPROACH FOR PITUITARY ADENOMAS AND OTHER PARASELLAR TUMORS: A 10-YEAR EXPERIENCE

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THE DIRECT ENDONASAL transsphenoidal approach to the sella with the operating microscope was initially described more than 20 years ago. Herein, we describe the technique, its evolution, and lessons learned over a 10-year period for treating pituitary adenomas and other parasellar pathology. From July 1998 to January 2008, 812 patients underwent a total of 881 operations for a pituitary adenoma ($n = 605$), Rathke's cleft cyst ($n = 59$), craniopharyngioma ($n = 26$), parasellar meningioma ($n = 23$), chordoma ($n = 18$), or other pathological condition ($n = 81$). Of these, 118 operations (13%) included an extended approach to the suprasellar, infrasellar/clival, or cavernous sinus regions. Endoscopic assistance was used in 163 cases (19%) overall, including 36% of the last 200 cases in the series and 18 (72%) of the last 25 extended endonasal cases. Surgical complications included 19 postoperative cerebrospinal fluid leaks (2%), 6 postoperative hematomas (0.7%), 4 carotid artery injuries (0.4%), 4 new permanent neurological deficits (0.4%), 3 cases of bacterial meningitis (0.3%), and 2 deaths (0.2%). The overall complication rate was higher in the first 500 cases in the series and in extended approach cases. Major technical modifications over the 10-year period included increased use of shorter (60–70 mm) endonasal speculums for greater instrument maneuverability and visualization, the micro-Doppler probe for cavernous carotid artery localization, endoscopy for more panoramic visualization, and a graded cerebrospinal fluid leak repair protocol. These changes appear to have collectively and incrementally made the approach safer and more effective. In summary, the endonasal approach provides a minimally invasive route for removal of pituitary adenomas and other parasellar tumors.

KEY WORDS: Chordoma, Craniopharyngioma, Endonasal transsphenoidal approach, Endoscope, Meningioma, Pituitary adenoma, Rathke's cleft cyst

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Transsphenoidal surgery has evolved dramatically since it was described a century ago by Schloffer, Cushing, and Hirsch (12). In the 1950s and 1960s, Dott, Guiot, and Hardy began using the sublabial transsphenoidal route for pituitary adenoma removal. With the advent of the operating microscope and the technique of selective adenectomy as described by Hardy (34) in the early 1970s, transsphenoidal surgery emerged into the modern microsurgical era (49, 52). Additional experience in the 1970s and early

1980s by Wilson, Weiss, Laws, and others further improved the safety and efficacy of transsphenoidal surgery (2, 10, 22, 28, 42, 60, 66–68). Subsequent modifications were developed to minimize mucosal trauma and patient discomfort associated with the sublabial approach (11, 13, 23, 33, 61, 62, 64), most notable of which was the direct endonasal approach first described by Griffith and Veerapen (33) in 1987 and later by Cooke and Jones (13) in 1994. This approach, which requires minimal posterior nasal mucosal dissection and no turbinate removal, is now commonly used with the operating microscope and often with endoscopic assistance (1, 13, 14, 33, 39, 44, 56, 63). Although it provides a some-

ABBREVIATIONS: CSF, cerebrospinal fluid; MRI, magnetic resonance imaging

what more restricted exposure than the sublabial approach and a slightly off-midline trajectory, these factors can be addressed and used to one's surgical advantage for tumor removal.

After initially using the sublabial route, we adopted the direct endonasal approach in 1998 and have since reported outcomes for a variety of parasellar tumors (17, 19, 24, 29, 51, 71). Herein, we describe the operative nuances of this approach, a summary of the pathological conditions treated, potential pitfalls, and surgical complications. The evolution of the approach over this period, resulting largely from better instrumentation, surgical navigation, and, perhaps most importantly, endoscopy, is also discussed (8, 18, 30, 35, 59).

PATIENTS AND METHODS

Since we began to use the direct endonasal approach in 1998, we have maintained an ongoing patient database that includes pre- and postoperative clinic visits, operative notes, imaging reports, and pathology reports. The brief "Clinical Experience" section, below, was compiled from this database and includes tumor categorization, patient demographics, use of endoscopy, use of an extended approach, and surgical complications. To demonstrate the evolution of the technique and experience gained over time, complication rates for the first 500 cases and for subsequent cases were compared, because Ciric et al. (11) previously showed a decreasing complication rate with increasing experience at thresholds of 200 and 500 cases. Comparisons were also made between standard cases and extended approach cases to the parasellar spaces, given that extended approach cases are generally of greater difficulty with a higher potential for complications. As previously described, cerebrospinal fluid (CSF) leaks were also categorized by grade as Grade 0 (no observed leak), Grade 1 (small), Grade 2 (moderate), or Grade 3 (large) (26). All procedures were performed by the senior author (DFK) at University of California, Los Angeles Medical Center, Harbor-UCLA Medical Center or Saint John's Health Center. The institutional review boards of each institution approved this retrospective study of patient data. For statistical analyses, comparisons of the complication rates and the rates of use of the endoscopy were compared with Fisher's exact test.

SURGICAL TECHNIQUE

Instrumentation

Given the narrow working space and requirement for visualization from the operating microscope, all instruments are as low-profile as possible, with angled or bayoneted handles to minimize visual obstruction and to maximize instrument maneuverability. Thus, Cottle dissectors, microdissectors, ring curettes, and microblades (Mizuho America, Inc., Beverly, MA) are on bayoneted handles. Similarly, microscissors, tumor-grasping forceps (both straight and up-angled) are used in a single-shaft, pistol-grip construct to minimize visual obstruction. High-speed drills and ultrasonic aspirators also are of the lowest possible diameter with angled hand-pieces. Endoscopic equipment includes 4-mm rigid endoscopes (18 cm in length) with 0-, 30-, and 45-degree angled lenses (Karl Storz, Tuttlingen, Germany). A micro-Doppler probe is also used for all cases to localize the cavernous carotid arteries before dural opening (18).

Patient Preparation, Positioning, and Room Setup

Endonasal surgery is performed as originally described by Griffith and Veerapen (33) with several modifications as described below and in our recent publications (17, 71). Preoperative antibiotics (typically, cefazolin) are given and continued for 24 hours. In patients with normal preoperative adrenal function or those with Cushing's disease, no perioperative glucocorticoids are administered (25). Those with adrenal insufficiency or borderline adrenal function are given 100 mg of intravenous hydrocortisone.

After induction of general anesthesia, the endotracheal tube emerges from the left corner of the mouth, and the anesthesiologists and anesthesia equipment are positioned on the left side of the patient. An arterial line and Foley catheter are placed. The patient is placed supine with the head resting freely in the horseshoe headholder and angled approximately 30 degrees toward the left shoulder, as originally described by Laws (47). This arrangement allows the surgeon to stand comfortably on the patient's right side. For sellar lesions, the head is inclined in a neutral plane (0 degrees) relative to the floor; for suprasellar lesions, 10 to 15 degrees of neck extension is used; and for infrasellar and clival lesions, 10 to 15 degrees of neck flexion is used.

For adenomas and Rathke's cleft cysts, the C-arm is typically used for fluoroscopic trajectory guidance. The base of the operating microscope and endoscopic video monitor are both placed just outside the arc of the C-arm above the patient's head, with the microscope to the patient's right side and the endoscopic video monitor on the left. For extended endonasal cases when surgical navigation is used (BrainLab VectorVision cranial; Westchester, IL); fluoroscopy is not used. The perinasal and right lower abdominal areas are sterilely prepared and draped. No nasal mucosal decongestants are used.

Nasal Portion and Sphenoidotomy

(see video at web site)

The initial portion of the procedure is performed with the operating microscope and a handheld speculum. The nostril chosen for the approach is based largely on tumor location, as defined by the patient's preoperative magnetic resonance imaging (MRI) scan. For tumors projecting more to one side of the sella, the contralateral nostril is used, given that exposure across the midline to the contralateral sella and cavernous sinus area is consistently wider than to the ipsilateral side. This rule applies even in the vast majority of patients with marked septal deviations. In patients with relatively midline tumors, the right nostril is typically chosen, considering that the surgeon stands on the patient's right side, and this will afford a more comfortable operating position for the surgeon. Although a relaxing alar incision was occasionally used early in our experience to accommodate the endonasal speculum, it was used in only 10% of cases overall and not in the last 556 cases, given the availability of smaller and thinner specula.

The approach is begun with a handheld speculum being passed into the anterior nostril to identify the inferior and middle turbinates. The speculum is then gently passed along the

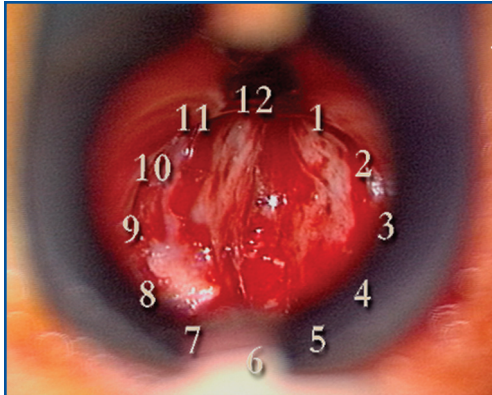


FIGURE 1. Intraoperative microscopic photograph of the sphenoid keel. When the endonasal speculum is in the appropriate trajectory aiming toward the sella, the sphenoid ostia are typically found at approximately the 10 and 2 o'clock positions, and the sphenopalatine arteries coursing through the posterior nasal mucosa along the keel are at the 4 and 8 o'clock positions.

trajectory of the middle turbinate (see Video 1 at web site). Care should be taken to minimize trauma to the anterior and mid-nasal septum and the turbinates. The speculum blades gently displace the middle turbinate laterally and pass further into the nasal cavity to expose the junction of the keel of the sphenoid and the posterior nasal septum. After confirming the correct trajectory to the sella with fluoroscopy or surgical navigation, the posterior septal mucosa is cauterized with a bipolar in a vertical swath, and a vertical mucosal incision is made with a Cottle elevator, extending for approximately 2 cm. The mucosa is elevated and reflected laterally to expose the midline keel of the sphenoid bone and ipsilateral sphenoid ostium, which is typically superolateral to the equator of the keel at the 10 or 2 o'clock position (Fig. 1). The posterior nasal septum is then displaced off the midline by the distal tips of the handheld speculum to expose the contralateral side of the keel. The Cottle elevator is used to further reflect this contralateral mucosa to expose the other sphenoid ostium.

Once the sphenoid keel and ostia are exposed, the handheld speculum is removed and replaced by a self-retaining endonasal speculum, typically 60 to 70 mm in length (Mizuho America, Inc.). Alternatively, the handheld speculum can act as a sleeve for the self-retaining endonasal speculum. After the endonasal speculum is placed, the 2 halves of the handheld speculum are removed in 2 separate pieces to minimize mucosal trauma (see Video 1 at web site). The distal speculum blades should straddle the sphenoid keel, and the nasal end of the speculum should be flush with the nostril. The sphenoid keel should be clearly exposed bilaterally, with the ostia seen at approximately 10 and 2 o'clock within the circumference of the speculum (Fig. 1). If the ostia are seen higher than this, the speculum trajectory is likely too inferior and aiming under the sella, which can be confirmed with fluoroscopy or surgical navigation.

A wide sphenoidotomy is then performed with pituitary and Kerrison rongeurs. Sphenoid bone and mucosal removal

should extend beyond the lateral edges of the ostia bilaterally and allow visualization of the tuberculum sellae and sellar floor. Given that the sphenopalatine arteries run in the postero-inferior nasal mucosa at a position of approximately 8 and 4 o'clock (Fig. 1), it is best to displace this mucosa laterally with the speculum or to cauterize it before removing it to avoid injuring the artery with a Kerrison or pituitary rongeur. However, this bleeding can be stopped relatively easily with bipolar or monopolar cautery.

Sellar Exposure

After the sphenoidotomy is completed, the face of the sella turcica is identified. At this point, it is important to correlate the intraoperative view of any intrasphenoidal bony septations with septations seen on the patient's preoperative MRI scan. Particular note should be made on the coronal images of where these septations reach the posterior wall of the sphenoid sinus relative to the carotid arteries, pituitary gland, and tumor, and on sagittal views where such septations reach the planum or sella. Septations that end on the sellar face are removed with a rongeur down to the sella; those that end over a carotid artery should be removed with care, and excessive torquing of the bone fragments should be avoided. Mucosa over the sella is removed, but the remaining sphenoid sinus mucosa is left undisturbed. The bony sellar face is then removed from cavernous sinus to cavernous sinus, and from the sellar floor inferiorly to the tuberculum sellae superiorly with a Kerrison rongeur or, in some instances, a high-speed diamond bit drill. In patients with large invasive tumors, the sellar bone may be markedly thinned or absent, and tumor may be directly under mucosa or under attenuated or absent sellar dura.

Cavernous Carotid Localization

After adequate sellar bone removal and before dural opening, the bayoneted micro-Doppler probe is used to insonate for the cavernous carotid arteries bilaterally (10-MHz MiniDop ES-100× with NRP-10H bayonet probe; Koven Technology, Inc., St. Louis, MO; or 20-MHz surgical Doppler; Mizuho America, Inc.). As previously described, the probe is placed initially at the edge of the bony opening at 90 degrees to the dura (18). If faint or no audible flow is present, the probe is angled more laterally, aiming under the bone edge, and, in most cases, the carotid flow will become louder. The probe is then moved superiorly and inferiorly to further determine the course of the carotid, which typically courses more medially in the superior sellar area. In most patients, the carotids have their most medial course superiorly near the tuberculum sellae just before they pass through the dural ring to enter the subarachnoid space. If no Doppler flow is evident, additional bone can be removed laterally to maximize sellar exposure. If audible flow is still not evident, consideration should be given to whether there is a technical problem with the probe, which can occur on occasion.

Dural Opening

A wide sellar dural opening is performed with a straight microblade in a U-shaped fashion, avoiding the area of great-

est audible Doppler flow (see Video 1 at web site) (18). Ideally, the initial dural opening should not transgress the pituitary gland or adenoma. After the initial opening, angled microdissectors are used to separate the dura from the underlying tumor and pituitary gland. The dural opening is then enlarged superiorly, inferiorly, and laterally, as needed, with the use of a right angle microhook blade or curved microscissors, which allow the cutting force of the blade to be directed away from the sellar and cavernous sinus structures (18). Care should be taken not to extend the dural opening too far superiorly in patients with microadenomas, as they often have a shallow sella and low-lying diaphragma sellae; such an opening can result in an early CSF leak. Laterally, the opening should generally extend to within 1 to 2 mm of the medial wall of the cavernous sinus. Low-pressure cavernous sinus venous bleeding generally is easily controlled using Surgifoam (Ethicon, Inc./Johnson & Johnson Co., Somerville, NJ) or Gelfoam (Pfizer, Inc., New York, NY) as needed.

Adenoma Removal

(see video at web site)

A selective and complete adenomectomy with preservation or improvement of pituitary gland function should be the goal for patients undergoing adenoma removal. In many instances, the tumor pseudocapsule can be identified and a plane can be established between the adenoma and the normal gland. Using microdissectors, irrigation, and gentle traction on the pseudocapsule, such adenomas can often be removed completely with preservation of the pseudocapsule, as described by Oldfield and Vortmeyer (58) (see Video 2 at web site). However, many, if not most, large macroadenomas are soft and require initial internal debulking with ring curettes and suction (see Video 1 at web site). After this debulking is accomplished, the tumor “rind” with an intact pseudocapsule can be gently separated from the normal gland and diaphragma sellae. For the occasional firm or rubbery adenoma, initial debulking with curved and straight pistol-grip microscissors may be needed. Adenomas with suprasellar extension should be debulked inferiorly first, followed by removal of the suprasellar component. This sequence allows the suprasellar tumor to partially deliver itself from above, and it may minimize the chances of causing an early CSF leak. For large macroadenomas, it is essential to confirm descent of the diaphragma sellae as an indication that a complete tumor removal has been accomplished. Probing the folds of the diaphragma with 45- and 90-degree up-angled ring curettes bilaterally, posteriorly, and anteriorly will help dislodge residual tumor in these areas. To further encourage downward descent of the suprasellar tumor, the anesthesiologist can induce a Valsalva maneuver to transiently increase intracranial pressure.

Most macroadenomas, even those with a large suprasellar extension, are contained by a thinned but largely intact diaphragma sellae; therefore, the diaphragma sellae should completely invert and fall into the enlarged sella when complete tumor removal is accomplished. A useful check for assessing completeness of removal of such suprasellar adeno-

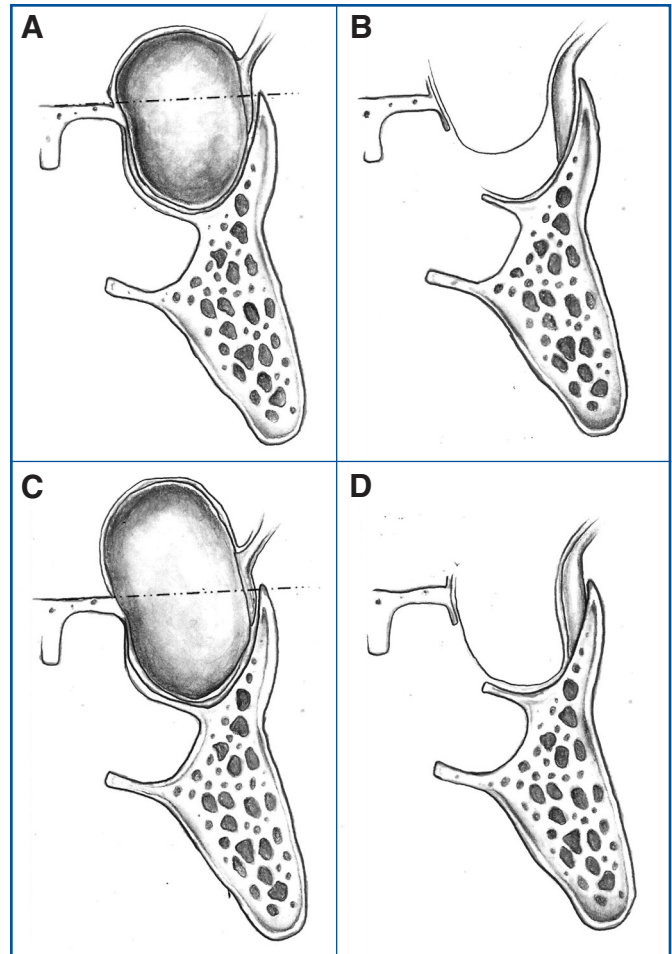


FIGURE 2. Schematic sagittal view drawings of small (A) and large (C) macroadenomas, both with suprasellar extension and a stretched diaphragma sellae containing the tumor superiorly. The dotted horizontal line extending from the planum to the posterior dorsum sellae in A and C depicts the normal location and point of attachment of the diaphragma sellae. B and D, after complete removal of the adenomas, the stretched diaphragma sellae is seen to invert into the sella in “mirror image” fashion equivalent to the degree of suprasellar extension. If only partial inversion of the diaphragma sellae occurs, there is likely residual tumor within the folds of the diaphragma.

mas comes from reviewing the preoperative sagittal MRI scan (Fig. 2). If a line is drawn from the planum across the tumor to the posterior dorsum sellae (where the diaphragma has its points of attachment), the volume of suprasellar tumor seen on MRI above this line should correspond to the volume created by the complete inversion of the diaphragma into the sellar space seen at surgery. If this “mirror image” descent of the diaphragma sellae is not seen intraoperatively and only a partial descent of the diaphragma is noted, residual tumor is likely present.

For tumors with obvious or possible cavernous sinus invasion, one should attempt to visualize the medial cavernous

sinus wall. A microscopic view of the cavernous sinus contralateral to the nostril of approach can often be achieved, provided that enough lateral sellar bone has been removed and a short endonasal speculum (60–70 mm) is in position. Under direct visualization, in some instances, what appears to be cavernous sinus invasion on MRI may only be tumor compression of the medial cavernous sinus wall (69, 70). However, in many cases, after the sellar tumor has been removed, a defect in the medial cavernous sinus wall is seen. Tumor in the medial cavernous sinus can often be removed, or at least effectively debulked, using gentle suction and angled ring curettes, which have smooth outer edges. Given the potential for injury to the cavernous carotid and the abducens nerve lateral to the carotid, aggressive curetting or grasping of tumor tissue along or lateral to the carotid artery should be avoided.

Endoscopic Assistance to Maximize Tumor Removal

(see video at web site)

Once tumor removal is as complete as possible with use of the microscope, the 0-, 30-, and 45-degree angled endoscopes can be used to further assess for residual tumor, particularly in patients with macroadenomas extending into the suprasellar or cavernous sinus regions (see Video 3 at web site). This endoscopic look is especially helpful in cases in which the diaphragma sellae may not have descended fully into the sella, and with extended approach cases for nonadenomatous lesions as described below. In the majority of such cases, the endoscope will reveal additional suprasellar tumor that hinders a full descent of the diaphragma. Removal of such tumor remnants can often be performed directly with the endoscope using angled suctions, tumor-grasping forceps, or ring curettes, or with microscopic visualization and angled ring curettes. Similarly, endoscopic visualization of the medial cavernous sinus will often allow additional tumor to be removed that was not visualized or was inaccessible with the operating microscope (see Video 3 at web site).

Endoscopic visualization and tumor removal is best performed with a 3-hand technique, in which the assistant holds and drives the endoscope and the surgeon holds the suction and a ring curette or tumor-grasping forceps. Alternatively, one can use a fixed endoscope holder, but this provides less maneuverability and flexibility compared with a surgical assistant. The endonasal speculum can also be removed, allowing a binostril approach; the endoscope can then be placed in one nostril and the working instruments in the opposite nostril, further reducing instrument conflict and crowding.

Extended Approach Modifications

As previously described, several important modifications are used for reaching suprasellar, infrasellar, and cavernous sinus lesions (17, 29, 30). Frameless surgical navigation is highly recommended for such cases, and endoscopy is now considered mandatory. To maximize maneuverability of the endoscope and other instruments, it is important to perform a wider and taller sphenoidotomy than for isolated sellar lesions; the sphenoidotomy should extend to the ethmoid roof

superiorly and to the level of the floor of the sphenoid sinus inferiorly. A short (60-mm) up- or down-angled trapezoidal speculum is used to provide greater suprasellar or infrasellar exposure and to facilitate use of the endoscope (30). To gain full advantage of these short specula, 1 to 2 cm of posterior nasal septum and all lateral obstructing bone or soft tissue along the keel are also removed.

Suprasellar and Planum Lesions

(see video at web site)

With increasing experience, the endonasal approach can be used to remove a variety of nonadenomatous suprasellar tumors such as craniopharyngiomas (particularly those in the retrochiasm space), supraglandular Rathke's cleft cysts, and smaller tuberculum sellae meningiomas (smaller than 30–35 mm in diameter and without far lateral extension). For such tumors, the patient is positioned with neck extension of 10 to 15 degrees from neutral, which affords a more comfortable operating position for the surgeon. As previously described (17), a low-profile, high-speed drill (Micromax; The Anspach Effort, Inc., Palm Beach Gardens, FL) with a 2- or 3-mm diamond bit is used to remove the tuberculum sellae and posterior planum. Care should be taken not to extend the bony opening too far laterally at the level of the optic canals, which are the width-limiting structures at this level. Most of these lesions are more fibrous, rubbery, or partially calcified and require sharp dissection with curved and straight microscissors along arachnoid planes (see Video 4 at web site). In patients with intact pituitary function, preservation of function is typically possible with supraglandular Rathke's cleft cysts and tuberculum sellae meningiomas, but it is often not possible in patients with craniopharyngiomas, particularly those that engulf the pituitary stalk (20). After tumor debulking, the tumor capsule is dissected away from arachnoid attachments using sharp dissection and gentle traction. Tumor remnants that are densely adherent to the infundibulum, the optic apparatus, or perforating vessels from the supraclinoid carotid or anterior cerebral complex should be left behind to avoid new neurological or hormonal deficits.

Clival Lesions and Cavernous Sinus Lesions

(see video at web site)

Given that most clival chordomas have their epicenter medial to the cavernous carotid arteries, they can typically be removed or debulked through an endonasal approach. As we recently described, to remove such chordomas in the infrasellar and cavernous sinus regions, a wide sphenoidotomy is carried to the floor of the sphenoid sinus (29). A short (60-mm) down-angled endonasal trapezoidal speculum is used as the working channel. Given the tendency of clival chordomas to distort the course of the petrous, vertical, and cavernous portions of the carotid arteries, the micro-Doppler probe and surgical navigation are used to help localize these vessels before and during tumor removal (see Video 5 at web site). Given the invasive nature of clival chordomas, complete microscopic tumor removal is rarely possible. However, in the instance of

intradural chordoma extension, the dura should be opened further to maximize tumor removal under both microscopic and endoscopic visualization (29).

For removal of tumors with extensive cavernous sinus invasion, such as invasive pituitary adenomas or clival chordomas, one can approach these lesions from the contralateral nostril or from the ipsilateral nostril after resecting the ipsilateral middle turbinate. After removal of the middle turbinate, the lateral speculum blade can expand more widely, allowing a greater removal of the ipsilateral sphenoid keel and providing direct cavernous sinus exposure lateral to the ipsilateral cavernous carotid artery. For tumors with extensive bilateral involvement, a binostril approach can be used. For removal of other tumor types such as Rathke's cleft cysts, sphenoid sinus carcinomas, and intradural retroclival epidermoid tumors, please refer to our recent publications (17, 24, 27).

Intrasellar Hemostasis

After tumor removal, hemostasis is obtained with hemostatic agents, including Surgifoam (Ethicon, Somerville, NJ) and full-strength hydrogen peroxide. The peroxide is irrigated directly into the sphenoid sinus and sella for up to 5 minutes. Its use appears safe from the standpoint of pituitary hormonal function, as we have recently demonstrated, and it may have additional tumoricidal effects on residual microscopic foci of adenoma (53). However, it should not be used if there is a large diaphragmatic defect which would allow it to track into the subarachnoid space. In cases in which there is persistent oozing, one should further inspect the sella with the endoscope to look for residual tumor. Of the 6 postoperative hematomas in this series requiring a return to the operating room, 4 were in patients with large macroadenomas (≥ 30 mm in maximal diameter) who, in retrospect, had residual tumor remnants left at the initial operation; these remnants presumably continued to ooze, prompting an urgent reoperation within 12 hours of the first surgery.

Cranial Base Reconstruction and CSF Leak Repair

(see video at web site)

As recently described (26), cranial base reconstruction and CSF leak repair is tailored to the size of the CSF leak and bony and dural defect. Before reconstruction, an assessment of the size of diaphragmatic defect is performed. If no obvious defect is seen, a Valsalva maneuver is induced to help visualize an occult or small (Grade 1) CSF leak emanating through a small diaphragmatic defect.

All repairs involve use of collagen sponge (DuraGen or Helistat; Integra, Plainsboro, NJ; or Instat, Ethicon, Inc.) as part of the repair, which acts as a scaffolding for fibroblast ingrowth and a vascularized dural replacement (41, 43, 54, 55). In patients with no CSF leak (Grade 0), a single layer of minimally moistened collagen sponge placed over the exposed diaphragma sellae, pituitary gland, and sellar dura is typically used as the only repair material (see Video 2 at web site). For most small (Grade 1) CSF leaks, the repair includes intrasellar collagen sponge with an intrasellar, extradural buttress of tita-

nium mesh or Medpor transsphenoidal sellar implant (Porex Surgical, Inc., Newnan, GA), and a second outer layer of collagen placed over the buttress and adjacent sellar and sphenoid bone. The repair is typically held in position with a small amount of BioGlue (CryoLife, Inc., Kennesaw, GA). For medium (Grade 2) CSF leaks or Grade 1 leaks with a large intrasellar dead space, the repair includes an intrasellar abdominal fat graft, a layer of collagen sponge followed by a buttress of titanium mesh, or a Medpor plate placed in the intrasellar extradural space. Additional fat is typically placed over the sella, followed by another layer of collagen; the construct is held in position with BioGlue. In some recent cases of Grade 1 and 2 leaks, no buttress has been used, and, instead, the repair with collagen sponge with or without a fat graft has been reinforced only with BioGlue, which is relatively rigid. These patients are also placed on acetazolamide (Diamox; Lederle Laboratories, Philadelphia, PA), 250 mg every 8 hours for 48 hours after surgery, to diminish CSF production. Although this account is anecdotal, to date, we have had no failures with this more simplified repair method. To further assess the adequacy of the repair, before BioGlue is placed, the anesthesiologist is asked to perform a Valsalva maneuver to raise the patient's intracranial pressure; if there is CSF streaming around the repair or movement of the buttress, the repair should be revised.

For large (Grade 3) defects, typically seen with extended suprasellar or transclival approaches, the repair construct is similar to the Grade 2 repair, and a lumbar drain for CSF diversion is also placed for 48 hours. Grade 3 leaks, however, are uncommon after adenoma removal unless they are extensively invasive above the diaphragma sellae. It is important to note that use of BioGlue in this repair paradigm is not for stopping egress of CSF per se, but rather to prevent migration of the construct materials (fat and collagen) away from the sella (21) (see Videos 1, 3, and 4 at web site).

Nasal Closure

(see video at web site)

Once sellar reconstruction is complete, the endonasal speculum is removed and the handheld speculum is used to explore both the operated and nonoperated nasal cavities with the microscope. In most instances, there may be mild venous oozing from along the nasal septum, inferior turbinate, or middle turbinate. Such mucosal bleeding is stopped with Surgifoam or the bipolar (see Video 1 at web site). Nasal hemostasis should be relatively complete to minimize the amount of blood the patient will swallow during the first few hours after surgery, which can otherwise result in nausea and vomiting. The middle turbinate on the side of the approach, which is outfractured by the speculum at the start of the procedure, is medialized toward the nasal septum; this minimizes the chance of development of a maxillary sinus mucocele. Finally, using the handheld speculum in the contralateral nostril, the nasal septum is returned to the midline. No nasal packing is used; a small gauze "mustache" dressing is placed over the nostrils. To minimize chances of postoperative CSF leak, nasal epistaxis, or intrasellar bleeding, excessive

TABLE 1. Endonasal series: pathological conditions^a

Pathological condition	No. of patients
Adenoma	605 (75%)
Endocrine-inactive adenomas	332
ACTH-secreting adenoma, Cushing's disease	109
ACTH-secreting adenoma, Nelson's syndrome	4
Prolactinoma	88
GH-secreting adenoma	67
Thyrotropin-secreting adenoma	5
Rathke's cleft cyst	59 (7%)
Craniopharyngioma	26 (3%)
Meningioma	23 (3%)
Chordoma	18 (2%)
Other pathological condition	81 (10%)
Sphenoid sinus carcinoma	12
Primary CSF leak	12
Arachnoid cyst	7
Dermoid/epidermoid cyst	6
Cavernous sinus schwannoma	5
Optic nerve glioma	3
Other	36

^a ACTH, adrenocorticotropic hormone; GH, growth hormone; CSF, cerebrospinal fluid.

coughing on the endotracheal tube should be avoided during extubation, and blood pressure should be carefully monitored and controlled in the early postoperative period.

Postoperative Care

Most patients undergoing adenoma or Rathke's cleft cyst removal are admitted to a non-intensive care unit bed, and their arterial line is removed before leaving the recovery room. For the first postoperative night, patients are given a humidified face tent, and decongestants are available upon request. Saline nasal spray is provided for a week after surgery and is used based on patient preference. The Foley catheter is removed on the morning of postoperative Day 1, and patients are encouraged to walk.

All patients with pituitary-related lesions are followed in-hospital by an endocrinologist. Patients are monitored for diabetes insipidus on the basis of urine output and urine specific gravity. Adrenal function is monitored by measuring morning serum cortisol and adrenocorticotropic hormone levels on the mornings of postoperative Days 1 and 2. For patients with acromegaly, a prolactinoma, or Cushing's disease, growth hormone, prolactin, and cortisol/adrenocorticotropic hormone levels are followed on postoperative Days 1 and 2 to document early remission based on subnormal hormone levels (25, 71). Most patients are

discharged home on postoperative Day 2 and have their serum sodium level checked on postoperative Day 4 or 5 to monitor for delayed hyponatremia (40, 72). The first postoperative visit is at 2 to 3 weeks after surgery, and a follow-up visit occurs 3 months after surgery and includes a complete pituitary hormonal evaluation. An early postoperative MRI or computed tomographic scan is typically performed within 2 days of surgery for patients with macroadenomas or other large tumors. The next follow-up MRI is usually performed 3 months after surgery.

Clinical Experience

Patient Population

Since July 1998, 812 patients have undergone a total of 881 operations for tumor removal or primary CSF leak repair by the senior author (DFK). Of these, 17% had undergone previous surgery, either transcranial or transsphenoidal, at an outside institution. As shown in Table 1, the pathological conditions included 75% pituitary adenomas, 7% Rathke's cleft cysts, 3% craniopharyngiomas, 3% parasellar meningiomas, 2% clival chordomas, and 10% other neoplasms or primary CSF leaks.

Extended Approach Cases and Endoscopy

An extended endonasal approach was used in 118 cases (13%), including lesions with suprasellar extension in 60 cases; cavernous sinus extension in 16 cases; infrasellar, clival, or pre-pontine extension in 16 cases; or extension into multiple parasellar regions in 26 cases. The endoscope was first used in 1998 and, overall, has been used in 163 cases, including 61% of extended cases and 12% of nonextended cases ($P < 0.0001$). Use of endoscopy has increased over time, being used in 71 (35%) of the last 200 cases in the series overall and in 18 (72%) of the last 25 extended endonasal cases.

Complications

As shown in Table 2, among 812 patients, major complications included 19 postoperative CSF leaks, 6 postoperative sellar/suprasellar hematomas requiring reoperation, 4 carotid artery injuries, 4 cases of permanent neurological deficits, 3 cases of bacterial meningitis, and 2 deaths. Overall, there was a higher complication rate in the first 500 cases (Tables 2 and 3). Complications rates in standard cases and extended approach cases are compared in Table 4.

Regarding CSF leaks, the overall postoperative CSF leak rate decreased to under 1% in the last 381 procedures, and there have been no postoperative leaks in the past 54 extended endonasal cases, of which 36 (67%) had an intraoperative leak. The rate of CSF leaks by intraoperative grade was 0.5, 3, 1.5 and 8% for Grades 0, 1, 2, and 3, respectively. Of the 19 postoperative leaks, 14 were repaired by reoperation and 4 were treated by transient CSF diversion with a lumbar drain. Of the 5 major pathological conditions treated, the postoperative CSF leak rate was highest in meningiomas (4 of 23; 17%), followed by craniopharyngiomas (1 of 26; 3.8%) and adenomas (11 of 605; 1.8%); there were no postoperative leaks in patients with Rathke's cleft cysts or chordomas, of which 41 (69%) and 11 (61%) had an intraoperative CSF leak, respectively.

TABLE 2. Endonasal series: complication rates in 881 cases (812 patients)^a

Complication	First 500 cases	Subsequent 381 cases	Total
Death	1 (0.2%)	1 (0.3%)	2 (0.2%)
Carotid artery injury	3 (0.6%)	1 (0.3%)	4 (0.4%)
New permanent neurological deficit	4 (0.8%)	0	4 (0.4%)
Transient neurological deficit	3 (0.6%)	6 (1.6%)	9 (1%)
Postoperative hematoma	5 (1%)	1 (0.3%)	6 (0.7%)
Postoperative CSF leaks overall ^b	16 (3%)	3 (0.8%)	19 (2%)
Postoperative CSF leaks with intraoperative leak ^c	15/275 (5%)	2/225 (0.9%)	17 (3.4%)
Bacterial meningitis	2 (0.4%)	1 (0.3%)	3 (0.3%)
Postoperative pulmonary embolism	3 (0.6%)	0	3 (0.3%)
Reoperation for overly large fat graft	2 (0.4%)	0	2 (0.2%)
Delayed epistaxis needing embolization	6 (1.2%)	4 (1%)	10 (1%)
Delayed removal of titanium mesh	3 (0.6%)	2 (0.5%)	5 (0.6%)
Delayed sinusitis requiring sinus endoscopy	8 (1.6%)	5 (1.3%)	13 (1.5%)

^a CSF, cerebrospinal fluid.

^b *P* = 0.017 (first 500 versus subsequent 381 cases; includes all CSF leaks, Grades 0, 1, 2, and 3).

^c *P* = 0.005 (first 275 versus subsequent 225 cases; includes only identified intraoperative CSF leaks, Grades 1, 2, or 3).

TABLE 3. Use of the endoscope

Endoscope-assisted procedures (n = 881)	No. of cases (%)	<i>P</i> value
Total	163 (19%)	
Portion of series		
First half	62 (14%)	
Second half	101 (23%)	<0.001
Endoscope use		
Standard approach (n = 763)	91 (12%)	
Extended approach (n = 118)	72 (61%)	<0.0001

Regarding carotid artery injuries, the first 2 cases were within the first 105 patients (both with adenomas) and occurred before our routine use of the micro-Doppler probe for carotid localization. The last 2 cases (Patients 414 and 618 in the series) were both extended-approach cases for cavernous sinus lesions, including the last case, in which the Doppler probe was clearly, in retrospect, malfunctioning and surgical navigation was not used. No patients sustained a permanent neurological deficit as a result of a carotid artery injury. The first 3 carotid artery injuries have been described previously (18). All 4 patients had local control of bleeding and underwent immediate angiography while still intubated. The first patient with acromegaly had successful balloon embolization

TABLE 4. Complications: extended approach compared with standard endonasal approach^a

Complication	Extended (n = 118)	Standard (n = 763)	<i>P</i> value
Death	1 (1%)	1 (0.1%)	0.3
Carotid artery injury	2 (2%)	2 (0.3%)	0.09
New permanent neurological deficit	2 (2%)	2 (0.3%)	0.09
Postoperative hematoma	1 (1%)	5 (0.7%)	0.6
Bacterial meningitis	2 (2%)	1 (0.1%)	0.05
CSF leak			
First half of series	6 (10%)	10 (3%)	0.01
Second half of series	1 (2%)	2 (0.5%)	0.4
Total (Grade 0, 1, 2, and 3)	7 (6%)	12 (2%)	0.008
Total (Grade 1, 2, 3 only)	7/88 (8%)	10/412 (2.4%)	0.02

^a CSF, cerebrospinal fluid.

of a cavernous carotid pseudoaneurysm, the second patient (with recurrent Cushing's disease), and the fourth patient (with a sphenoid sinus carcinoma) had asymptomatic carotid occlusion seen at the time of their angiograms, and the third patient with a cavernous sinus schwannoma had a normal postoperative angiogram.

The 4 permanent neurological deficits included the following: 1) Patient 63: left hemiplegia and cognitive impairment in a 73-year-old man who underwent repeat surgery for a clival chordoma treated by prior biopsy and radiotherapy; he sustained a postoperative suprasellar hematoma requiring craniotomy for evacuation but improved minimally after hematoma evacuation; 2) Patient 366: right hemiparesis in a 77-year-old man with a giant endocrine-inactive adenoma resulting from inadvertent placement of a nasogastric tube by nursing staff that went trans-sellar and into the left hemisphere; fortunately, he had no resultant CSF leak or meningitis; 3) Patient 385: delayed monocular blindness 8 days after endonasal tumor debulking in a 66-year-old man with a sphenocavernous meningioma who had undergone prior transcranial surgery and radiotherapy and had preexisting ophthalmoplegia in the affected eye; 4) Patient 454: mild visual hemifield worsening in a 72-year-old woman who presented with a bitemporal hemianopsia after complete removal of a tuberculum sellae meningioma.

The 2 deaths included the following: 1) Patient 413: an 84-year-old man with an invasive endocrine-inactive macroadenoma with associated visual loss; he sustained a suprasellar hematoma requiring reoperation but developed communicating hydrocephalus and multiple medical complications and died 45 days after surgery; 2) Patient 706: a 57-year-old man with a spontaneous sphenoid sinus CSF leak, preexisting cardiopulmonary disease, and a history of methamphetamine abuse; his CSF leak was repaired uneventfully, but he developed respiratory distress and died of a likely pulmonary embolus 9 days after surgery.

ILLUSTRATIVE CASES

Patient 1: Endocrine-inactive Macroadenoma (Standard Endonasal Approach)

(see Video 1 at web site)

A 79-year-old woman had progressive growth of a macroadenoma over a 3-year period (Fig. 3). Before surgery, the tumor had grown to 23 × 15 mm and caused bitemporal hemianopsia. Complete tumor removal was performed via a left endonasal approach. A Grade 1 CSF leak was repaired with collagen sponge and BioGlue. Four months after surgery, she is doing well, without endocrinopathy; no residual tumor seen on MRI.

Patient 2: Adrenocorticotropic Hormone-secreting Microadenoma (Removal with Pseudocapsule Preservation)

(see Video 2 at web site)

A 32-year-old woman with weight gain who was recently diagnosed with hypertension and diabetes mellitus was diagnosed with Cushing's disease on the basis of blood and urinary biochemical testing, includ-

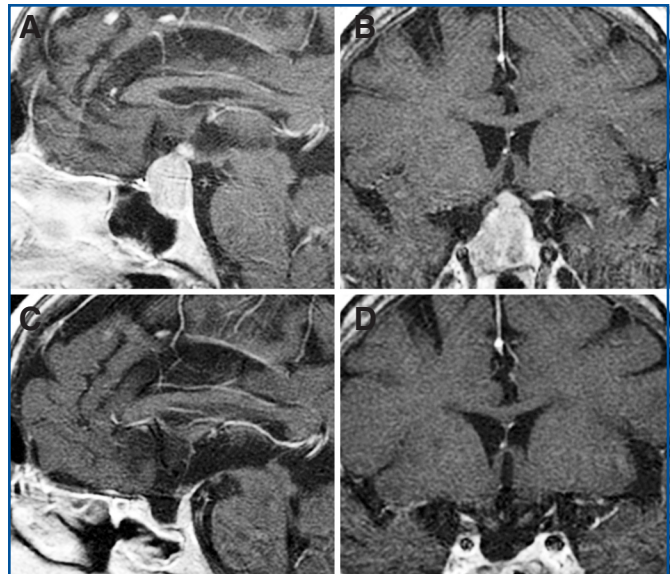


FIGURE 3. Endocrine-inactive macroadenoma in Patient 1 (see Video 1 at web site). Pre- (A and B) and postoperative (C and D) T1-weighted post-gadolinium sagittal and coronal magnetic resonance imaging (MRI) scans.

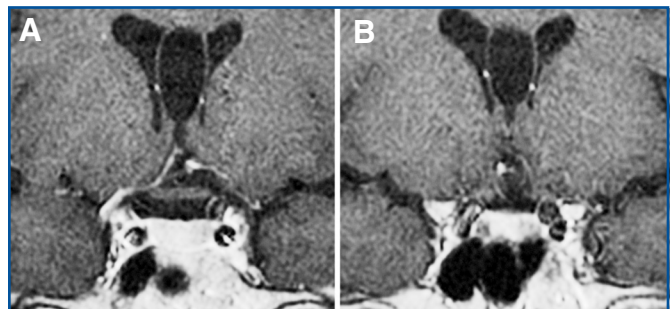


FIGURE 4. Adrenocorticotropic hormone-secreting microadenoma in Patient 2 (see Video 2 at web site). A and B, preoperative coronal T1-weighted postgadolinium MRI scans showing subtly seen left-sided microadenoma.

ing petrosal sinus sampling. Her MRI scan (Fig. 4) showed a subtle 5-mm area of left-sided hypoenhancement. As shown in Video 2, she underwent selective adenomectomy. Her postoperative Day 1 serum cortisol level was nonmeasurable, and she was placed on glucocorticoid replacement therapy. She remains in remission 20 months after surgery.

Patient 3: Invasive Growth Hormone-secreting Adenoma with Left Cavernous Sinus Invasion

(see Video 3 at web site)

A 39-year-old man with acromegaly and a 15 × 19-mm invasive macroadenoma underwent endonasal tumor removal with endoscopic assistance (Fig. 5). Video 3 demonstrates endoscopic visualization of a left cavernous sinus defect and additional tumor removal from the medial left cavernous sinus under endoscopic visualization. The patient had near-complete tumor removal; 1 year after surgery, he is in

biochemical remission on octreotide therapy.

Patient 4: Retrochiasmal Craniopharyngioma (Suprasellar Extended Approach)

(see Video 4 at web site)

A 21-year-old man with a 4-month history of progressive visual loss, headaches, and weight gain was found to have a $40 \times 33 \times 32$ -mm cystic and solid craniopharyngioma (Fig. 6). He underwent uncomplicated near-complete tumor removal with endoscopic assistance. A small calcified tumor nodule was left in the left hypothalamus. He completed 27 fractions of stereotactic radiotherapy 3 months after surgery. He is on full pituitary hormone replacement therapy with normal vision and no evidence of tumor regrowth 8 months after surgery.

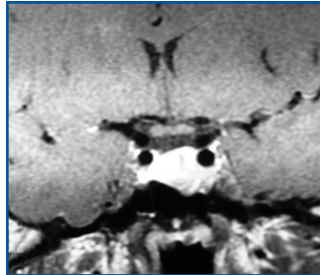


FIGURE 5. Invasive growth hormone-secreting macroadenoma in Patient 3 (see Video 3 at web site). Preoperative postgadolinium coronal T1-weighted MRI scan.

Patient 5: Clival Chordoma (Extended Transclival Approach)

(see Video 5 at web site)

A 58-year-old woman with progressive diplopia and complete right Cranial Nerve VI palsy was found to have a $15 \times 14 \times 13$ -mm clival mass with intradural and right cavernous sinus invasion (Fig. 7). She underwent near-complete endonasal tumor removal with surgical navigation and endoscopic assistance. She completed 28 fractions of stereotactic radiotherapy 6 months after surgery. Twelve months after surgery, her abducens palsy persisted; she has no evidence of tumor regrowth on MRI.

DISCUSSION

The major advantage of the direct endonasal approach over the sublabial transsphenoidal approach is the obviation of mucosal tunnels and nasal packing, resulting in a more rapid and less painful recovery (19, 71). The major disadvantage of this approach is restricted visualization and maneuverability imposed by the endonasal speculum and operating microscope, with resultant tunnel vision. As described above, to minimize these limitations and to maximize parasellar access, several strategies are recommended. These include: 1) approaching from the nostril contralateral to the greatest degree of tumor extension, 2) performing a wide sphenoidotomy that incorporates both sphenoid ostia, 3) using a short endonasal speculum (60–70 mm) to maximize maneuverability and visualization, 4) performing a wide sellar bony opening that extends to the edges of the cavernous sinus bilaterally and to the tuberculum sellae superiorly, 5) confirming adequate but safe lateral bony removal with the micro-Doppler or surgical navigation before dural opening, and 6) using endoscopy to ensure as complete and safe a removal as possible, particularly for tumors extending beyond the confines of the sella.

Given that there has been such an increase in the use of the endoscope in transsphenoidal surgery over the past decade, a

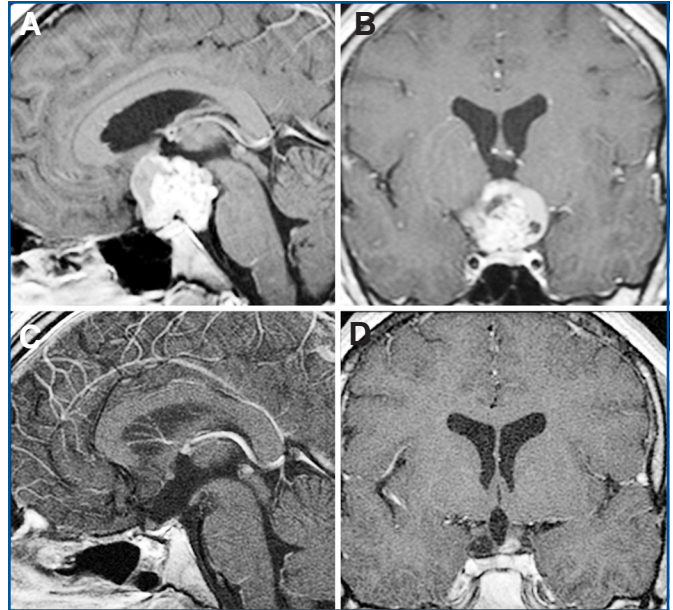


FIGURE 6. Retrochiasmal craniopharyngioma in Patient 4 (see Video 4 at web site). Preoperative (A and B) and 8-month postoperative (C and D) postgadolinium sagittal and coronal T1-weighted MRI scans.

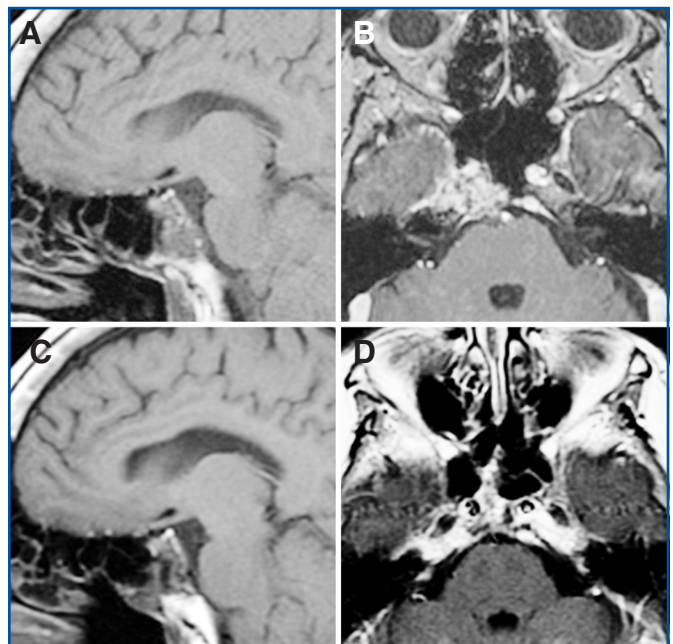


FIGURE 7. Clival chordoma in Patient 5 (see Video 5 at web site). Preoperative (A and B) and 12-month postoperative (C and D) postgadolinium sagittal and axial T1-weighted MRI scans.

comment regarding the endonasal approach with the operating microscope versus the purely endoscopic approach seems warranted, particularly concerning 3 issues: 1) nasal recovery; 2) removal of functional adenomas; and 3) removal of suprasellar,

cavernous sinus, or clival lesions. Regarding nasal recovery, based on our experience and other reports, there appears to be little difference in the degree of rhinological trauma and patient recovery after the direct endonasal approach with the operating microscope versus the purely endoscopic approach (4, 5, 19, 71). In both instances, patients typically recover rapidly and relatively completely with few long-term nasal complaints.

Regarding whether a complete removal of a hormonally active adenoma can be accomplished with the endoscope versus the microscope, the answer is unclear. Currently, for removal of functional microadenomas or small macroadenomas, the microscopic approach remains the “gold standard,” with numerous publications indicating long-term remission rates of 80 to 95% for patients with microprolactinomas, Cushing’s disease, and acromegaly (9, 45, 50, 58, 65). There are fewer data available for the purely endoscopic approach, but it appears that remission rates with this approach are improving, particularly at centers with a focused interest in endoscopy (3, 6, 31, 57). It is likely that, in experienced hands, the purely endoscopic approach will rival the microscopic approach in terms of remission rates for functional pituitary adenomas.

Regarding whether a complete and safe removal of a tumor with suprasellar, cavernous sinus, or clival extension can be performed with the microscope alone as compared with an endoscope-assisted or purely endoscopic approach, the answer appears to be no. For the microscopic removal of parasellar tumors such as craniopharyngiomas, tuberculum sellae meningiomas, clival chordomas, and invasive adenomas, it is increasingly clear that the endoscope is essential for maximizing safe tumor removal (15, 16, 29, 31, 32, 36–38, 46, 48). For those who continue to use the endonasal microscopic approach for such parasellar lesions, endoscopic assistance should be routine. Additionally, as we are increasingly doing, one can remove the endonasal speculum at the point in the procedure when the microscope is providing suboptimal visualization. Then, a purely endoscopic binostril technique, as described by others, can be used (7, 15, 32, 37).

CONCLUSION

In summary, the direct endonasal approach with the operating microscope provides an effective, minimally invasive route for removal of parasellar tumors. As our results over time suggest, its use for the removal of more challenging tumors such as craniopharyngiomas, tuberculum sellae meningiomas, and clival chordomas should be attempted only after gaining considerable experience with simpler sellar lesions such as adenomas and Rathke’s cleft cysts. For those using the extended endonasal approach, the microscopic surgeon must be willing to take advantage of the expanded visualization provided by the endoscope and face the learning curve that goes with it in a cautious and incremental way that ensures patient safety.

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COMMENTS

In this well-written article, Fatemi et al. described very clearly the technique of the direct endonasal microsurgical approach first described by Griffith and Veerapen in 1987 (2) and later by Cooke and Jones in 1994 (1).

Technical improvement with respect to the original technique is provided as a result of the experience of the senior author. The video is excellent. The direct endonasal microsurgical approach and the endoscopic endonasal approach are recent developments. Both techniques are less traumatic and less invasive than classic microsurgical transsphenoidal surgery. When “pituitary neurosurgeons” are dealing with pituitary adenomas using the microscopic transsphenoidal approach, it is understandable that they may prefer the direct endonasal microsurgical approach, thus avoiding the training and learning curve required to perform a safe endoscopic endonasal procedure. However, I believe that young residents should familiarize themselves with the endoscopic approach, adding to their versatility in cranial base approaches.

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1. Cooke RS, Jones RA: Experience with the direct transnasal transsphenoidal approach to the pituitary fossa. *Br J Neurosurg* 8:193–196, 1994.
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This study by Fatemi et al. is an interesting review of a consistent series of patients operated on transsphenoidally with both standard and extended approaches over a 10-year period with the same microsurgical endonasal strategy. The description of the surgical technique is well done, showing in detail the modern updated version of the classic transsphenoidal operation performed by means of the operating microscope. I really appreciate once more the clear proposals of Dr. Kelly, who has been always done honest and reliable work for our neurosurgical community.

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Fatemi et al. presented a large series of patients in whom the endonasal transsphenoidal approach and the microscope were used to remove a variety of sellar and parasellar pathological lesions. Unlike recent similar series, the endoscope was not used as the primary method of visualization but rather was introduced at the end of the operation to improve the field of view. On the basis of the senior author’s extensive experience and excellent results, useful tips that are applicable to both endoscopic and microscopic transsphenoidal surgical approaches are presented.

Some of the data in this article deserve particular attention. The rate of cerebrospinal fluid leak was not as much dependent on the approach, i.e., extended versus transsellar, but rather on the experience of the surgeon, the size of the intraoperative cerebrospinal fluid leak, and the pathological lesion. Large openings to remove

intradural pathological lesions such as meningiomas carry a risk of leak between 8 and 17% compared with the rate for smaller tumors, particularly those that are extradural. Our experience has been similar. Hence, in patients with meningiomas, a more stringent closure technique, such as a “gasket-seal” or nasoseptal flap (2, 3), may be warranted. Fatemi et al. recommended the use of BioGlue (Cryolife, Inc., Kennesaw, GA), which prevents the closure from dislodging. Several other authors have emphasized the importance of a rigid buttress to support the closure, and other viable mechanisms, such as bone reconstruction, cranioplasty, or even an inflated balloon in the nasopharynx, have been described. Prevention and management of carotid injury are also critical. Not only is the Doppler probe useful for identifying the carotid artery, but we have found that using a diamond rather than a cutting drill bit or even a Kerrison rongeur when removing bone over the carotid decreases the risk of carotid injury. Likewise, the lack of permanent morbidity associated with carotid injury is a tribute to the efficacy of interventional neuroradiological techniques and the importance of performing these extended transsphenoidal procedures at an institution with readily available interventional facilities.

Ultimately, the senior author, who has extensive experience with both the microscope and the endoscope, concluded that the endoscope provides superior visualization. Hence, it is likely that this series will ultimately be viewed as an excellent description of a transitional, hybrid technique, soon to be replaced by purely endoscopic surgery. Whether the one limitation of the endoscope, namely the lack of stereoscopic vision, will be remedied with novel three-dimensional endoscopes is a topic of ongoing investigation (1).

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Fatemi et al. described their experience treating more than 800 pituitary and parasellar lesions by an endonasal approach during a 10-year interval. They have achieved excellent results with low morbidity and negligible mortality. Of note, there has been an apparent improvement in complication rates in the latter segment of this series, presumably owing to increased experience and better use of technology by the surgeons.

Many pituitary surgeons now use essentially the same approach and management parameters for treatment of these lesions, including the endonasal approach, an endoscopic adjunct, and management of cerebrospinal fluid leaks. In contrast to this description, I use preoperative portable computed tomography scans for navigation in most patients and intraoperative low-field magnetic resonance imaging for tumors with significant suprasellar extension. With less invasive surgical techniques, most patients undergoing surgery for pituitary tumor can be discharged within 24 to 36 hours.

As documented in this article, techniques in pituitary surgery continue to evolve, and excellent results are achievable in the setting of a dedicated pituitary team.

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