J Neurooncol (2008) 87:317–325
DOI 10.1007/s11060-007-9512-2

CLINICAL STUDY-PATIENT STUDIES

Safety and efficacy of the direct endonasal transsphenoidal approach for challenging sellar tumors

Nader Sanai · Alfredo Quiñones-Hinojosa · Jared Narvid · Sandeep Kunwar

Received: 14 July 2007 / Accepted: 5 December 2007 / Published online: 19 December 2007

Abstract *Introduction* The direct endonasal approach to pituitary microadenomas is relatively atraumatic, rapid, and carries a lower complication rate than the sublabial approach. Large macroadenomas (3–4 cm) can still be addressed with this simple, unmodified direct endonasal approach. We present our experience with this unique and challenging patient population. *Methods* About 64 consecutive patients with large (3–4 cm) pituitary adenomas and craniopharyngiomas were treated by the senior author (SK) using the direct endonasal approach from May 2001 to July 2004. The hospital course, endocrinological function, radiographic imaging, and outpatient follow-up were retrospectively reviewed for each patient. *Results* The mean volume of these lesions was 31.5 cm^3 (range, 10.3–168 cm^3). Tumor pathologies included 2 craniopharyngiomas, 16 functional, and 46 nonfunctional pituitary adenomas. Suprasellar extension of tumor was evident in all patients and 10 had cavernous sinus invasion. Gross total resection was achieved in 30 patients, near-gross total in 6 patients, and subtotal resection in 26 patients. Eight patients (12.5%) demonstrated postoperative complications, with diabetes insipidus for less than 1 year ($n = 4$) being the most common. There was no incidence of CSF leak, new panhypopituitarism, or worsened vision. Five patients (7.8%) had tumor residual requiring radiation therapy. Additionally, after a mean clinical follow-up of 24.5 months, 4 patients (6.3%) demonstrated recurrent disease. *Conclusions* Direct endonasal transsphenoidal surgery enables safe and effective resection of large sellar masses while maintaining a favorable morbidity profile.

Keywords Pituitary adenoma · Transsphenoidal · Endonasal · Endoscopic · Extended

N. Sanai (✉) · J. Narvid · S. Kunwar
Department of Neurological Surgery, University of California at San Francisco, 505 Parnassus Avenue, M-779, P.O. Box 0112, San Francisco, CA 94143, USA
e-mail: sanain@neurosurg.ucsf.edu

A. Quiñones-Hinojosa
Department of Neurological Surgery, The Johns Hopkins Hospital, Brain Tumor Surgery Program & Pituitary Center, Baltimore, MD, USA

Introduction

The sublabial transsphenoidal approach has been the favored route for the resection of intrasellar tumors in prior years [1–4]. However, more recently, the endonasal transsphenoidal approach [5, 6] has steadily gained popularity in the resection of microadenomas [5, 7]. This modified approach avoids much of the soft tissue dissection, operative time, and postoperative complications (epistaxis, facial ecchymosis, and upper lip dysesthesia) associated with the traditional sublabial transsphenoidal technique, but allows for a quicker approach and closure [8–10].

Giant intrasellar tumors (>4 cm), however, often necessitate a modified surgical strategy in order to gain wider exposure. Traditionally, this meant a combined approach, employing transsphenoidal access along with a pterional or subfrontal craniotomy [11–13]. Others have advocated an "extended" sublabial transsphenoidal approach with the additional bony removal of the tuberculum sellae and proximal planum sphenoidale, which abrogated the need for a craniotomy [14]. Similarly, as the endonasal route has gained popularity, an "extended" endonasal transsphenoidal has also been effective in resecting giant intrasellar tumors

[15, 16]. Other adjunct techniques, including endoscopic assistance , intraoperative MR imaging [17, 18], and intraoperative carotid Doppler ultrasound [19–21] have also been reported to improve resection rates of giant sellar masses while minimizing operative and perioperative complication rates.

Large (3–4 cm) sellar tumors, however, represent an intermediate population that is more challenging than routine microadenomas, but falls short of "giant" status. Although the safety and efficacy of the direct endonasal approach is well-established for both routine and giant sellar lesions, its role in the treatment of large (3–4 cm) sellar masses remains undefined.

Methods

Patient population

We retrospectively reviewed inpatient, intraoperative, and outpatient data available for 64 consecutive patients with a sellar tumor greater than 3 cm in its maximal diameter who had undergone a direct endonasal transsphenoidal approach for tumor resection. The treatment dates ranged from May 2001 to July 2004 and all patients were treated by a single neurosurgeon (SK) at the University of California at San Francisco. All data collection was approved by our institutional Committee for Human Research.

Surgical technique

All patients had a lumbar drain placed following intubation to allow for saline infusion intraoperatively to sometimes bring the suprasellar component down towards the operative field. The direct endonasal approach was used in all cases with an operating microscope as well as fluoroscopy in order to evaluate bony anatomy, confirm intraoperative trajectory, and evaluate the extent of resection. In 4 cases where the anatomy was significantly altered from prior surgery, Stealth® neuronavigation (Medtronic; Minneapolis, MN) was also employed.

The initial approach through the nostril was performed using a hand-held speculum (Aesculap; Tuttlingen, Germany), taking care to identify the middle and superior nasal turbinates. This anatomy guided our trajectory and the superior ostia marked the superior extent of the approach. In no case was a relaxing alar incision used for speculum placement. Once the bony septum was fractured and displaced contralaterally, and a single mucosal incision was made along the junction of the rostrum and septum. A modified Hardy Endonasal Speculum (Aesculap; Tuttlingen, Germany) was then placed through this entrance to the sphenoid sinus, which was then enlarged to gain a wider view of the sella. The sphenoid sinus mucosal leaflets were separated with microdissectors and retracted with the endonasal speculum. The rostrum of the sphenoid sinus was identified and removed with a pituitary rongeur.

The tuberculum sella and sellar floor were visualized and confirmed with fluoroscopy. The anterior wall of the sella turcica was then removed using a Kerrison bone punch and/or an Anspach drill (Anspach Inc., Palm Beach Gardens, FL). An "extended" approach, with resection of tuberculum sellae or posterior planum sphenoidale, was not employed in any case. By identifying the carotid grooves on either side, the lateral limits of the bony exposure were noted prior to bony removal. Once the dura was exposed, it was incised sharply with an 11-blade in a rectangular fashion and then bipolar cautery was used to control bleeding. Early on, the gland was identified based on the location of the stalk on MR imaging or the anatomy of the tumor. In some cases a plane between gland and tumor or a pseudocapsule around the tumor was developed and maintained, particularly superiorly to allow descent of the suprasellar capsule. A subdural, extracapsular dissection was also employed, when necessary, to take down adhesions of the tumor capsule to the walls of the cavernous sinus laterally and to the dura of the floor of the sella inferiorly. For the suprasellar components of tumor, the central portion was debulked in order to allow the tumor capsule to prolapse downwards. Dissection was performed around the margins, particularly behind the tuberculum sella, to better allow descent of the suprasellar portion of tumor into the sella. Descent of the tumor into the sella was also facilitated by the infusion of sterile saline into the lumbar drain and/or the utilization of vasalva maneuvers when tolerated by the patient.

Prior to closure, the anesthesiologist was asked to place the patient in a Valsalva position to detect any CSF fistula between the subarachnoid space and the sella. An abdominal fat graft was then placed in the sellar cavity and held in place using 1.5 mm bioabsorbable plates (Synthes Inc., West Chester, PA) cut to the appropriate size and inserted under the dural leaflets bilaterally. Tisseel® (Baxter; Deerfield, IL) fibrin glue was then placed over the entire dural opening. The endonasal speculum was removed and the mucosal leaflets over the sphenoid sinus were then reapproximated, and the septum returned to midline. Meticulous hemostasis was achieved along the mucosa and the middle turbinates were then medialized.

In no case was nasal packing or prophylactic antibiotcs used following the procedure. In most cases, the lumbar drain was left in place, clamped, to maintain positive intracranial pressure until the 11 pm the evening of the operation, at which time the drain was removed. In cases where CSF egress was a concern, continuous lumbar drainage was used for 24 h and then removed.

Outcome analysis

Tumor characteristics of size, suprasellar extension, and cavernous sinus invasion were noted based on magnetic resonance (MR) imaging. 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, testosterone, and prolactin, when appropriate. Serum sodium levels were obtained on postoperative day 1. Urine output and urine specific gravity were recorded throughout the patient's hospital course. Both visual acuity and visual field tests as documented in clinic notes were reviewed for pre- and postoperative visual function. Complication rates were determined by examining operative and postoperative notes, as well as follow-up clinic notes. Extent of resection was determined radiographically, based upon postoperative imaging 3 months after surgery. Gross total tumor removal was defined as no residual or recurrent tumor demonstrated on the postoperative MR image. Near-gross total removal was defined by residual, small (< 5 mm) tumor fragments remaining and subtotal removal was defined by larger (>5 mm) tumor residual, but less than 1 cm. A partial resection was defined as greater than 1 cm of residual tumor.

Results

Patient characteristics

Over a 3-year period, 64 patients (median age 51 years (range 10–76 years); 29 female and 35 male patients) underwent 64 endonasal transsphenoidal operations for tumor removal (Table 1). The mean duration of procedure was 3.1 h. All patients had clinical follow-up with neurosurgery and, when appropriate, neuroendocrinology. Mean hospital stay was 3.3 days (50% on postoperative day 1 and 30% on postoperative day 2) and mean clinical follow-up was 24.5 months. Diagnoses included 2 craniopharyngiomas (Fig. 1), 16 functioning pituitary adenomas, and 46 nonfunctioning pituitary adenomas (Fig. 2). Eight patients had previously undergone transsphenoidal surgery or craniotomy for tumor resection at another institution or by other surgeons. The maximum tumor diameter ranged from 3.0 to 7.0 cm (median, 3.5 cm) and tumor volume ranged from 10.3–168 cm^3 (mean 31.5 cm^3). The majority of patients ($n = 46$, 72%) presented with visual field deficits (Table 2). Other common presenting symptoms included headache ($n = 14$, 23%), hypogonadism ($n = 6$, 9%), and ophthalmoplegia ($n = 4$, 6%). Of note, nine patients (14%) presented with pituitary apoplexy (Table 2) (Fig 3).

Table 1 Patient and tumor characteristics

Number of patients	64
Mean age	51 years
Male:female	29:35
Mean tumor volume	31.5 cm^3
Tumor pathology	
Nonfunctioning	46
GH-secreting	4
ACTH-secreting	2
PRL-secreting	10
Craniopharyngioma	2
Prior treatment	
Transsphenoidal	4
Craniotomy	4
Radiosurgery	1
Mean procedure duration	3.1 h
Mean hospital stay	3.3 days
Mean clinical follow-up	24.5 months

Classification of tumor anatomy

Although grading systems have been proposed specifically for large tumors of the sella [12], tumors in this series were categorized according to the standard Wilson classification of pituitary lesions [22]. Every patient in this series demonstrated suprasellar extension of their tumor on preoperative MR imaging (Table 3). Additionally, 3 patients (5%) had tumors that obliterated the recesses of the third ventricle and/or grossly displaced the third ventricle. 10 patients (15.6%) demonstrated parasellar extension of their tumor intracranially or into a cavernous sinus. Intraoperatively, 39 patients (61%) were noted to have tumors that locally perforated and/or diffusely destroyed the sellar floor, therefore falling into categories III and IV.

Efficacy of tumor removal

Based upon postoperative MR imaging, gross total resection was achieved in 30 of 64 patients (47%). Of the remaining patients, 6 of 64 patients (9%) demonstrated a near-gross total resection and 26 of 64 patients (41%) had a subtotal resection. To date, 4 patients (6.3%) have demonstrated radiographic recurrence of their tumor and have all been successfully treated with gamma knife radiosurgery.

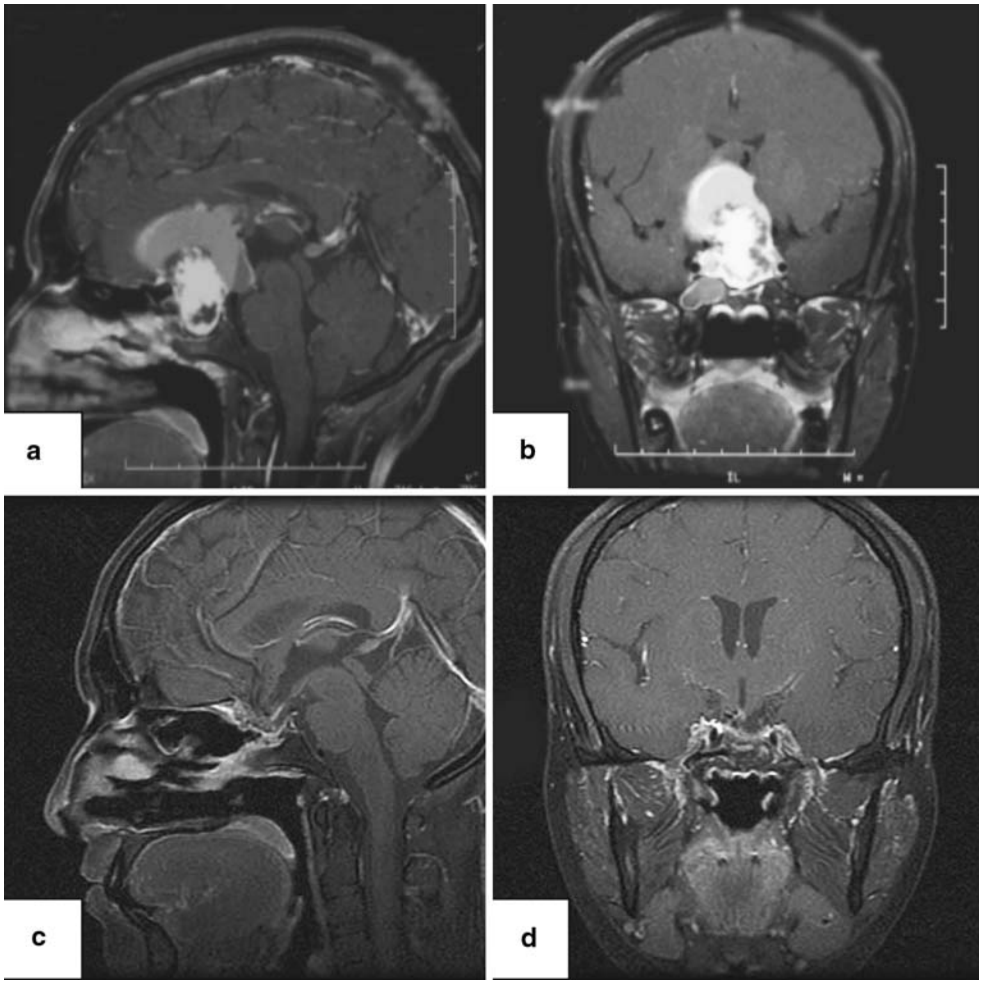

Fig. 1 29 year-old female status post transphenoidal resection of a craniopharyngioma at an outside hospital presenting with panhypopituitarism and 2 months of progressive visual loss. A preoperative MRI demonstrated a cystic 4.0 × 5.0 × 3.0 cm craniopharyngioma on (**a**) sagittal and (**b**) coronal views. Postoperatively, (**c**) sagittal and (**d**) coronal T1-weighted MR imaging demonstrate a gross-total resection. The patient's visual acuity and visual field examination have subsequently improved to near baseline

Additionally, of the 26 patients with subtotal resection, 5 (19%) required postoperative Gamma Knife radiosurgery and 7 (27%) were controlled with medical management. All other patients have been followed with serial postoperative imaging and have remained radiographically stable to date.

Neurological deficits

Preoperatively, 46 patients (71.8%) presented with visual changes, some with a combination of both visual field and visual acuity deficits (Table 4). 31 of these patients (48.4%) demonstrated bitemporal hemianopsia on physicial examination, 11 patients (17.2%) had a left or right visual field cut, 10 patients (15.6%) had low visual acuity, and 4 patients (6.3%) were blind. On last clinical follow-up, 34 of 42 patients (81%) exhibited clinical improvement of their visual fields, with 14 patients (33.3%) demonstrating complete visual field recovery. Eight (80%) of 10 patients with decreased visual acuity also showed improvement, although no patients that were completely blind preoperatively regained function. Overall, 41 (89.1%) of 46 patients experienced improvement in their preoperative visual field or acuity changes. Importantly, no patient had a decrease in visual fields or visual acuity following surgery. In regards to other neurological deficits, 4 patients (6%) demonstrated preoperative ophthalmoplegia, 3 of whom showed improvement or resolution of their symptoms following surgery. In this series, there was no incidence of new, permanent neurological deficit following surgery.

Neuroendocrinological outcome

Four patients (6.3%) experienced new endocrinopathy including 3 (4.7%) with persistent diabetes insipidus (DI) and

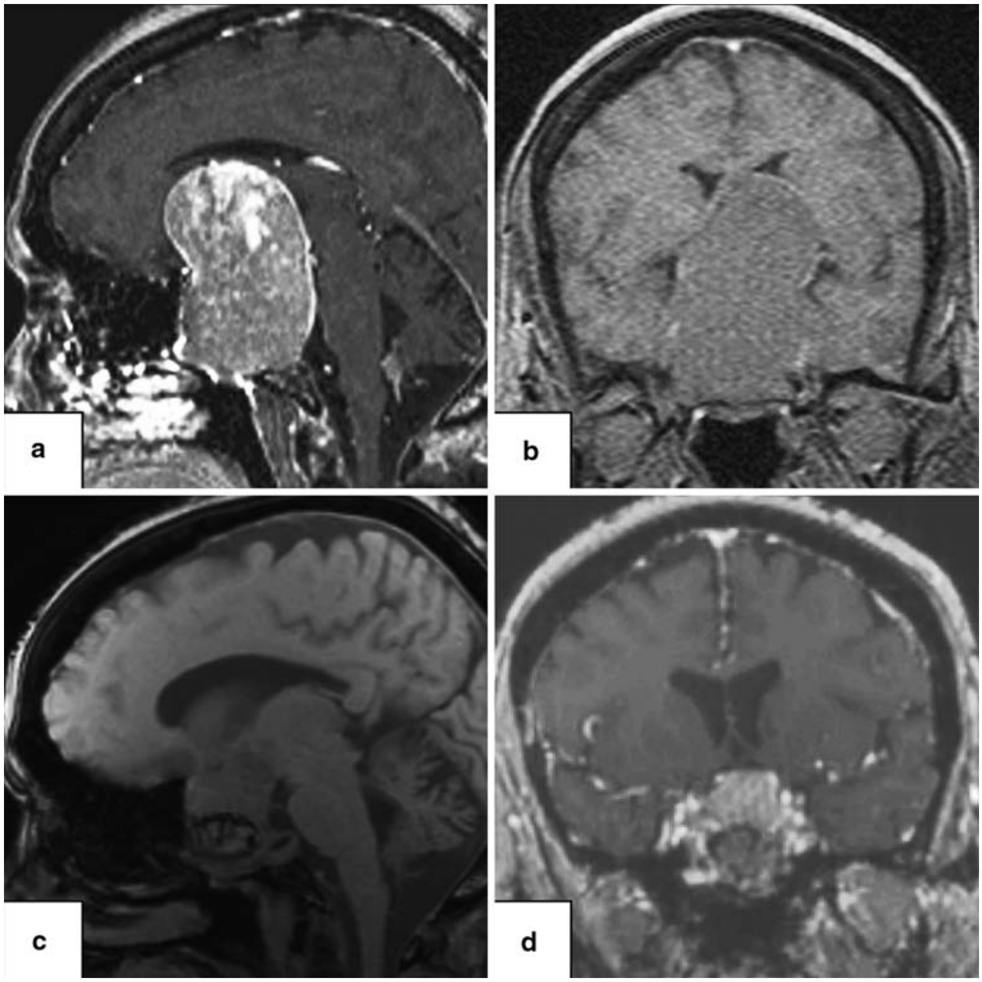

Fig. 2 58 year-old female with 5 years of progressive visual loss initially thought to be due to optic disc disease. The patient presented with light vision only and panhypopituitarism. Preoperative (**a**) sagittal and (**b**) coronal T1-weighted MR images demonstrate a 3.8 × 7.1 × 4.0 cm pituitary adenoma laterally displacing the carotid arteries and eroding into the clivus. Postoperatively, (**c**) sagittal and (**d**) coronal T1-weighted MR images show a subtotal resection of approximately 80% of the lesion with the superior portion of the tumor prolapsing downwards. The patient has regained color and movement discrimination bilaterally

Table 2 Presenting signs and symptoms

Signs/symptoms	No. of patients (frequency %)
Visual field defect	46 (71.9)
Headache	23 (35.9)
Visual acuity deficit	15 (23.4)
Apoplexy	9 (14.1)
Ophthalmoplegia	4 (6.3)
Hypogonadism	6 (9.4)
Acromegaly	6 (9.4)
Seizure	2 (3.1)

1 (1.6%) with panhypopituitarism. Preoperatively, one of these patients had preexisting anterior pituitary function failure along 3 axes; all others had normal preoperative pituitary function. One patient had transient DI lasting less than 2 weeks. The 16 functioning pituitary adenomas included 8 prolactinomas, 6 somatotrophic adenomas, 1 thyrotrophic adenoma, and 1 corticotrophic adenoma (Table 5). For patients with normal hormonal function preoperatively, the postoperative hormonal evaluation showed that normal anterior lobe function could be preserved in all cases.

Other complications

One patient with a 4 × 6 × 5 cm nonfunctioning macroadenoma developed a postoperative hemorrhage into her residual tumor with extension of the hemorrhage into the 3rd ventricle. The patient, who had been previously shunted at an outside institution for her pituitary tumor, developed hydrocephalus and had her ventriculoperitoneal shunt removed and replaced with an external ventricular drain. This drain was eventually removed and another ventriculoperitoneal shunt was placed once the CSF had

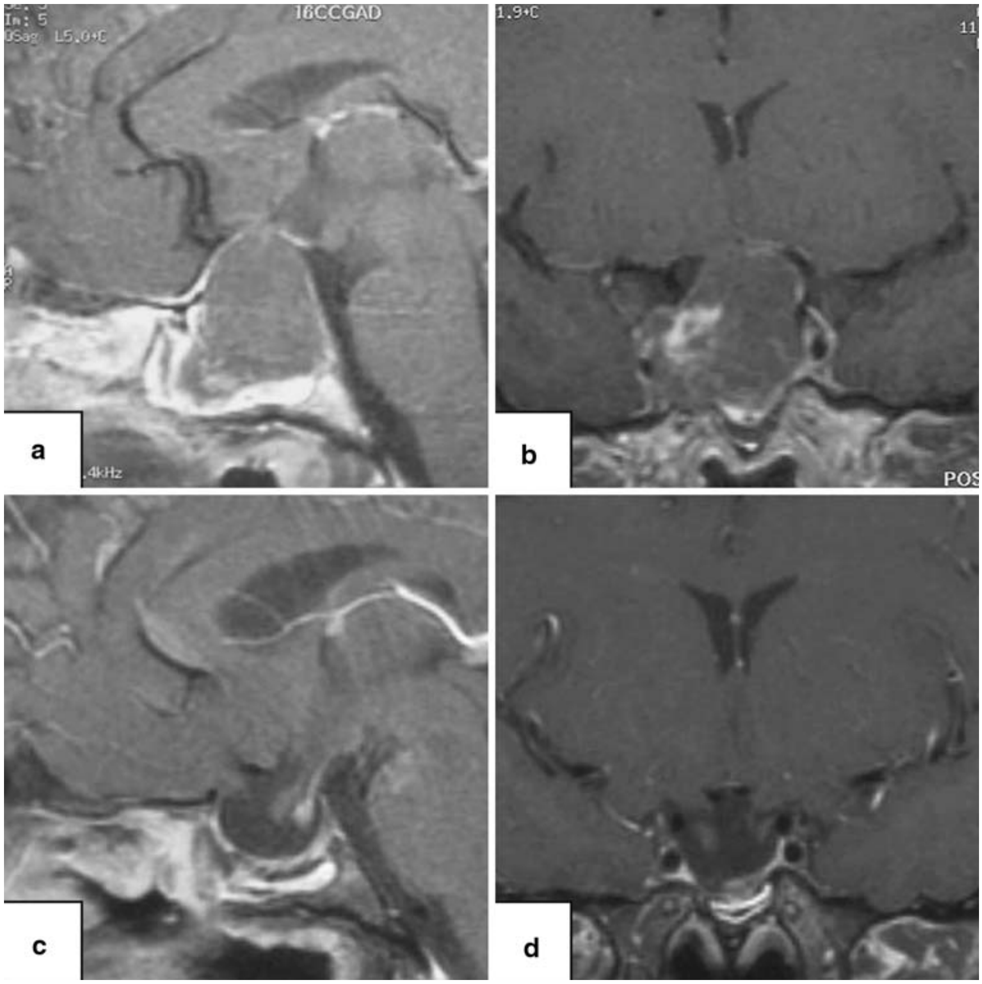

Fig. 3 40 year-old female with severe headache, a right sixth cranial nerve palsy, and acute left-eye blindness. Preoperative T1-weighted MR (**a**) sagittal and (**b**) coronal imaging shows a 3.0 × 3.5 × 3.5 cm non-enhancing, infracted pituitary adenoma without a hemorrhagic component. Following emergent decompression, postoperative (**c**) sagittal and (**d**) coronal T1-weighted MR imaging demonstrate a gross total resection. The patient experienced a near-total recovery of visual acuity and complete recovery of ophthalmoplegia

cleared. There were no new, permanent neurologic deficits attributable to the hemorrhage or hydrocephalus. Two other patients developed postoperative sinusitis, both resolving with a 5-day course of oral antibiotics. There was no incidence of new neurologic deficits, carotid artery injury, stroke, hematoma, CSF leak, meningitis, or postoperative epistaxis in any patients in our series.

Discussion

The transsphenoidal approach is being increasingly employed to successfully resect large (3–4 cm) sellar masses with a large suprasellar component that have been previously approached by more invasive methods. Here we examined the role of the endonasal transsphenoidal approach, the most simple and least traumatic surgical approach to the sella, for the resection of large tumors of this region. Our results suggest that the vast majority of challenging sellar tumors can still be resected safely, effectively, and efficiently with a standard endonasal approach.

Patient selection, as one would expect, is the most critical element in the deciding how to employ a direct endonasal approach. This is particularly true with respect to the "waist" of each tumor, where its passage through the diaphragma sella may be narrowed or widened. In our experience, a narrow "waist" and a non-enlarged sella turcica often preclude a successful gross total resection of a large sellar tumor's suprasellar component. Others have noted that such a "bottleneck" constriction at the diaphragma sellae can be a particularly dangerous risk factor for vision loss in the setting of a postoperative suprasellar hemorrhage [23]. In select cases, the diaphragmatic opening can be enlarged by removal of the tuberculum sella, however, significant lateral extension can not be approached by this method and it carries a higher risk of CSF leak.

Table 3 Radiographic and intraoperative classification of Sellar tumor

Wilson classification (21)	No. of patients (frequency %)
I	
Sella normal or focally expanded; tumor < 10 mm	0
II-O	
Sella enlarged; tumor ≥ 10 mm No suprasellar extension	0
II-A	
Sella enlarged; tumor ≥ 10 mm Occupies cistern	12 (18.8)
II-B,C	
Sella enlarged; tumor ≥ 10 mm Recesses of third ventricle obliterated or third ventricle displaced	3 (4.7)
II-D,E	
Sella enlarged; tumor ≥ 10 mm Intracranial (intradural) extension or into cavernous sinus (extradural)	10 (15.6)
III, IV	
Local perforation or diffuse destruction of sellar floor	39 (60.9)

Despite, the challenging size, parasellar extension, and bony invasion of these lesions, 56% of our patients demonstrated a gross-total or near-gross-total resection and none had a postoperative CSF leak. While endoscopic assistance can be useful in visualizing blind corners and confirming the extent of resection, our experience suggests that it may not necessary for all large sellar lesions. After 2 years of follow-up, only 4 patients have demonstrated radiographic recurrence, all of which were successfully controlled with radiosurgery. Additionally, since the endonasal approach does not require postoperative obstructive nasal packing, most of our patients were discharged home the day following the operation, which itself was often only 2–3 h in duration. This short procedure time is likely a function of both operative efficiency and the lack of additional intraoperative devices.

Although the preoperative morbidity among patients with large sellar tumors may be high, there can still be dramatic improvement postoperatively. Among our patients, 71.8% demonstrated significant visual field and visual acuity changes on preoperative examination, but 89.1% of these patients demonstrated clinical improvement postoperatively. Comparable rates of visual improvement for suprasellar adenomas have been previously reported with the transsphenoidal approach and range from 79% to 97.8% [24–26]. Similarly, the vast majority of patients showed improvement in their tumor-induced endocrinopathy, with only four patients developing worsened symptoms postoperatively.

Importantly, there was no incidence of CSF leak in any of our patients. Although the resection of large pituitary tumors can carry with it a risk of CSF leak as high as 50% [12, 16, 27, 28], this morbidity may be attributed to the use of an "extended" approach, where additional bony exposure beyond the sellar face is attempted. In our experience, the routine use of lumbar drainage to control CSF pressures and fat graft in all patients with large adenomas presenting with suprasellar extension has helped to decrease this risk of CSF leak.

The greatest risk in attempting removal of large pituitary lesions is incomplete resection or inadequate debulking of the suprasellar extension, which may lead to infarction and/or hemorrhage of this portion of the tumor with subsequent increased mass effect. This, in turn, can precipitate acute vision loss, hydrocephalus, or subarachnoid hemorrhage. One patient (1.5%) demonstrated such a complication, although this patient's residual tumor could only be safely resected through a transcranial approach. Nevertheless, this case emphasizes the tremendous importance of achieving a total resection for large sellar tumors.

Conclusions

The standard direct endonasal transsphenoidal approach using anatomical landmarks and lateral fluoroscopy

Table 4 Preoperative and postoperative visual function

		Preoperative	Postoperative examination		
			Improved	Same	Worsened
Visual fields	Intact	18	n/a	18	0
	Bitemporal Hemianopsia	31	29	2	0
	Field cut	11	5	6	0
Visual acuity	Intact	50	n/a	50	0
	Below normal	10	8	2	0
	Blind	4	0	4	n/a

Table 5 Endocrinological outcome for functional pituitary tumors

Hormone secreted	Preoperative hormone level(s)	Postoperative hormone level(s)
Prolactin	Prolactin = 266	Prolactin = 73
Prolactin	Prolactin = 1,100	Prolactin = 52
Prolactin	Prolactin = 1,200	Prolactin = 27
Prolactin	Prolactin = 5,000	Prolactin = 215
Prolactin	Prolactin = 463	Prolactin = 59
Prolactin	Prolactin = 800	Prolactin = 84
Prolactin	Prolactin = 5,000	Prolactin = 28
Prolactin	Prolactin = 2100	Prolactin = 20
Growth hormone	Insulin-like growth factor 1 = 900, Growth Hormone = 83	Growth hormone = 2.9
Growth hormone	Insulin-like growth factor 1 = 1215, Growth Hormone = 60	Growth hormone = 0.3
Growth hormone	Insulin-like growth factor 1 = 755, Growth Hormone = 72	Growth hormone = 0.4
Growth hormone	Insulin-like growth factor 1 = 455, Growth Hormone = 59	Growth hormone = 0.9
Growth hormone	Insulin-like growth factor 1 = 564, Growth hormone = 19	Growth hormone = 8.9
Growth hormone	Insulin-like growth factor 1 = 427, growth hormone = 66	Growth hormone = 2.1
Thyroid stimulating hormone	Thyroid stimulating Hormone = 11.3, Free T4 = 22	Thyroid stimulating Hormone = 3.9 Free T4 = 20
Adrenocorticotropic hormone	Adrenocorticotropic hormone = 99, Serum cortisol = 22, Urine free cortisol = 422	Adrenocorticotropic hormone = 93, Serum cortisol = 8,

appears to be a safe, effective, and efficient method for treating not only routine pituitary adenomas, but also large suprasellar adenomas and craniopharyngiomas.

References

1. Wilson CB (1997) Surgical management of pituitary tumors. J Clin Endocrinol Metab 82:2381–2385
2. Ebersold MJ, Quast LM, Laws ER Jr, Scheithauer B, Randall RV (1986) Long-term results in transsphenoidal removal of non-functioning pituitary adenomas. J Neurosurg 64:713–719
3. Honegger J, Fahlbusch R, Buchfelder M, Huk WJ, Thierauf P (1993) The role of transsphenoidal microsurgery in the management of sellar and parasellar meningioma. Surg Neurol 39:18–24
4. Jane JA Jr, Thapar K, Kaptain GJ, Maartens N, Laws ER Jr (2002) Pituitary surgery: transsphenoidal approach. Neurosurgery 51:435–442; discussion 442–434
5. Griffith HB, Veerapen R (1987) A direct transnasal approach to the sphenoid sinus. Technical note. J Neurosurg 66:140–142
6. Zada G, Kelly DF, Cohan P, Wang C, Swerdloff R (2003) Endonasal transsphenoidal approach for pituitary adenomas and other sellar lesions: an assessment of efficacy, safety, and patient impressions. J Neurosurg 98:350–358
7. Liu JK, Das K, Weiss MH, Laws ER Jr, Couldwell WT (2001) The history and evolution of transsphenoidal surgery. J Neurosurg 95:1083–1096
8. Spencer WR, Levine JM, Couldwell WT, Brown-Wagner M, Moscatello A (2000) Approaches to the sellar and parasellar region: a retrospective comparison of the endonasal-transsphenoidal and sublabial-transsphenoidal approaches. Otolaryngol Head Neck Surg 122:367–369
9. Sheehan MT, Atkinson JL, Kasperbauer JL, Erickson BJ, Nippoldt TB (1999) Preliminary comparison of the endoscopic transnasal vs the sublabial transseptal approach for clinically nonfunctioning pituitary macroadenomas. Mayo Clin Proc 74:661–670
10. Das K, Spencer W, Nwagwu CI, Schaeffer S, Wenk E, Weiss MH, Couldwell WT (2001) Approaches to the sellar and parasellar region: anatomic comparison of endonasal-transsphenoidal, sublabial-transsphenoidal, and transethmoidal approaches. Neurol Res 23:51–54
11. Fahlbusch R, Schott W (2002) Pterional surgery of meningiomas of the tuberculum sellae and planum sphenoidale: surgical results with special consideration of ophthalmological and endocrinological outcomes. J Neurosurg 96:235–243
12. Goel A, Nadkarni T, Muzumdar D, Desai K, Phalke U, Sharma P (2004) Giant pituitary tumors: a study based on surgical treatment of 118 cases. Surg Neurol 61:436–445; discussion 445–436
13. Alleyne CH Jr, Barrow DL, Oyesiku NM (2002) Combined transsphenoidal and pterional craniotomy approach to giant pituitary tumors. Surg Neurol 57:380–390; discussion 390
14. Weiss MH (1987) Transnasal transsphenoidal approach. In: Apuzzo MLJ (ed) Surgery of the third ventricle. Williams & Wilkens, Baltimore, pp 476–494
15. Agrawal A, Cincu R, Goel A (2007) Current concepts and controversies in the management of non-functioning giant pituitary macroadenomas. Clin Neurol Neurosurg 109(8):645–650
16. Dusick JR, Esposito F, Kelly DF, Cohan P, DeSalles A, Becker DP, Martin NA (2005) The extended direct endonasal transsphenoidal approach for nonadenomatous suprasellar tumors. J Neurosurg 102:832–841
17. Nimsky C, von Keller B, Ganslandt O, Fahlbusch R (2006) Intraoperative high-field magnetic resonance imaging in transsphenoidal surgery of hormonally inactive pituitary macroadenomas. Neurosurgery 59:105–114; discussion 105–114
18. Schwartz TH, Stieg PE, Anand VK (2006) Endoscopic transsphenoidal pituitary surgery with intraoperative magnetic resonance imaging. Neurosurgery 58:S44–S51; discussion ONS44–S51
19. Dusick JR, Esposito F, Malkasian D, Kelly DF (2007) Avoidance of carotid artery injuries in transsphenoidal surgery with the Doppler probe and micro-hook blades. Neurosurgery 60:322–328; discussion 328–329

20. Ram Z, Bruck B, Hadani M (1999) Ultrasound in pituitary tumor surgery. Pituitary 2:133–138
21. Yamasaki T, Moritake K, Nagai H, Kimura Y (2002) Integration of ultrasonography and endoscopy into transsphenoidal surgery with a “picture-in-picture” viewing system–technical note. Neurol Med Chir (Tokyo) 42:275–277; discussion 278
22. Wilson CB (1979) Neurosurgical management of large and invasive pituitary tumors. In: Tindall GT, Collins, WF (ed) Clinical managment of pituitary disorders. Raven Press, New York, pp 335–342
23. Barrow DL, Tindall GT (1990) Loss of vision after transsphenoidal surgery. Neurosurgery 27:60–68
24. Cohen AR, Cooper PR, Kupersmith MJ, Flamm ES, Ransohoff J (1985) Visual recovery after transsphenoidal removal of pituitary adenomas. Neurosurgery 17:446–452
25. Marazuela M, Astigarraga B, Vicente A, Estrada J, Cuerda C, Garcia-Uria J, Lucas T (1994) Recovery of visual and endocrine function following transsphenoidal surgery of large nonfunctioning pituitary adenomas. J Endocrinol Invest 17:703–707
26. Zhang X, Li A, Yi S, Zhang Z, Fei Z, Zhang J, Fu L, Liu W, Chen Y (1998) Transsphenoidal microsurgical removal of large pituitary adenomas. Chin Med J (Engl) 111:963–967
27. Kim J, Cheong J, Yi H, Bak K, Kim C, Lee S (2002) Usefulness of silicone plate for sellar floor reconstruction. Minim Invasive Neurosurg 45:124–127
28. Kitano M, Taneda M (2004) Subdural patch graft technique for watertight closure of large dural defects in extended transsphenoidal surgery. Neurosurgery 54:653–660; discussion 660–651