

Extended endoscopic endonasal approach for selected pituitary adenomas: early experience

Clinical article

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Object. Whereas most pituitary adenomas are removable via the transsphenoidal approach, certain cases, such as dumbbell-shaped or suprasellar adenomas and recurrent and/or fibrous tumors, remain difficult to treat. The authors present their experience with the extended endoscopic endonasal approach to the suprasellar area in managing this subset of tumors, which are classically treated through a transcranial route.

Methods. From June 1997 to December 2008, 615 patients underwent endoscopic endonasal transsphenoidal surgery for pituitary adenomas in the Department of Neurosurgery of the Università degli Studi di Napoli Federico II. Of this group, 20 patients with pituitary adenomas needed an extended endoscopic endonasal transtuberulum/transplanum approach for tumor removal. Two surgical corridors were used during the transsphenoidal approach: 1) the conventional endosellar extraarachnoidal corridor and 2) a suprasellar transarachnoidal corridor.

Results. The extent of resection was gross total in 12 (60%) of the 20 patients, near total in 4 (20%), subtotal in 3 (15%), and partial in 1 (5%). Postoperative CSF leakage occurred in 1 patient. One patient experienced worsening of temporal hemianopsia.

Conclusions. The authors' initial results with the extended endoscopic approach to the suprasellar area for selected pituitary adenomas are promising and may justify a widening of the current classical indications for transsphenoidal surgery. (DOI: 10.3171/2010.9.JNS10262)

KEY WORDS • extended endoscopic endonasal approach •
pituitary adenoma • transsphenoidal surgery • fibrous adenoma •
dumbbell adenoma • extended suprasellar approach

PITUITARY adenomas are common, constituting approximately 15%–20% of primary intracranial neoplasms, and are the third most frequent histological type.²⁶ Whereas the transsphenoidal approach is widely accepted as the standard surgical technique for most pituitary adenomas, certain pituitary adenomas, such as those with an “hourglass” or “dumbbell” configuration; selected giant, recurrent, or fibrous adenomas; and purely suprasellar adenomas remain difficult and are considered relative contraindications to transsphenoidal resection.

With our growing experience with the extended endoscopic endonasal approach⁴ to the planum sphenoidale and tuberculum sellae,^{3,11,22} we have begun to widen our surgical indications to include the above-mentioned selected cases of pituitary adenomas. In this article we present our preliminary results with the extended endonasal approach in the management of pituitary adenomas.

Abbreviations used in this paper: EEEA = extended endoscopic endonasal approach; GH = growth hormone; PRL = prolactin.

Methods

Study Design

This study is a retrospective outcome review of pituitary adenomas removed via an extended endoscopic endonasal approach tailored to the suprasellar area. Selection criteria included giant adenomas; recurrent and/or fibrous adenomas; and dumbbell-shaped or pure suprasellar adenomas in which, aside from the standard intracapsular emptying of the lesion, an additional extracapsular dissection was made thanks to the wide osteodural opening obtained over the sella. The decision to proceed with an expanded endonasal approach was dictated either by radiological appearance preoperatively (for example, a frank dumbbell appearance) or by intraoperative findings (for example, a firm, fibrous tumor consistency or failure of suprasellar tumor to descend into the surgical corridor). Fibrous tumors were defined as those adenomas that, because of their consistency, were not removable by means of curettage and suctioning. Dumbbell-shaped tumors were defined by the presence of a competent dia-

phragma sellae creating a focal constriction between the sellar tumor and a large suprasellar component.

Patients were excluded if additional lateral extension of the approach would have been necessary for complete removal, as was the case in 2 patients with wide cavernous sinus invasion. Tumor invasiveness was described according to the Hardy-Vezina classification scheme.²⁹ The extent of cavernous sinus invasion was assessed on coronal postcontrast T1-weighted MR images and graded according to the Knosp scale.⁴⁰ The extended approach used was described according to nomenclature previously published,^{33,34,55} including that of our own group.¹⁷ Outcome measures included extent of resection, visual and hormonal outcomes, and surgical complications, including the rate of postoperative CSF fistula formation. The extent of resection was categorized as gross total (100% resection), near total (> 90% resection), subtotal (> 70% resection), and partial (< 70% resection) based on the 3-month postoperative MR imaging.

Operative Technique

The primary steps of the extended purely endoscopic endonasal technique used at our institution have been described in detail in previous publications.^{4,20,33} The basic steps of the extended endoscopic approach as originally defined by Kassam et al.³³ include 1) removal of the middle turbinate on one side, 2) lateralization of the contralateral middle turbinate, 3) posterior septectomy, and 4) a wide anterior sphenoidotomy. These maneuvers allow introduction of 2 or 3 instruments, in addition to the endoscope, into both nostrils.

Standard adjuncts include use of a high-speed microdrill, dedicated low-profile instruments, and a micro-Doppler probe. A rigid endoscope measuring 4 mm in diameter with 0° and 30° lenses (Karl Storz) was used. Neuronavigation was used in all surgeries and was particularly useful in recurrences in which the usual surgical landmarks (sellar floor, clival indentation, carotid and optic nerve protuberances, and the opticocarotid recess) were obscured by scar tissue, violated, or remodeled by tumor expansion and not easy to identify.

For intrasellar intracapsular debulking, the same principles of conventional transsphenoidal microsurgery were applied, including curettage and suction. Nevertheless, in most cases such maneuvers were ineffective in obtaining a satisfactory debulking of the lesion or a descent of its suprasellar component.

Except for a case of purely suprasellar pituitary adenoma, we found in all cases an obliterated superior intercavernous sinus due to compression by the suprasellar part of the tumor, a condition different from what we usually encounter in treating craniopharyngiomas, but similar to the one in tuberculum sellae meningiomas treated through the endonasal approach.

For extracapsular access in the suprasellar space, the planum sphenoidale is removed using a high-speed microdrill starting from the tuberculum sellae and continuing to the optic strut laterally and to the anterior wall of the sphenoid sinus anteriorly, depending on the extension of the suprasellar component of the adenoma.

The dura over the planum is then opened, allowing visualization of the suprasellar part of the lesion. This part of the lesion is debulked and its capsule is dissected from the surrounding neurovascular structures through an arachnoid plane, using microscissors and sharp dissection in a manner similar to open microsurgical technique (Figs. 1–3).

Reconstruction of the cranial base defect following tumor removal is accomplished following the same principles used during extended suprasellar approaches. Large osteodural defects with significant transgression into the subarachnoid space are repaired in the following manner. Initially the intradural space is filled with a thin layer of fibrin glue to seal the arachnoid space,⁷ followed by a heterologous dural substitute combined with an autologous septal bone or synthetic bone substitute (Lactosorb), which is placed extradurally in an overlapping fashion^{10,44} when the bony borders are detachable from the dura. If this is not possible, multiple layers of dural substitute are overlapped over the posterior wall of the sphenoid sinus to cover the osteodural defect; in some cases this technique is used in combination with a pedicled nasoseptal flap.^{28,36,51} The sphenoid sinus is packed with either cel-

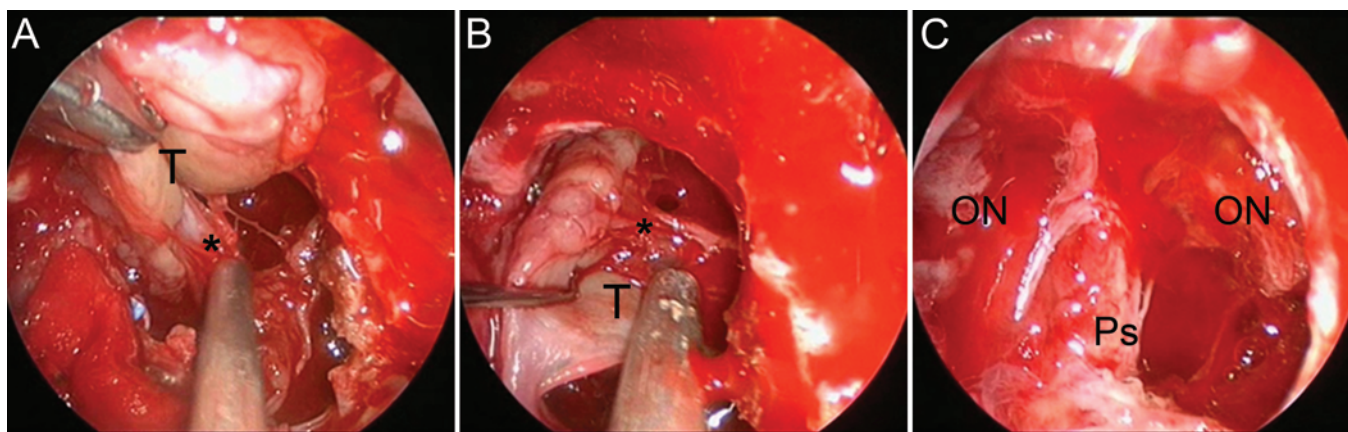


FIG. 1. Case 13. **A and B:** Arachnoid dissection of the tumor capsule of a recurrent pituitary adenoma. **C:** Panoramic view of the surgical field after lesion removal. The asterisks indicate arachnoid adhesions. T = tumor; ON = optic nerve; Ps = pituitary stalk.

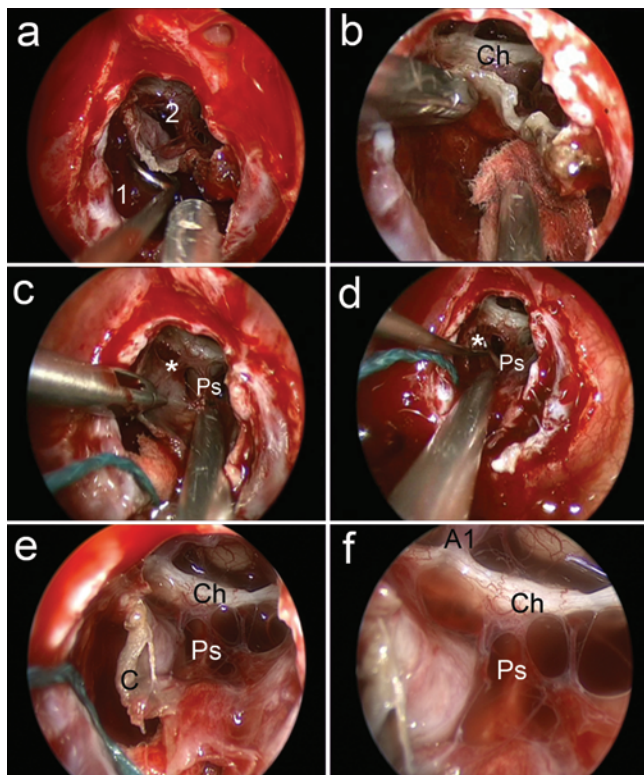


FIG. 2. Case 19. Intraoperative photographs illustrating the double corridor technique used for the removal of a recurrent fibrous pituitary adenoma. **a:** Following removal of the tuberculum sellae and the posterior part of the planum sphenoidale, two surgical corridors are used to remove the lesion: a conventional endosellar extraarachnoid corridor (1) and a suprasellar transarachnoid corridor (2). **b:** Close-up view of the endosellar corridor after sellar emptying. **c:** View of the suprasellar corridor with arachnoid adhesions between the tumor capsule and the optic chiasm. **d:** Dissection of the arachnoid adhesions with a microdissector. **e and f:** Panoramic (**e**) and close-up (**f**) views of the surgical field at the end of the procedure. The asterisks indicate arachnoid adhesions. Ch = chiasm; A1 = anterior cerebral artery; C = tumor capsule.

lulose gelatin (Surgicel) or collagen sponge and surgical glues (Tisseel or DuraSeal).^{5,10,42,44}

Results

We have been performing pure endoscopic transsphenoidal surgery since 1997 and started using EEEAs in 2003 for a variety of histologically different lesions.⁸ To date, 92 EEEAs have been performed by the senior authors in the Department of Neurosurgery of the Università degli Studi di Napoli Federico II (L.M.C., P.C.). Of these, 20 were removals of pituitary adenomas via EEEA; these 20 lesions were included a larger group of 615 pituitary adenomas resected via a standard endoscopic transsphenoidal approach during the same period. Five additional pituitary adenomas were removed via craniotomy. Among the 20 patients who underwent an EEEA in our case series, 3 had previously undergone surgical treatment elsewhere via craniotomy.

The demographic and clinical characteristics of the

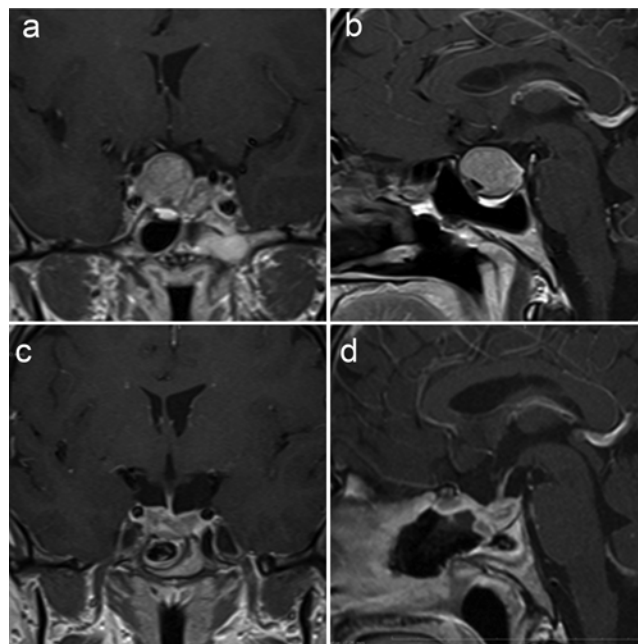


FIG. 3. Case 19. Preoperative (**a and b**) and postoperative (**c and d**) coronal and sagittal MR images of the recurrent fibrous pituitary adenoma shown in Fig. 2.

20 patients who underwent EEEA for resection of pituitary adenomas are summarized in Table 1. The mean age for the cohort was 49.4 years and the male/female ratio was 1.75:1. Of the 20 patients, 16 (80%) had undergone prior surgical treatment, including craniotomy in 3 cases, microscopic transsphenoidal surgery in 10, and endoscopic transsphenoidal surgery in 5. Three patients had been treated with radiation therapy. Five (25%) of the pituitary adenomas were secretory (2 prolactinomas, 2 GH-secreting adenomas, and 1 PRL-GH cosecreting adenoma) and refractory to medical management and/or prior resection. The remaining 15 were nonfunctioning macroadenomas.

With regard to tumor configuration, there were 9 adenomas with intrasuprasellar extension, 3 intrasuprasellar adenomas with dumbbell configurations, 1 purely suprasellar adenoma, and 7 giant adenomas, including 3 with a wide suprasellar extension, 1 with a wide parasellar extension, and 1 with nasopharyngeal extension (see Fig. 4). The degree of cavernous carotid encasement was described according to the Knosp grade.⁴⁰ In 6 cases (35%), the Knosp grade was 3 or 4 corresponding to cavernous sinus invasion; in the remainder, the Knosp grade was 1 or 2. All the patients in the present series underwent a transplanum/trans-tuberculum approach. The extent of resection was gross total in 12 (60%), near total in 4 (20%), subtotal in 3 (15%), and partial in 1 (5%); hence, more than 90% resection was achieved in 80% of cases. The intraoperative tumor consistency as appreciated by the senior authors was fibrous or partially fibrous in 12 (60%) of 20 cases.

In the 5 patients with endocrinologically functioning tumors, surgery resulted in a cure without medical therapy in 1 patient who had a GH-secreting tumor (Case 18).

TABLE 1: Characteristics of 20 cases of pituitary adenoma treated by means of an EEEA*

Case No.	Age (yrs), Sex	Pathology	Tumor Configuration	Cavernous Sinus Extension (Knosp grade)	Previous Treatment
1	54, M	null cell	intrasuprasellar	2	ETA
2	40, M	null cell	intrasuprasellar	2	
3	44, M	null cell	intrasuprasellar	2	TCA
4	58, F	null cell	giant, w/ wide parasellar extension	4	
5	55, M	silent ACTH-sec	giant, w/ rhinopharynx extension	4	MTA
6	33, M	PRL-sec	giant w/ larger suprasellar extension	4	P
7	25, F	null cell	purely suprasellar	—	MTA
8	50, F	null cell	giant w/ larger suprasellar extension	2	MTA
9	75, M	GH-PRL sec	giant	3	ETA, TCA, P
10	62, M	null cell	intrasuprasellar	1	MTA
11	40, F	GH-sec	dumbbell-shaped	3	TCA, P
12	41, M	null cell	intrasuprasellar	2	
13	73, M	null cell	dumbbell-shaped	2	MTA, RT
14	47, F	null cell	giant w/ larger suprasellar extension	1	ETA
15	60, M	null cell	giant	2	MTA
16	47, F	PRL-sec	intrasuprasellar	3	MTA, ETA, P, RT
17	68, F	null cell	intrasuprasellar	2	MTA, MTA, RT
18	42, M	GH-sec	dumbbell-shaped	1	P
19	39, M	null cell	intrasuprasellar	2	MTA, ETA
20	42, M	null cell	intrasuprasellar	2	

* ACTH = adrenocorticotropic hormone; ETA = endoscopic transsphenoidal approach; MTA = microsurgical transsphenoidal approach; P = pharmacological therapy; RT = radiotherapy; sec = secreting; TCA = transcranial approach; — = suprasellar tumor without cavernous sinus involvement.

In 3 patients (Cases 6, 11, and 16), control was achieved with medical therapy in addition to surgery; in 1 patient with a GH-PRL secreting tumor (Case 9), control was not achieved despite surgery and medical therapy.

The mean follow-up period was 24.9 months (range 6–46 months) (Table 2).

In 14 of 20 cases, an EEEA was planned preoperatively based on the results of preoperative MR imaging or on findings from previous operations, whereas in 6 cases, an intraoperative decision was made to convert to an EEEA due to unforeseen conditions encountered—namely fibrous tumor consistency and/or lack of descent of suprasellar tumor.

With respect to visual outcome, 14 of 20 patients had a preoperative visual field defect. Postoperatively, the defect completely resolved in 2 cases, improved in 10, and remained stable in 1. The remaining patient (Case 4) experienced a worsening of the visual field defect in the left eye as described below (Table 3). The results and complications of the present series are listed in Tables 2, 3, and 4. There were no perioperative mortalities. One patient had postoperative CSF rhinorrhea (Case 17), resulting in a series rate of 5%. This patient underwent a successful reoperation to repair the osteodural defect. One patient experienced a further worsening of a left temporal hemianopsia 1 week after removal of a giant adenoma with a wide left parasellar extension (Case 4). One patient (Case 9) died of tumor progression. This patient was a man who

had undergone a prior craniotomy and transsphenoidal resection of a prolactinoma that was refractory to medical therapy. At the age of 75 years, he underwent a subtotal resection via an EEEA at our institution. He was subsequently treated with a course of temozolomide therapy and ultimately died of local progression 2.5 years postoperatively. Interestingly, the resected tumor specimen had an elevated Ki 67 labeling index of 15%.

Discussion

Although more than 90% of pituitary adenomas may be successfully removed via a transsphenoidal approach, there are a number of relative contraindications that remain similar to those initially put forth by Guiot in the 1960s.²⁷ These include adenomas with fibrous consistency and/or with an “hourglass” or “dumbbell” configuration.⁴⁶ In these cases, blind curettage through the constriction may be complicated by transgression of instruments into the subarachnoid space causing CSF leak and/or injury to the optic apparatus or adjacent perforating vessels. Other relative contraindications to transsphenoidal removal include fibrous or recurrent tumors for which curettage via a standard transsphenoidal technique is difficult. Exclusively suprasellar adenomas and adenomas whose suprasellar component fails to descend into the sella are also difficult to remove via a simple transsphenoidal approach,

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as are many giant pituitary adenomas. Surgical options include combined or staged transsphenoidal-transcranial approaches^{2,16,50} and staged transsphenoidal resections after residual tumor descends into the sella.^{1,52,60} Some authors have used lumbar infusions or air injection to encourage descent of the suprasellar tumor component.^{57,61} This is the first report concerning the removal of selected pituitary adenomas using an extended endoscopic endonasal transtuberculum/transplanum approach.

The population of pituitary adenomas we considered is certainly selective and these lesions were, in fact, more difficult: the majority of patients either had undergone previous surgery (or radiation) and had significant scar/fibrous tissue formation or had tumors with morphological characteristics (hourglass shape with competent diaphragma sellae, large suprasellar components) that would otherwise render standard transsphenoidal removal difficult.

The extended endonasal transsphenoidal approach, with microscopic and/or endoscopic visualization, has become well established in a number of surgical centers, and is used with expanding indications for a variety of midline skull base lesions.^{4,6,9,12,14,15,18,19,21–24,30–35,37–39,41–43,45,48,54,55,58}

The transtuberculum/transplanum approach was proposed within the last decade to address selected midline suprasellar lesions, such as craniopharyngiomas, Rathke cleft cysts, or tuberculum sellae meningiomas. Selected pituitary adenomas have also been treated with such an extended approach, but this has been limited to a handful of case reports, including that of Weiss in 1987,⁵⁹ Mason et al. in 1997,⁴⁷ and others.^{32,62}

As an extension of our growing experience with the EEEA,⁴ we have widened our own indications for endonasal resection of pituitary adenomas to include 1) dumbbell-shaped adenomas, 2) pure suprasellar adenomas or adenomas whose suprasellar component fails to descend within the sella after sellar debulking, and 3) recurrent and/or fibrous adenomas. In this manuscript we have described an endoscopic transsphenoidal approach in which, besides opening the sella, an additional bony and dural removal is made over the planum sphenoidale. This allowed us to obtain a double surgical corridor. The first, an endosellar, extraarachnoidal corridor is implemented for debulking the sellar component of a tumor; the second, a suprasellar transarachnoidal corridor to debulk the suprasellar component of the lesion and to sharp-dissect the tumor capsule from the overlying parasellar cisterns and optic apparatus under direct visualization.

A dumbbell-shaped adenoma configuration is not a usual indication for an extended transsphenoidal approach. Most cases can be treated with a standard microscopic or endoscopic transsphenoidal approach through a single or staged approach. In the 3 cases of tumors with a dumbbell configuration in which we had planned an extended approach from the outset, the patients had a very narrow diaphragma opening that made descent of the suprasellar component of the lesion improbable. Furthermore, 2 of these 3 patients had undergone a previous operation: 1 (Case 11) via a transcranial approach and the other (Case 13) via a transsphenoidal approach. We recommend converting a standard approach to an extended

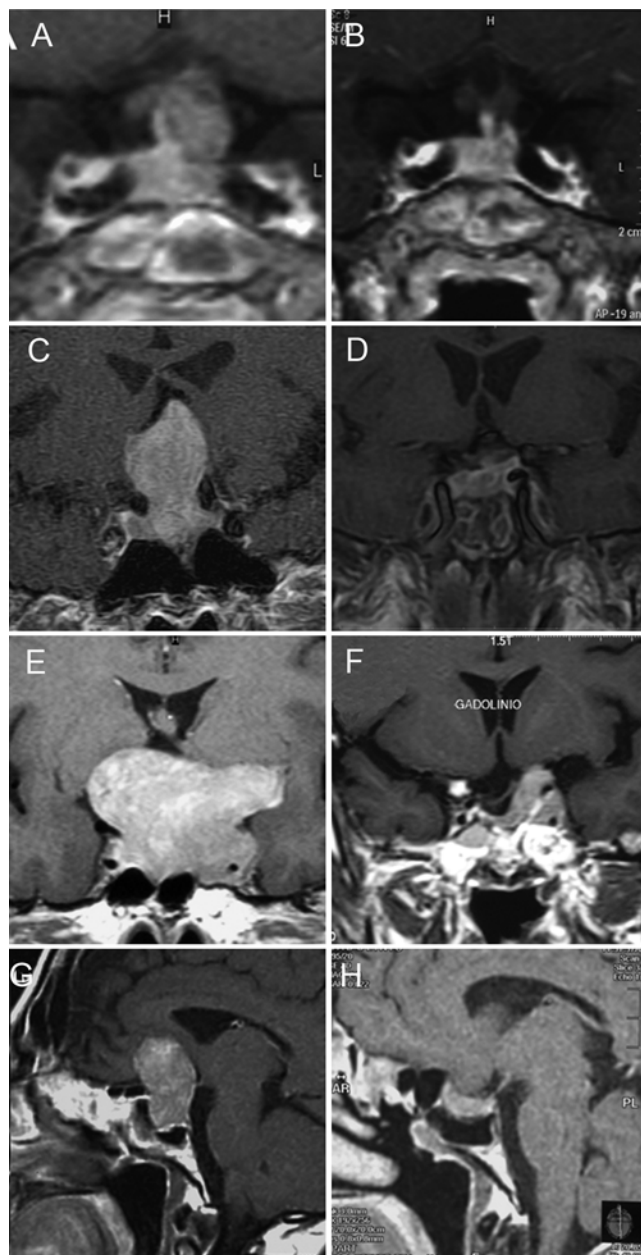


FIG. 4. Preoperative and postoperative MR images obtained in selected cases of pituitary adenomas treated with an EEEA. **A and B:** Coronal preoperative (**A**) and postoperative (**B**) MR images showing a macroadenoma with purely suprasellar extension (Case 7). **C and D:** Coronal preoperative (**C**) and postoperative (**D**) MR images showing an intrasellar and suprasellar dumbbell-shaped macroadenoma (Case 15). **E and F:** Coronal preoperative (**E**) and postoperative (**F**) MR images showing a giant macroadenoma with intrasellar, suprasellar, and wide parasellar extension (Case 5). **G and H:** Sagittal preoperative (**G**) and postoperative (**H**) MR images showing a sella-suprasellar adenoma with a primarily vertical growth axis (Case 1).

approach only when a relatively large suprasellar remnant of the lesion fails to descend and is therefore difficult to remove. In such cases use of the EEEA can minimize the risk of swelling. For patients who have undergone prior craniotomy, the EEEA offers a virgin surgical route on the opposite side of a fibrotic or gliotic reaction from the

TABLE 2: Clinical findings and results in 20 cases*

Case No.	Preop Endocrine Function	Tumor Consistency	Extent of Resection	Pathology	Complications	Postop Endocrine Function/Therapy	FU (mos)
1	normal	soft	GTR	null cell	none	normal	46
2	pan-HP	fibrous	GTR	null cell	none	unchanged	40
3	normal	soft	GTR	null cell	none	normal	37
4	normal	soft & fibrous	near-total	null cell	none	hydrocortisone, L-thyroxine	35
5	normal	fibrous	STR	silent ACTH	none	normal	34
6	↑PRL, ↓FSH-LH, ↓testosterone	soft & fibrous	near-total	PRL-sec	none	cabergoline	34
7	normal	soft	GTR	null cell	none	normal	32
8	normal	soft	GTR	null cell	none	normal	31
9	pan-HP, ↑PRL	soft & fibrous	partial	GH-PRL sec	none	unchanged	30 (disease progr, death)
10	normal	soft	GTR	null cell	none	normal	27
11	↑GH, ↑IGF-I	soft	STR	GH-sec	none	octreotide LAR	24
12	pan-HP	fibrous	GTR	null cell	none	unchanged	24
13	↓cortisol, ↓testosterone	fibrous	GTR	null cell	none	unchanged	23
14	normal	soft & fibrous	GTR	null cell	none	hydrocortisone, L-thyroxine	18
15	normal	fibrous	near-total	null cell	none	hydrocortisone	14
16	↑PRL	fibrous	STR	PRL-sec	none	cabergoline	14
17	pan-HP	fibrous	near-total	null cell	CSF rhinorrhea	unchanged	12
18	↑IGF-I	soft	GTR	GH-sec	none	normal	10
19	normal	soft & fibrous	GTR	null cell	none	normal	7
20	normal	soft	GTR	null cell	none	normal	6

* CN = cranial nerve; FSH = follicle-stimulating hormone; FU = follow-up; GTR = gross-total resection; IGF-I = insulin-like growth factor-I; LAR = long-acting release; LH = luteinizing hormone; pan-HP = panhypopituitarism; progr = progression; STR = subtotal resection.

intracranial operation. Areas of the tumor that may not have been accessed in the first operation, such as retrochiasmatic, subchiasmatic, and in some cases sellar components, can be visualized directly in the plane of the endonasal approach without disruption by surgical arachnoid scarring. The EEEA may thus be complementary to craniotomy in some difficult-to-treat pituitary adenomas or may represent an alternative approach for tumors with configurations that would make them difficult or unsafe to access via craniotomy. In cases in which a conventional transsphenoidal operation had been previously performed, either from sublabial or transseptal incisions, and reoperation using the same approach would have been difficult, the EEEA also provides a relatively well-preserved route. Finally, for repeated endoscopic endonasal approaches, the nasal corridor is typically well preserved aside from occasional synechia formation, and we have not encountered significant limitations.

We have noted several other advantages using the endoscopic endonasal approach for selected pituitary adenomas. First, it may offer a greater extent of resection for certain adenomas and avoids an anterior skull base approach or staged transsphenoidal approach. Second, blind curettage of the suprasellar component of adenoma through the diaphragma sellae is avoided, potentially reducing the risk of neurovascular injury. Furthermore, anatomical relationships of certain pituitary adenomas may

favor a purely endonasal resection versus an anterior cranial approach, such as below the chiasm in the retrosellar space, which is in fact extended in the endonasal corridor. Even in the presence of large lesions, the extended endonasal approach facilitates exposure of a wide part of the lesion just after the dural opening over the sellar-suprasellar space and thus allows the surgeon to avoid any retraction of neurovascular structures. This advantage is critical, especially for the optic apparatus, and the associated morbidity remains low using such an approach. The tumor is dissected from the neurovascular structures in a method different from that used in the transcranial route; in fact, all the dissection maneuvers are made over the tumor surface without the risk of brain injury or traction on the olfactory tracts. Finally, when treating macroadenomas, the residual pituitary gland can be difficult to recognize. With the endoscope, the tumor-gland interface can be better distinguished due to its closer position near the surgical target area, hence facilitating dissection of the tumor pseudocapsule.^{25,58}

The primary disadvantages of the EEEA for these selected pituitary adenomas includes the substantial increase in potential morbidity compared with a simpler standard transsphenoidal technique, most notably the increased risk of CSF leak—5% in our series, compared with the rate of less than 1% associated with standard pituitary surgery. Nevertheless the current rate is substan-

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TABLE 3: Visual outcome in 20 cases*

Case No.	Preop Visual Function	Visual Outcome
1	bitemporal hemianopsia (OD > OS)	improved
2	quadrantopsia in OS	improved
3	bitemporal hemianopsia	improved
4	bitemporal hemianopsia	worsened in OS
5	normal	unchanged
6	bitemporal hemianopsia	improved
7	temporal hemianopsia in OS	recovery
8	bitemporal hemianopsia	recovery
9	rt CN III palsy	unchanged
10	normal	unchanged
11	normal	normal
12	concentric defect in OS	unchanged
13	bitemporal hemianopsia (OS > OD)	improved
14	bitemporal hemianopsia	improved
15	bitemporal hemianopsia (OD > OS)	improved
16	rt CN III & VI palsy	unchanged
17	bitemporal hemianopsia	improved
18	normal	normal
19	bitemporal hemianopsia	improved
20	bitemporal hemianopsia	improved

* OD = right eye; OS = left eye.

tially lower than that reported in earlier series, thanks in large part to the use of the nasoseptal flap³⁶ and meticulous multilayer reconstruction of the cranial base defect.^{5,10} This method of reconstruction is more technically demanding and requires additional experience and dedicated surgical tools, because the anatomy is faced from a different and even opposite point of view.

Additionally, specific limitations should be emphasized in relationship to both the surgical route and the lesion itself. Anatomical variations in the sphenoid sinus can influence lesion management via the transsphenoidal

route. If a well-pneumatized sphenoid sinus allows a better visualization of all important landmarks, thus favoring surgical orientation, a conchal-type sphenoid sinus represents an obstacle; a small sella, with 2 close intracavernous carotid arteries, could determine a narrower approach, while an enlarged sella, especially if the tumor protrudes inside the sphenoid sinus, renders the approach much easier. The limitations concerning the lesion are mainly related to its position, which for the most part is in the midline and within the range of the maneuverability of the surgical instruments and without the presence of vessel encasement. Invasive pituitary adenomas, with transgression through the sellar dura or the medial wall of the cavernous sinus or with infiltration into the suprasellar space, occur with a relatively high frequency, and larger tumors are particularly likely to be invasive.^{13,49,53,56} In grossly invasive tumors, opening into the subarachnoid space is unlikely to be warranted given the low likelihood of gross-total resection.

In performing extracapsular dissection of the adenoma, it is necessary to use instruments designed for extended approaches to the planum sphenoidale and tuberculum sellae for the removal of tumors such as meningiomas or craniopharyngiomas; these instruments include microscissors, hooks, and micrograsping forceps. In some instances, we have used the ultrasonic aspirator. Indeed, lesion removal was not limited by the consistency of the lesion in any case, but rather by the invasion of the cavernous sinus/sinuses or the parasellar compartment.

Limitations of the current study include the small study population, the lack of a control group, and the evolving techniques of endoscopic endonasal surgery, particularly with respect to reconstruction and closure, during the study period. Nevertheless, this preliminary series of challenging pituitary adenomas seems to support the expansion of indications for the EEEA, given the extent of resection achieved and the limited complication profile.

Conclusions

Use of the EEEA for selected pituitary macroad-

TABLE 4: Endocrinological outcome in patients with functioning adenomas*

Case No.	Preop Hormonal Status	Preop Med Tx	Postop Hormonal Status w/o Med Tx	Postop Med Tx	Outcome After Postop Med Tx†
6	PRL: >6000 ng/ml	cabergoline	PRL: 121 ng/ml	cabergoline	controlled
9	PRL: 2938 ng/ml HGH: 8.9 ng/ml IGF-I: 392 ng/ml (71–290)	cabergoline octreotide LAR	PRL: 670 ng/ml HGH: 6.10 ng/ml IGF-I: 370 ng/ml (71–290)	cabergoline octreotide LAR	not controlled, death due to disease progr
11	HGH: 76.8 ng/ml IGF-I: 620 ng/ml (90–360)	octreotide LAR pegvisomant	HGH: 16.4 ng/ml IGF-I: 49.8 ng/ml (90–360)	octreotide LAR	controlled
16	PRL: 993 ng/ml	bromocriptine	PRL: 117 ng/ml	cabergoline	controlled
18	HGH: 2.27 IGF-I: 1430 ng/ml (90–360)	octreotide LAR	HGH: 0.58 ng/ml IGF-I: 175 ng/ml (90–360)	none	cured

* The values in parentheses represent reference ranges. Abbreviations: HGH = human GH; Med = Medical.

† Controlled: The clinical features and biochemical values are normal with medical treatment. Not controlled: The clinical features and biochemical values are abnormal despite medical treatment. Cured: The clinical features and biochemical values are normal without medical treatment.

enomas offers the possibility of managing these lesions through a double corridor: an endosellar extraarachnoidal corridor to debulk the sellar component and a suprasellar transarachnoidal corridor for the dissection and removal of the suprasellar and capsular parts of the tumor. Our selection criteria for using the EEEA for certain pituitary adenomas are quite strict, and our initial impressions from these early results encourage a widening of the standard indications for the transsphenoidal approach in pituitary adenoma surgery. Longer follow-up and larger published series are needed to establish the efficacy of this approach.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Cavallo. Acquisition of data: Di Maio, Stagno, Corriero. Analysis and interpretation of data: Di Maio, Esposito, Stagno. Drafting the article: Cavallo, Di Maio, Esposito, Corriero. Critically revising the article: Cavallo, Di Maio, Esposito, Cappabianca. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: Di Maio, Stagno. Study supervision: Cavallo, Cappabianca.

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