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RESEARCH

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Surgical outcome of endoscopic endonasal approach as a modality of management for large and giant pituitary adenomas: a retrospective case series

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Abstract

Background Large and giant pituitary adenomas (defined as tumors of maximal diameter ≥ 3–3.9 cm and ≥ 4 cm, respectively) present considerable surgical challenges regarding the extent of resection and perioperative morbidity. Endoscopic endonasal resection is considered the most effective treatment for pituitary adenomas. It allows for better visualization, maneuverability, and access to distant and lateral tumor compartments, ultimately enhancing the extent of resection. This article evaluates our initial experience with endoscopic endonasal resection of large and giant pituitary adenomas. The clinical outcomes, perioperative complications, and extent of tumor resection would be specifically addressed.

Patients and methods The primary goal of surgery was to decompress the optic pathways, and the secondary goals were to achieve maximal safe resection and hormonal control in hormone-secreting adenomas. The degree of tumor resection was classified as gross-total resection (100%), near-total resection (90–100%), subtotal resection (70–90%), and partial resection (< 70%).

Results 42 patients were included in this study. A good visual outcome achieved with 80% improvement in visual symptoms. Gross-total resection (GTR) was achieved in 19 patients (45.2%), near-total resection (NTR) was achieved in 12 patients (28.6%), subtotal resection (STR) in 6 patients (14.3%), and partial resection in the remaining 5 patients (11.9%). Subgroup analysis revealed that GTR, NTR rates were higher in large, compared to giant tumors. GTR, NTR rates of large adenomas were 59.3%, and 29.6%, compared to 20%, and 26.7% in giant adenomas respectively (*p-value: 0.01428*). Surgical complications were observed in 19 patients (45.2%) with CSF leakage being the most common complication (11 patients, 26.2%). Post-operative diabetes insipidus was observed in 5 patients (11.9%), major vascular injury in one case (2.4%), transient post-op 6th nerve palsy observed in 3 patients (7.1%), while two patients (4.8%) presented with post-operative paranasal sinuses infection.

Conclusions Endoscopic endonasal transsphenoidal resection of large and giant pituitary adenomas is a safe and efficient procedure. Large adenomas (3–3.9 cm) have excellent resection rates and lower complications than giant adenomas (≥ 4 cm), which may require extending our approach to achieve more tumor resection rates

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in the future. However, only adequate resection of these giant adenomas can be enough to achieve the main surgical goals of visual improvement, hormonal control, and decompression of surrounding structures.

Keywords Pituitary adenoma, Large, Giant, Endoscopic, Endonasal, Transsphenoidal

Introduction

A pituitary adenoma, by definition, is a benign tumor affecting the pituitary Gland's anterior lobe, causing symptoms either by excess hormonal secretions or by a local mass effect by direct compression on neighboring structures (e.g., pituitary stalk, hypothalamus, optic chiasm) [1].

Large and giant pituitary adenomas (defined as tumors of maximal diameter ≥ 3–3.9 cm and ≥ 4 cm, respectively) present considerable surgical challenges regarding the extent of resection and perioperative morbidity. Their size, extensions, and invasiveness make surgical resection extremely difficult, with higher complications than smaller tumors [2–4].

For decades, microscopic approaches (transsphenoidal, transcranial, or a combination) have been the workhorse for the surgical management of such complex lesions. Transsphenoidal surgery, the current standard of care, has an essential shortcoming of a narrow corridor that limits maneuverability and access to lateral tumor compartments with unsatisfactory radical resection rates. On the other hand, transcranial approaches, although with a slight advantage regarding the radicality of resection, still carry significant perioperative morbidity. Overall, the rate of total gross resection utilizing microsurgical approaches for giant adenomas is still under 50% [5, 6].

Endoscopic endonasal resection is considered the most effective treatment for pituitary adenomas. It represents a minimally invasive approach, gaining worldwide popularity for better visualization, maneuverability, and access to distant and lateral tumor compartments via the endonasal route, ultimately enhancing the extent of resection [7–11].

Although various promising data exist in the literature promoting this approach [8, 10, 11], no high-quality studies report the surgical outcomes of the endoscopic endonasal approach for giant and large pituitary adenomas.

This article evaluates our initial experience of large and giant pituitary adenomas treated with endoscopic endonasal resection. The clinical outcomes, perioperative complications, and extent of tumor resection would be specifically addressed.

Patients and methods

Study design

This study is a retrospective cohort study, done on 42 patients (23 males and 19 females), operated between January 2020 to January 2023.

Inclusion criteria constituted histopathologically confirmed large and giant pituitary adenomas, operated upon via an endoscopic endonasal approach. Large tumors would be defined as ≥ 3–3.9 cm in maximal diameter. 4 cm would be the cutoff for the definition of giant adenomas. Both functioning and nonfunctioning adenomas are included in the study. Recurrent and residual lesions after previous transcranial or trans-sphenoidal surgery are also included.

Tumors of the sellar and juxtasellar region proven histopathologically to be non-pituitary adenomas were excluded, as well as pituitary adenomas of less than 3 cm in maximal diameter.

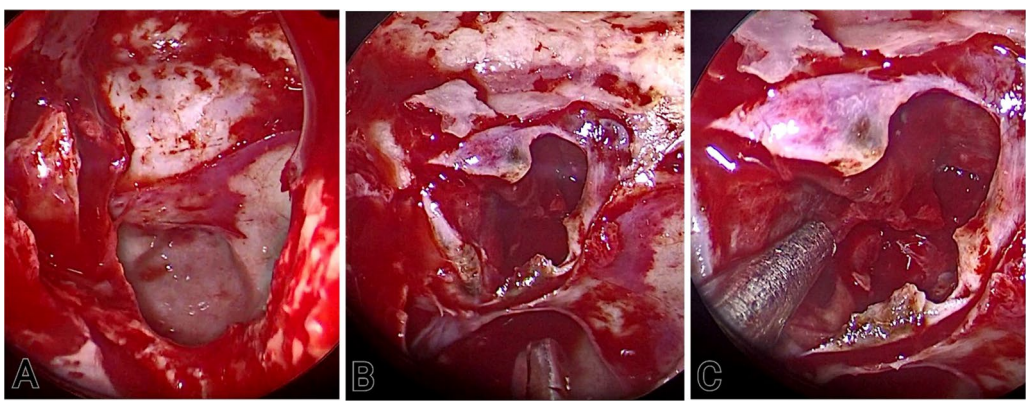

Fig. 1 Endoscopic intra-sphenoid (**a**), and intrasellar (**b**, **c**) views during tumor resection

Surgical management

All patients included were operated via endonasal endoscopic approach (Fig. 1). The primary goal of surgery was usually to decompress the optic pathways, and the secondary goals were to achieve maximal safe resection and hormonal control in hormone-secreting adenomas. Extended approaches with combination of trans-sellar, trans-planum, and trans-cavernous approaches were used whenever needed. Nasoseptal flaps or fat grafts were harvested and used in repair whenever cerebrospinal fluid leakage was observed intraoperatively.

All tumor specimens were sent for histopathological examination by a neuropathologist (± immunohistochemical analysis) to confirm the diagnosis of pituitary adenoma.

Surgical outcome post-operatively was assessed by radiological imaging, endocrinological evaluation via pituitary hormonal assay, and visual acuity assessment.

Radiological evaluation

Preoperative Magnetic Resonance (MR) images were done and evaluated by an independent neuroradiologist for all patients together with a Computed Tomographic image (CT) of the paranasal sinuses to evaluate the transnasal route. The degree of tumor resection and any postoperative sequalae like tumor bed hematoma or pneumocephalus was evaluated on the 24-h postoperative Brain (CT). Contrast enhanced Brain and Sella MRI were done at 3, 6, and 12 months of follow-up for tumor progression monitoring.

The degree of tumor resection was classified according to *Juraschka* et al. [12] as gross-total resection (100%), near-total resection (90–100%), subtotal resection (70–90%), and partial resection (< 70%).

Endocrinological evaluation

Pituitary hormonal profile was routinely assessed in all patients preoperatively and postoperatively including the following tests as a minimum: serum prolactin, random growth hormone, insulin-like growth factor 1, thyroid-stimulating hormone (TSH), and circulating thyroid hormones (T3, T4), diurnal cortisol and Adrenocorticotrophic hormone (ACTH) levels.

Visual evaluation

In all patients, preoperative, postoperative, follow-up visual field (VF) and acuity tests were performed by an independent ophthalmologist. Visual acuity was assessed with Snellen charts, and the Humphrey VF analyzer was used to evaluate VF defects. A good visual outcome was regarded as improved or stable visual tests over the follow-up period.

Clinical evaluation

Clinical and/or radiological evidence of an apoplectic event throughout the course of the disease was evaluated and reported. Clinically evidenced by an acute deterioration of the conscious level, visual acuity, cranial nerve function, or the development of acute hydrocephalus in a previously stable patient. A tumor component with a hemorrhagic MRI signal was reported independently.

Perioperative complications were recorded, including intraoperative vascular injuries and postoperative CSF leaks, Diabetes Insipidus, cranial nerve deficits, infection, and mortality.

Statistical analysis

Patient demographics, clinical presentation, tumor characteristics, surgical approaches, and outcomes were reported by descriptive statistics. Rates of radical resection for each tumor type were evaluated using Fisher exact test.

A $P\text{-}value < 0.05$ was considered statistically significant. P-values significance were assessed after Bonferroni correction. Tumor diameter was calculated using Digimizer image analysis software (*MedCalc Software Ltd*, *Belgium*) (Fig. 2), data were stored and analyzed using Microsoft Excel 2016 (*Microsoft Corporation, Redmond, Washington*, *USA*).

Results

Demographic data

This study was approved by the ethics review committee of Ain Shams University. All patients were operated on by authors between January 2020 and January 2023 at the neurosurgery department, Ain Shams University, and Nasser Institute for research and treatment hospital, Egypt.

Medical records of the patients who underwent endoscopic endonasal resection were collected and retrospectively reviewed. 42 patients met the criteria for large (≥ 3–3.9 cm) and giant (≥ 4 cm) histopathologically confirmed pituitary adenoma.

In this series, slight male predominance was observed (23 males and 19 females), with an average age of 43.6 years (22–66 years).

Tumor characteristics

Tumors were categorized into three groups according to their appearance in MRI: round (18 patients, 42.8%), multilobular (12 patients, 28.6%), and dumbbell-shaped tumors (12 patients, 28.6%). There were 27 patients

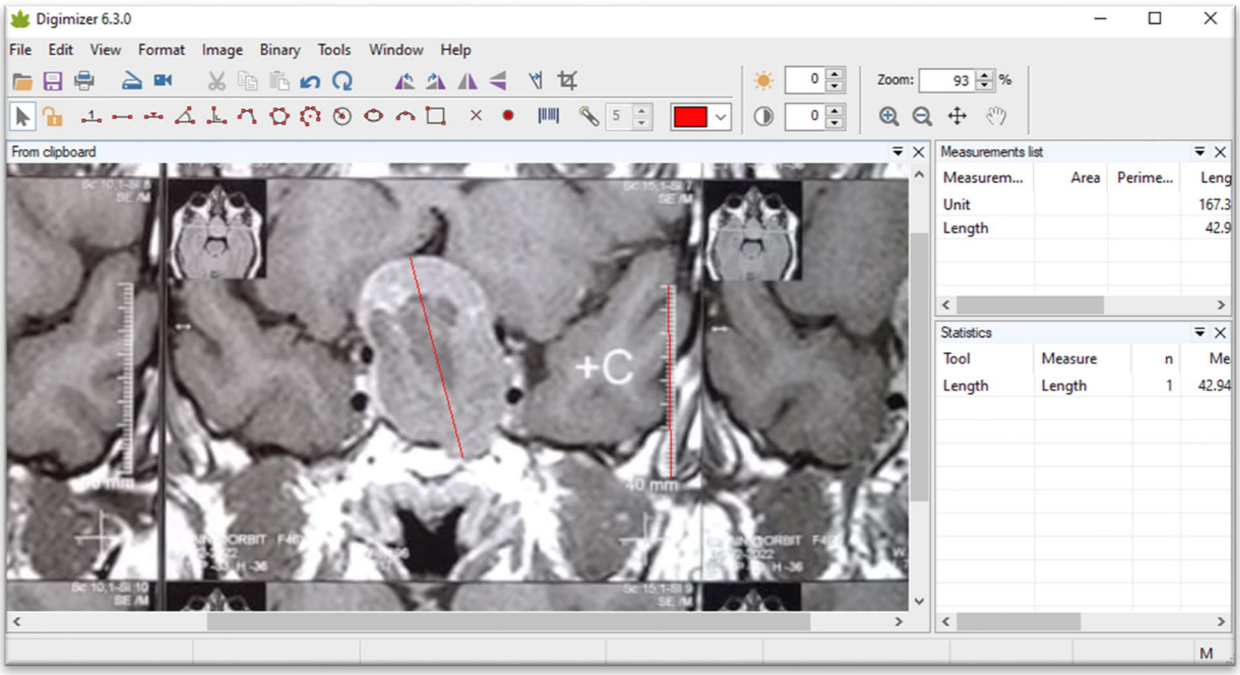

Fig. 2 Calculation of tumor diameter using Digimizer © software with calibration of MRI scale

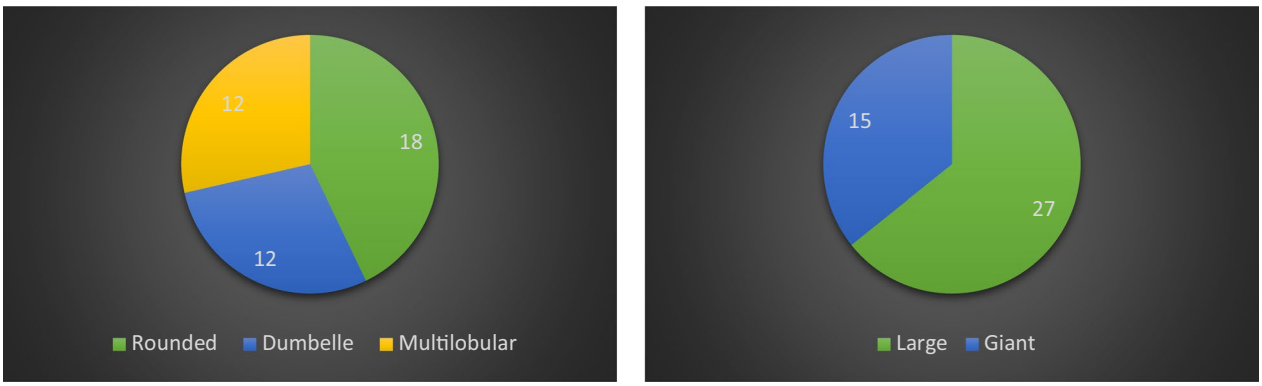

Fig. 3 Tumor shape and size

with large (64.3%) and 15 patients with giant (35.7%) adenomas (Fig. 3).

Cavernous sinus invasion was evaluated according to *Knosp* criteria [13] and was present in 29 patients (69%) with complete encasement of the cavernous internal carotid artery (Knosp grade 4) in 9 patients.

Five patients had pituitary apoplexy pre-operatively (11.9%). 11 patients (26.2%) had tumors extending into the sphenoid sinus, 4 patients (9.5%) into the temporal lobe, while 3rd ventricle extension was seen in 3 patients (7.1%).

Seven patients had recurrent (4 patients) and residual (3 patients) tumors (16.7%), with majority of them having multilobular and dumbbell-shaped tumors.

Visual outcome

Visual impairment, defined as field restriction on perimetric examination or decreased visual acuity, was the most common symptom presenting in 40 patients (95.2%). Good visual outcome was achieved in all patients, with improvement in visual symptoms in 32

Table 1 Clinical presentation

Pre-operative complaint	Number of patients	Improved (%)	Unchanged (%)	Worsened (%)
Visual impairment	40	32 (80)	8 (20)	0 (0)
Hormonal disturbances	11	8 (72.7)	3 (27.3)	0 (0)

patients (80%), and 8 patients (20%) had stable vision and none of the patients reported worsened vision (Table 1).

Endocrinological outcome

Non-functioning pituitary adenoma was the most common type (31 patients, 73.8%), followed by GH-secreting adenoma (6 patients, 14.3%), prolactinoma (4 patients, 9.5%) and ACTH secreting tumors (1 patient, 2.4%). Of these 11 patients presented with functioning adenomas, 8 patients had improvement in at least 1 preoperative endocrinological dysfunction (72.7%).

Degree of tumor resection

Gross-total resection (GTR) was achieved in 19 patients (45.2%), near-total resection (NTR) in 12 patients (28.6%), subtotal resection (STR) in 6 patients (14.3%), and partial resection in 5 patients (11.9%). Subgroup analysis revealed that GTR was achieved in 66.7% of patients with rounded-shaped tumors (12 out of 18 patients) (*p-value: 0.0455*), while NTR was achieved in the remaining 33.7% of patients. The GTR rates for dumbbell and multilobular adenomas were 41.7% and 16.7% respectively (*p-value: 0.3843*) (Table 2) (Figs. 4, 5).

Extended approaches were used whenever needed, drilling of the planum sphenoidale was done in 7 patients and trans-cavernous resection was done in 5 patients using angled endoscopic lenses to ensure radical resection.

Concerning patients with recurrent and residual tumors (7 patients, 16.7%), GTR was achieved in 1 patient, NTR was achieved in 1 patient, STR was achieved in 4 patients, while partial resection was achieved in the other 1 patient and required another session for transcranial approach to achieve radical resection.

Complications and management

Surgical complications were observed in 19 patients (45.2%) (Table 3), none of our patients died during the study period. The most common complication was post-operative CSF leak (11 patients, 26.2%), three of whom were complicated with pneumocephaly (7.2%). Conservative measures by 48-h immobilization, oral acetazolamide, and insertion of a lumbar intrathecal drain; stopped the leak in 9 patients (81.8%), while 2 patients (18.2%) required endoscopic endonasal repair using fat grafts and synthetic sealants.

Post-operative transient diabetes insipidus (D.I) was observed in five patients (11.9%), all of them resolved conservatively. Three patients were controlled within the hospital stay period, while the other two required oral desmopressin for one month after discharge.

Major vascular injury occurred in one patient (2.4%) in which there was a left ICA injury during the sellar phase

Table 2 Degree of tumor resection by shape and extension

Tumor characteristics	Num of patients	Gross total resection	Near total resection	Subtotal resection	Partial resection
Tumor shape					
Rounded	18	12 (66.7%)	6 (33.3%)	0 (0%)	0 (0%)
Dumbbell	12	5 (41.7%)	3 (25%)	3 (25%)	1 (8.3%)
Multilobular	12	2 (16.7%)	3 (25%)	3 (25%)	4 (33.3%)
Tumor size					
Large	27	16 (59.3%) *p-value: 0.01428*	8 (29.6%)	1 (7.4%)	1 (3.7%)
Giant	15	3 (20%)	4 (26.7%)	4 (26.7%)	4 (26.7%)
Tumor extension					
Cavernous sinus	29	11 (37.9%)	9 (31%)	3 (17.3%)	4 (13.8%)
Sphenoid sinus	11	5 (45.4%)	4 (36.4%)	0 (0%)	2 (18.2%)
3rd Ventricle	3	0 (0%)	1 (33.3%)	1 (33.3%)	1 (33.3%)
Middle fossa	4	0 (0%)	0 (0%)	2 (50%)	2 (50%)

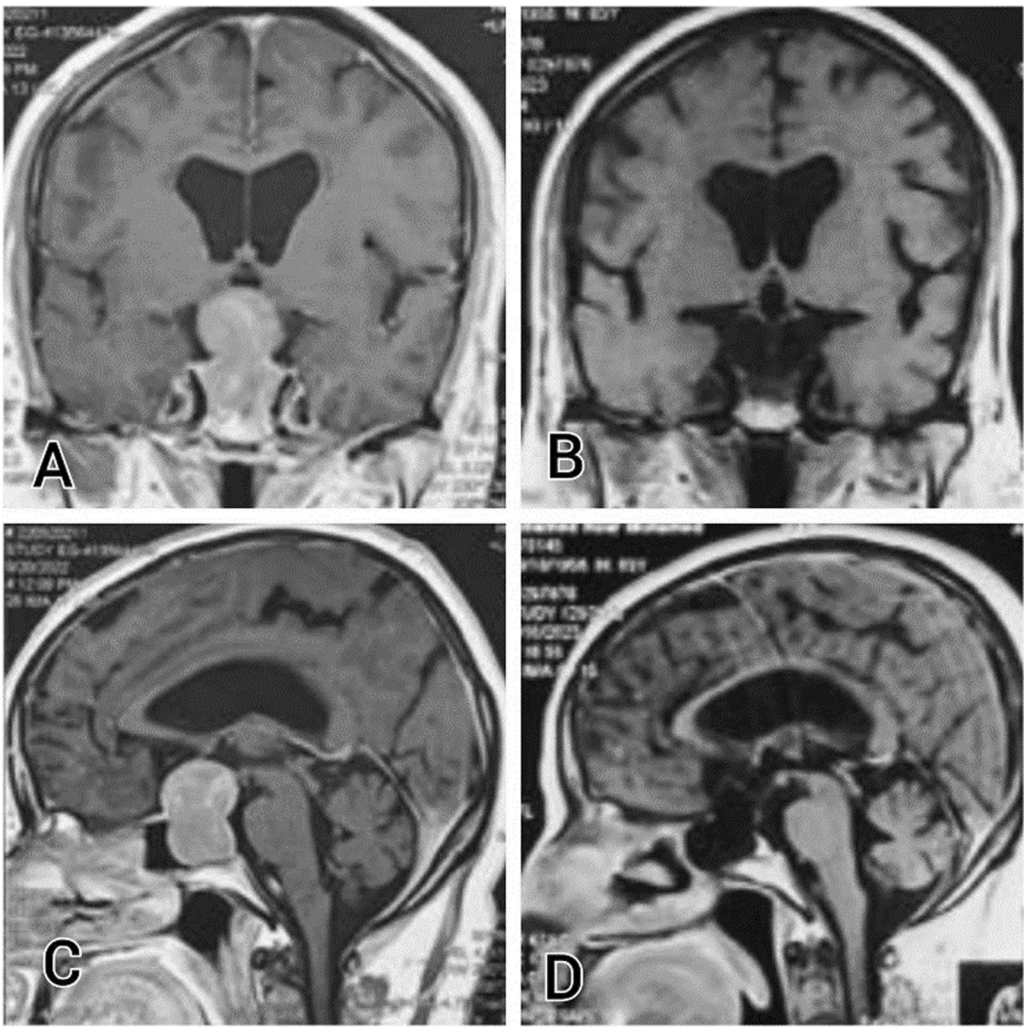

Fig. 4 Preoperative (**a**, **c**) and postoperative (**b**, **d**) MRI showing GTR of large pituitary adenoma

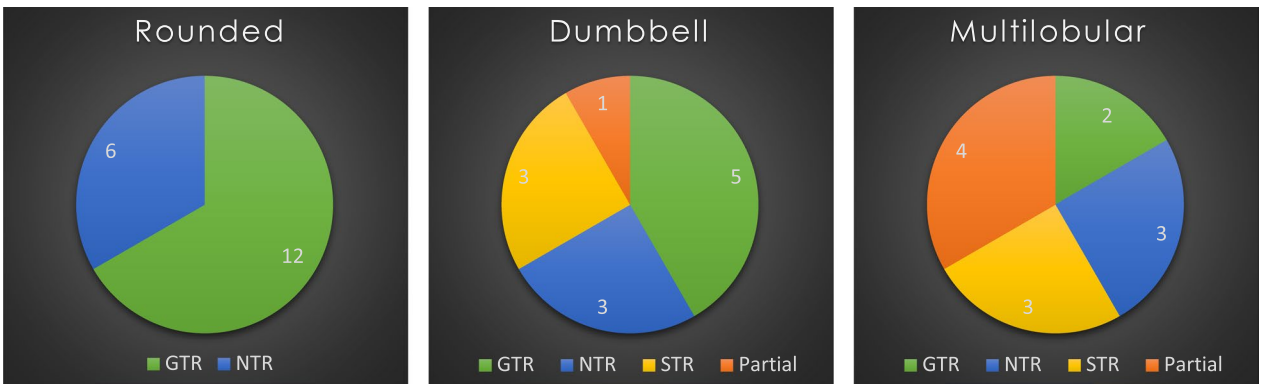

Fig. 5 Degree of tumor resection by shape and size

Table 3 Post-operative complications

Tumor characteristics	Num of patients	CSF leak	Diabetes insipidus	Cranial N Palsy	Sinus infection	Vascular injury
Tumor shape						
Rounded	18	6	3	0	1	0
Dumbbell	12	4	1	1	1	1
Multilobular	12	1	1	2	0	0
Tumor size						
Large	27	8	3	0	1	0
Giant	15	3	2	3	1	1

while trying to maximize sellar floor resection laterally over the cavernous sinus & parasellar ICA. However, bleeding was controlled with temporalis muscle graft packing, conventional angiography was urgently done to exclude pseudoaneurysm formation or vascular leakage, and a carotid balloon occlusion test beyond injury point revealed good collateral flow from the other side and accordingly the ICA was occluded with coils at the level of the injury (Fig. 6). The patient was reoperated after one week for endoscopic tumor resection with uneventful recovery afterward. Transient post-operative 6th nerve palsy was observed in 3 patients (7.1%) which improved spontaneously. Two patients (4.8%) presented with post-operative paranasal sinuses infection.

Recurrences and follow-up

The mean follow-up period was 12.3 months (6–23 months). None of the patients with GTR or NTR experienced recurrences or residual tumor progression, while 5 patients (11.9%) with STR and partial resection had recurrences that needed surgical intervention, either transcranial or endoscopic endonasal redo. Six patients (14.3%) were lost to follow up during the study period.

One interesting phenomenon happens with residual pituitary tumors, they may tend to arrest and regress owing to abrupt decrease in blood supply induced by surgery that intervenes with the tumor's vascular network, causing more blood deprivation for the residual part. *Raeesa* et al. [14] described spontaneous tumor regression following tumor apoplexy, which may have caused compression on portal vessels and deprived the tumor from its blood supply (Fig. 7).

Discussion

Endoscopic endonasal transsphenoidal approach is considered the mainstay treatment for pituitary tumors [2]. Over the past century, approaches to pituitary tumors have undergone multiple evolutions in surgical techniques [15]. *Hermann Schloffer* [16] was the first neurosurgeon to introduce transsphenoidal approach in 1907, while *Harvey Cushing* [15] described the first sublabial transseptal transsphenoidal procedure in 1910, and is still used till today by some surgeons. *Hardy* [17] was the first neurosurgeon to use operating microscope for pituitary surgery in 1967, improving the visualization and accuracy of the transsphenoidal surgeries.

Pure endoscopic endonasal transsphenoidal approach was first described by *Jankowski* et al. [18] in 1992. Since the 2000s, the use of endoscopic endonasal approaches for skull base surgeries showed a jump, with superiority over microscopic approaches in terms of fewer complications and shorter hospital stay [19]. The use of new techniques, high-definition cameras, low profile instruments and advanced technologies, such as computer assisted navigation systems, enabled surgeons to access giant skull base tumors from short and narrow corridors and achieve best results for irregular tumors with lateral extensions, which were once considered inoperable [20].

This study describes our initial experience in management of large and giant pituitary adenomas using endoscopic endonasal transsphenoidal approach. The biggest advantage for this approach is the ability of the endoscope to visualize and protect the optic chiasm resulting in ability to preserve or improve the vision which is even more evident with irregular and recurrent tumors. In our series, the most common pre-operative compliant was visual disturbances. Visual improvement was achieved in 80% of patients post-operatively, which correlates with results published by other authors [2, 4, 21, 22]. There were no patients with post-operative visual deterioration.

The use of the endoscope allows visualization and preservation of the compressed pituitary gland, which is often stretched over the periphery of large tumors. Most of our patients had good hormonal outcome, out of the 11 patients presenting with preoperative hormonal disturbances due to functioning adenomas, (72.7%) showed improvement in post-operative hormonal status, while (27.3%) required continued post-operative hormonal

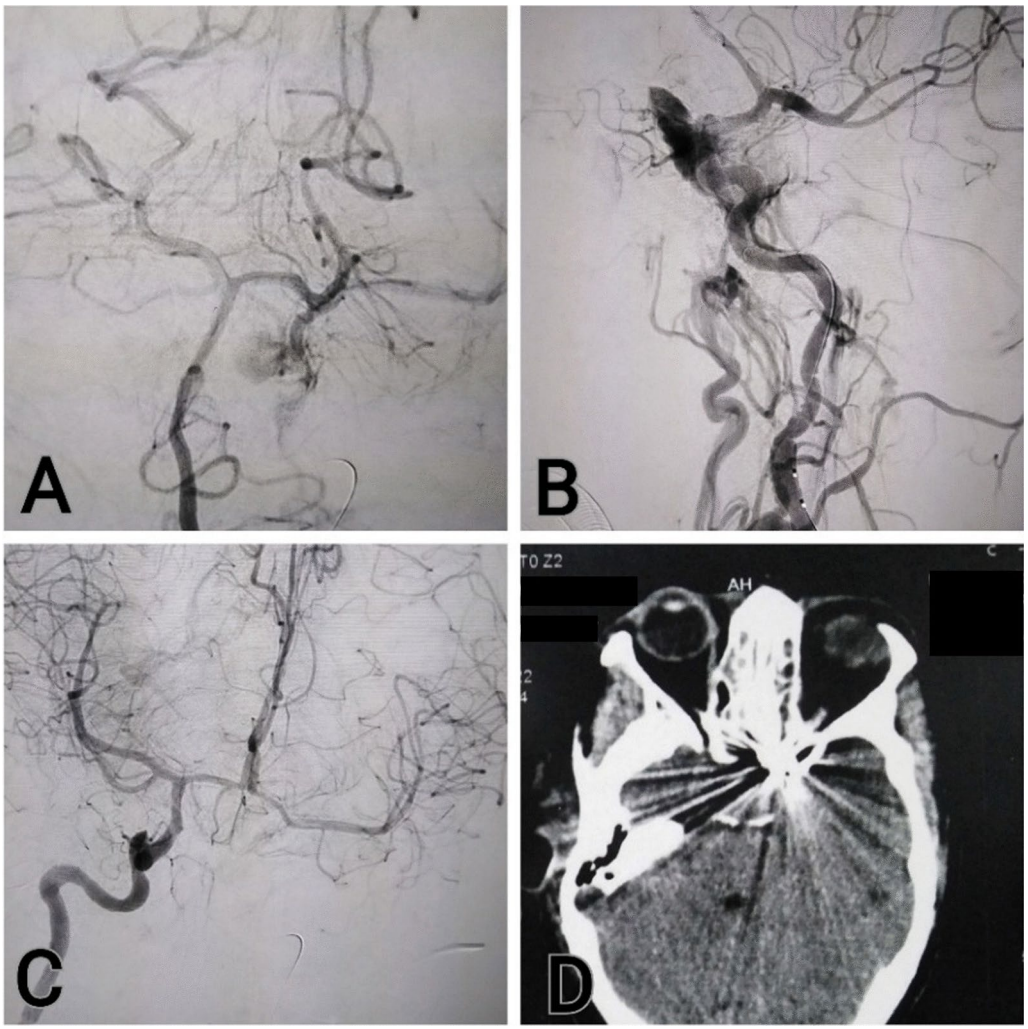

Fig. 6 Conventional angiography showing vascular leakage from injury site (**a**, **b**), ballon occlusion test showing good collateral flow from the other side (**c**), and post-operative (**d**) scan after coil occlusion

therapy. Transient DI occurred in 5 patients (11.9%) and resolved spontaneously. There were no patients with post-operative long-term hormonal deficiencies.

Complete resection of giant pituitary tumors is very challenging [2, 21], and it's accepted that adequate resection remains the principal goal of surgery, which provides the patients with visual improvement, control of hormonal status and decompression of surrounding structures.

In this series, GTR was achieved in 19 patients (45.2%), NTR in 12 patients (28.6%), STR in 6 patients (14.3%), and partial resection in 5 patients (11.9%). Subgrouping into radical (GTR + NTR) and non-radical (STR + Partial) resection was done, and radical resection was achieved in 31 patients (73.8%). These results are comparable with results published by *De Paiva* et al. [2] (61%), *Koutourousiou* et al. [4] (66.7%), *Juraschka* et al. [12] (40.9%), *Chabot* et al. [23] (84.6%), and *Rahimli* et al. [22] (63.6%) (Table 4).

The remaining 11 patients with non-radical resection were followed up, 4 patients needed another endoscopic redo sessions, one patient needed transcranial resection, and the other 6 patients had clinical improvement and are followed up till now with no visual or hormonal deterioration or progression in tumor size in serial follow up MRI studies.

According to shape, patients with rounded-shaped tumors had the best results, with radical resection rates of 100% (66.7% + 33.3%), followed by patients with dumbbell-shaped tumors, with radical resection rates of 66.7% (41.7% + 25%) and non-radical resection rates of 33.3% (25% + 8.3%). The lowest resection rates were found in patients with multilobular tumors, with

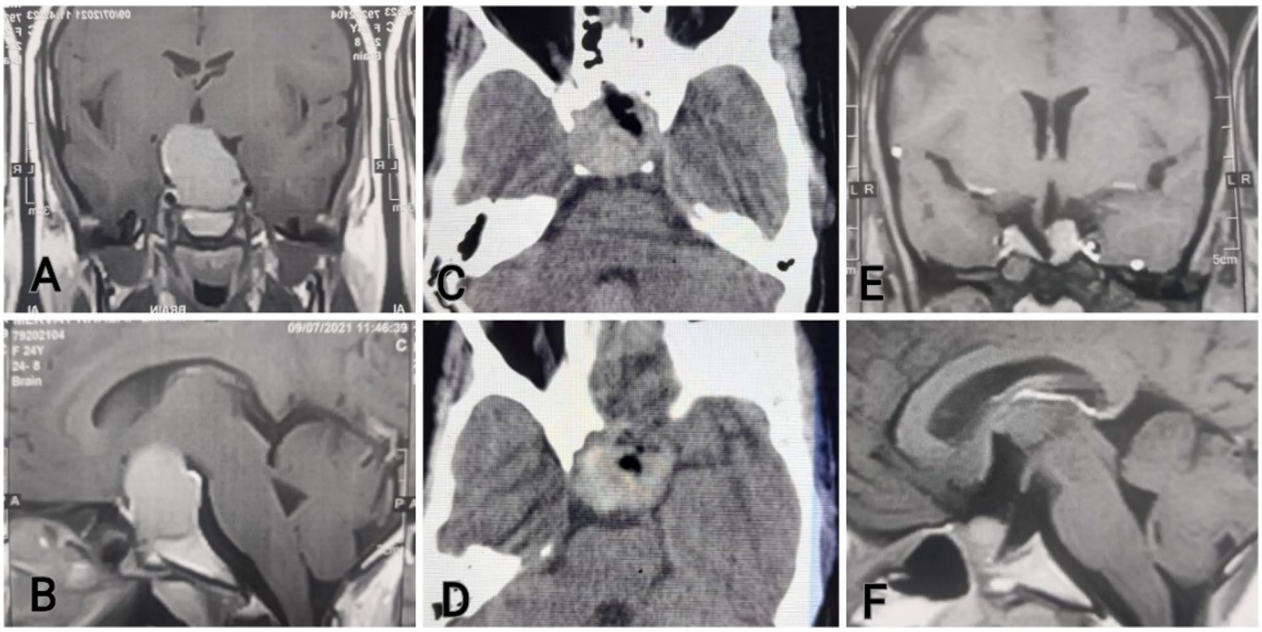

Fig. 7 Pre-operative (**a**, **b**) MRI showing large adenoma, with large residual tumor in immediate post-operative CT (**c**, **d**), and spontaneous regression after 3 months (**e**, **f**)

Table 4 Literature review of surgical outcomes

Author	Total patients	Visual outcome (%)			Hormonal outcome			Rate of resection	
		Improved	Worsen	Unchanged (%)	Improved (%)	Worsen (%)	Unchanged (%)	Radical (GTR + NTR) (%)	STR + Partial (%)
Mortini et al. [21]	85	74.7	6.3	19	–	10.6	89.4	15.3	63.5
De Paiva et al. [2]	51	81.5	–	18.5	49	14.6	36.4	61	39
Koutourousiou et al. [4]	54	80	4.4%	15.6	3.6	17.8	78.6	66.7	33.3
Juraschka et al. [12]	73	73	4.8%	22.2	1.4	5.5	93.1	40.9	59.1
Chabot et al. [23]	39	79	–	21	87.2	12.8	–	84.6	15.4
Rahimli et al. [22]	44	81.8	–	18.2	72.3	–	27.7	63.6	36.4
Current study, 2023	42	80	–	20	72.7	–	27.3	73.8	26.2

radical resection rates of 41.7% (16.7% + 25%) and non-radical resection rates of 58.3% (25% + 33.3%) (Fig. 8).

In comparison, large (3–3.9 cm) tumors had the best results compared to giant (≥ 4 cm) tumors. Patients with large (27 patients, 64.3%) tumors had the best resection rates, with radical resection rates of 88.9% (59.3% + 29.6%) and non-radical resection rates of 11.1% (7.4% + 3.7%), while patients with giant (15 patients, 35.7%) tumors had lower radical resection rates of 46.7% (20% + 26.7%) and non-radical resection rates of 53.4% (26.7% + 26.7%) (Fig. 9).

These results show a statistical significance with better resection rates in patients with rounded-shaped tumors (*p-value: 0.0455*) compared to those with dumbbell-shaped, and multilobular tumors. Also, patients with large tumors have better resection rates

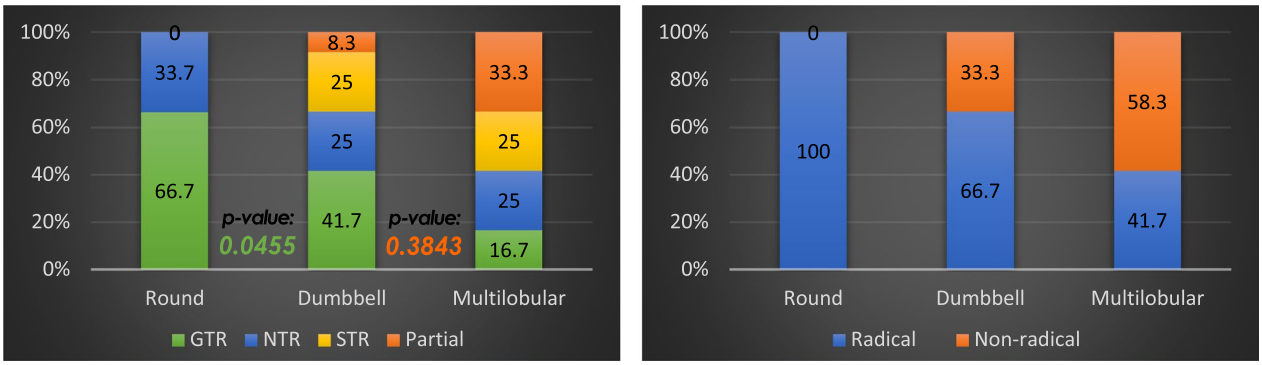

Fig. 8 Degree of tumor resection by shape

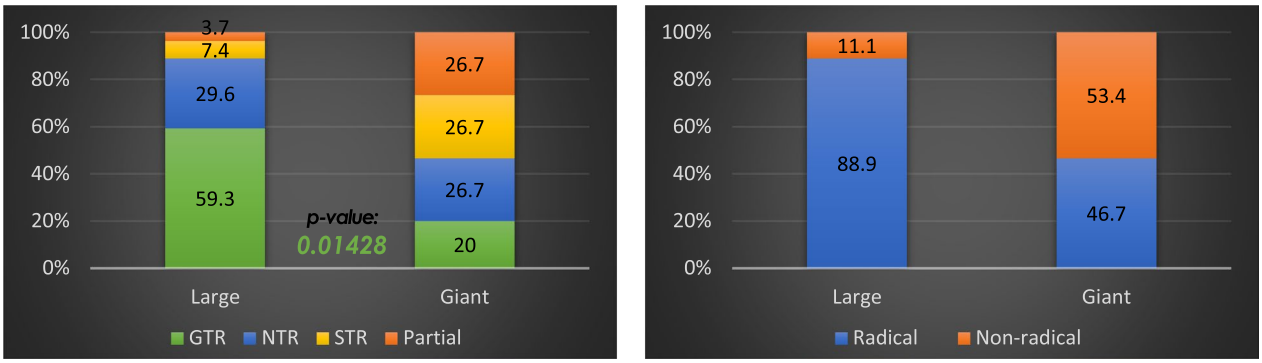

Fig. 9 Degree of tumor resection by size

(*p-value: 0.01428*) and lower complications compared to those with giant tumors.

In our initial experience, tumor extension to the medial wall of cavernous sinus does not restrict tumor resection, with using angled endoscopes and wider exposures we can visualize these lateral boundaries safely, cavernous sinus invasion was present in 29 patients, radical resection rates of 68.9% (37.9% + 31%), while non-radical resection was observed in 31.1% of patients (%17.3 + 13.8%). Patients with tumors extending to 3rd ventricle had lower resection rates, also, those with tumors with extreme lateral extensions to cavernous sinus (Knosp grade 4) or temporal lobe, gross-total resection cannot be achieved due to natural boundary of the cranial nerves at the lateral wall of the cavernous sinus [4].

In general, huge and giant pituitary adenomas have a higher post-operative complication rate, highlighting the difficulty of their treatment. The most common complication observed in this series was postoperative CSF leak (11 patients, 26.2%), 9 patients were managed conservatively while only 2 patients (4.8%) required another surgery for endoscopic repair, these results are comparable

Table 5 Literature review of post-operative complications

Author	Total patients	CSF leak (%)	Diabetes insipidus (%)	Cranial N Palsy (%)	Infection (%)	Vascular injury (%)
Mortini et al. [21]	85	1.2	8.2	–	–	–
De Paiva et al. [2]	51	1.9	25	–	6	–
Koutourousiou et al. [4]	54	16.7	9.6	11.1	5.6	–
Juraschka et al. [12]	73	9.6	4.1	–	13.7	–
Chabot et al. [23]	39	10.3	7.7	–	15.4	–
Rahimli et al. [22]	44	11.4	9.1	6.8	2.3	6.8
Current study, 2023	42	26.2	11.9	7.1	4.8	2.4

to those described by *Koutourousiou* et al. [4] (16.7%), *Juraschka* et al. [12] (9.6%), *Chabot* et al. [23] (10.3%), and *Rahimli* et al. [22] (11.4%) (Table 5).

The most serious complication that might be met with endoscopic approach is major vascular damage with the paraclival segment of the internal carotid artery being the usual affection site [24]. Unfortunately, it occurred once during our study (2.4%) where parasellar carotid was injured during the sellar phase while trying to maximize sellar floor resection laterally over the cavernous sinus & parasellar ICA and was controlled by temporalis muscle graft packing and conventional angiographic intervention. *Rahimli* et al. [22] described higher incidence (6.8%) associated with extended approaches.

Post-operative sinusitis was observed in 2 patients (4.8%) and managed conservatively. Also, transient 6th N. palsy was observed in 3 patients (7.1%) and improved spontaneously. Post-operative cranial palsies may be due to vigorous tumor removal from lateral extensions and manipulations near the lateral wall of the cavernous sinus.

Conclusions

Endoscopic endonasal transsphenoidal resection of large and giant pituitary adenomas is a safe and efficient procedure. Large adenomas (3–3.9 cm) have excellent resection rates and lower complications than giant adenomas (≥ 4 cm), which may require extending our approach to achieve more tumor resection rates in the future. However, vigorous tumor resection is not mandatory for clinical improvement, and only adequate resection of these giant adenomas can be enough to achieve the main surgical goals of visual improvement, hormonal control, and decompression of surrounding structures.

Abbreviations

MRI	Magnetic resonance imaging
CT	Computed tomography
GH	Growth hormone
TSH	Thyroid stimulating hormone
ACTH	Adrenocorticotropic hormone
VF	Visual field
GTR	Gross total resection
NTR	Near total resection
STR	Subtotal resection
CSF	Cerebrospinal fluid
DI	Diabetes insipidus
ICA	Internal carotid artery

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Author contributions

All authors made a significant contribution to the work reported, whether that was in the conception, study design, execution, acquisition of data, analysis and interpretation; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agreed to be accountable for all aspects of the work.

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Availability of data and materials

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request. Other data consists of bibliographic references, which are included in the References section.

Declarations

Ethics approval and consent to participate

A research committee approval has been granted for this study by the "Ain Shams University Research Ethics committee" (*reference number: FMASU R26/2023*). Informed consent according to the criteria set by the local research ethics committee in our center obtained in writing before surgery. The identity of any patient has not been revealed in the study.

Consent for publication

All authors accept that only EJNS has all authority for publications and subsequent responsibilities.

Competing interests

The authors declare that they have no competing interests.

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