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EFFICACY AND SAFETY OF ENDOSCOPIC ENDONASAL SURGERY FOR PITUITARY ADENOMAS: SINGLE-CENTER CLINICAL STUDY

Ayman M. Ismail[1], Mohamed Adel Moustafa*[1], Taha A. Ismail [3], Mohammad Fathy[2], Nabil Amin Nasef [1], Mohamed A. Abbas[1]

[1] Neurosurgery Department, Faculty of Medicine, Kafr Elsheikh University, Kafrelsheikh, Egypt
[2] Neurosurgery Department, Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt
[3] General Surgery Department, Faculty of Medicine, Kafr Elsheikh University, Kafrelsheikh, Egypt

ABSTRACT

Introduction: The transsphenoidal endonasal approach has emerged as the most widely adopted technique for primary pituitary surgery. This study aimed to assess the endoscopic endonasal transsphenoidal technique for pituitary adenoma treatment in terms of safety, effectiveness, and surgical outcomes; specifically, it examined the correlation between tumor resection extent and functional recovery following surgery.

Methods: We conducted a single-arm clinical trial on patients undergoing endoscopic endonasal transsphenoidal resection for pituitary adenoma at a tertiary healthcare center. Preoperative assessment included hormonal profiles, radiological evaluation, and ophthalmological examination. Analysis of surgical outcomes included endocrine remission, postoperative complications, clinical improvement, and the incidence of gross total resection (GTR).

Results: The research comprised twenty-five patients, the average age of whom was 37.6 ± 13.1 years. Twenty patients (80%) reported visual impairment as their primary complaint, with headache coming in at ten patients (40%) and diplopia at two patients (8%). Incidental diagnosis was made in one case (4%). Nineteen patients (76%) had gross complete resection (GTR), whereas six patients (24%) underwent subtotal resection (STR). Knosp grading showed that 22 patients (88%) had no or minimal cavernous sinus invasion (Knosp 0–2), whereas 3 patients (12%) had true cavernous sinus invasion (Knosp 3–4), mostly managed with STR. Among the 20 patients with preoperative visual impairment, 11 had visual field deficits only, 3 had decreased visual acuity only, and 6 had both visual field and visual acuity deficits. Improvement was observed in 9 of 11 patients (82%) with visual field deficits only, in 2 of 3 patients (67%) with decreased visual acuity only, and among the 6 patients with both deficits, 4 (67%) improved in both domains, 1 (17%) improved in visual field only, and 1 (17%) showed no improvement. Overall, 16 of the 20 patients (80%) with visual impairment demonstrated postoperative improvement. Headache resolved in 8 of 10 patients (80%), and diplopia improved in 1 of 2 patients (50%). Hormonal remission was achieved in 7 of 11 patients (64%) with functioning adenomas. A statistically significant correlation was observed between the extent of resection and overall clinical outcome. Clinical improvement was more frequent in the GTR group compared with the STR group: headache improved in 87.5% versus 50%, visual function improved in 87.5% versus 50%, and diplopia improved in 100% versus 0% (P = 0.001). Postoperative complications were low. CSF leakage occurred in 2 patients (8%), transient diabetes insipidus in 2 patients (8%), and permanent diabetes insipidus in 1 patient (4%). No cases of meningitis, significant epistaxis, mortality, or postoperative visual deterioration were reported.

Conclusion: Endonasal transsphenoidal resection is a safe and highly effective surgical approach for the management of pituitary adenomas, providing substantial improvement in both visual and endocrine function. Maximizing the extent of tumor resection remains the most important determinant of favorable postoperative clinical outcomes.

KEYWORDS: Endonasal resection, transsphenoidal, pituitary adenoma, gross total resection, clinical trial.

INTRODUCTION

Pituitary adenomas are among the most common intracranial neoplasms, accounting for approximately 10–15% of all central nervous system (CNS) tumors, and are responsible for nearly 25% of all surgical resections for CNS tumors [1]. These tumors are functionally classified as either secreting (e.g., hyperprolactinemia, acromegaly, or Cushing's disease/hypercortisolism) or non-secreting, and their clinical presentation is highly variable [2]. Symptoms range from non-specific complaints such as headaches to severe endocrine dysfunction and significant neurological deficits, most commonly visual impairment resulting from optic chiasmal compression [3].

The majority of symptomatic pituitary adenomas are best treated by surgical excision; however, secretory prolactinomas are usually treated mostly with medication [3]. Surgery provides effective tumor control, is generally well-tolerated, and offers the benefit of immediate symptom relief. In cases of recurrence or subtotal resection, adjunctive treatments such as radiotherapy, stereotactic radiosurgery, and medical management may be employed [4]. The transsphenoidal endonasal technique has become the gold standard for primary pituitary surgery because it avoids manipulating brain parenchyma by going straight to the sella turcica [5]. This approach consistently yields favorable outcomes, including low morbidity and mortality rates, high rates of clinical recovery, and satisfactory endocrinological remission [6,7]. Historically, transsphenoidal surgery utilized either microscopic or endoscopic visualization. Technological advancements have established the purely endoscopic endonasal technique as the favored approach. Views of the sella and parasellar areas are better, more comprehensive, and better lighted with the endoscope [8]. Furthermore, the maneuverability of endoscopic instrumentation and the use of angled telescopes facilitate the visualization and resection of residual disease in traditionally difficult-to-access areas, making the technique particularly valuable for primary surgery and for re-operations through a pre-existing sphenoidotomy [8].
Building upon the established efficacy of this modern technique, we aimed to prospectively evaluate the surgical outcomes of the purely endoscopic transsphenoidal approach in the management of pituitary adenomas, specifically assessing the extent of tumor resection, visual function improvement, and hormonal remission rates in our cohort.

METHODS

Study design and approval

We performed a single-arm clinical trial on patients scheduled for pituitary surgery at the Neurosurgery Department of Kafrelsheikh University Hospital from September 2024 to August 2025. The study adhered to the principles of the Declaration of Helsinki and received ethical approval from the institution's ethics committee **(KFSIRB200-297).** The study protocol was registered in Pan African Clinical Trial Registry **(PACTR202512728520659).** All participating patients provided informed written informed consent prior to inclusion.

Eligibility criteria

Patients aged 12–70 years with a radiologically and clinically confirmed diagnosis of pituitary macroadenoma (tumor diameter >10 mm) who were scheduled for endoscopic transsphenoidal resection were included. Patients were required to have a pneumatized sphenoid sinus. Exclusion criteria included pituitary microadenoma, recurrent pituitary adenoma, prior pituitary surgery or radiotherapy, and active sinusitis.

Patients' preparation

Demographic data, past medical history, and specific details regarding clinical symptoms including visual and endocrinological disturbances were recorded. The clinical and ophthalmological evaluation focused on neurological status, visual acuity (using Snellen charts), visual fields (using computerized VF measurement), and signs of hormonal imbalance. Laboratory investigations included measuring plasma levels of key pituitary hormones. Patients underwent MRI and CT imaging to determine tumor size (categorized as microadenoma, macroadenoma, or gigantic adenoma) and invasiveness, with cavernous sinus extension assessed via the Knosp classification [8].

Surgical technique

Orotracheal intubation was used throughout all surgeries that required general anesthesia. Using a headrest, the patient was placed supine with their head slightly bent. With the patient on his or her right side, the neurosurgeon stood. The periumbilical region was prepared aseptically for possible abdominal fat graft harvesting for sellar reconstruction. The endoscopic endonasal approach was performed in three phases: the nasal phase, the sphenoidal phase, and the sellar phase. In order to access the sellar floor, a rigid endoscope with a 4-mm diameter and a length of 18 cm (0° and 30°) was maneuvered into the endonasal channel. A Kerrison rongeur was used to open the sellar floor, which was then extended in order to reveal the sellar dura. There was a linear or cruciate opening in the dura. The endoscope was then fixed to a holder to allow a stable two-handed microsurgical technique. Tumor debulking was performed using ring curettes, progressing laterally toward the cavernous sinus, posteriorly toward the dorsum sellae, and superiorly toward the diaphragma sellae. Descent of the diaphragma sellae was considered an indicator of adequate tumor decompression. Tumor specimens were obtained for histopathological examination during the intrasellar debulking phase. The Valsalva maneuver was routinely performed to detect intraoperative cerebrospinal fluid (CSF) leakage. Sellar reconstruction was performed using a synthetic dural substitute when available. In cases of intraoperative CSF leakage, abdominal fat grafts were used for reconstruction of the sellar defect. Expanding nasal sponges were placed for 48 hours postoperatively. The extent of tumor resection was assessed intraoperatively based on endoscopic inspection of the sellar cavity and confirmed postoperatively using magnetic resonance imaging (MRI). Postoperative CSF leakage was managed with lumbar drainage when necessary. All tumor specimens were submitted for

histopathological examination, and immunohistochemical analysis was performed when available to confirm the diagnosis and determine the hormonal profile of the adenoma.The Valsalva maneuver was systematically implemented to identify any cerebrospinal fluid (CSF) leakage. Dural closure was performed using a synthetic dura mater substitute when available. In the event of an intraoperative CSF leak, abdominal fat was inserted into the sphenoid sinus. Expanding sponges were inserted into the nasal cavity for 48 hours. Postoperative CSF leakage was managed with a lumbar puncture within three days following the operation. All resected tumor specimens were submitted to a neuropathologist for histopathological evaluation, including immunohistochemical analysis, to confirm the pituitary adenoma diagnosis, hormonal status, and assess for indicators of necrosis or hemorrhage.

Study outcomes

Postoperative assessment of study outcomes included comprehensive radiological, endocrinological, visual, and clinical evaluations. Radiological outcome was determined by assessing the extent of tumor resection and early postoperative complications (e.g., hematoma or pneumocephalus) using an early postoperative CT scan, followed by pituitary MRI within three months for final classification of the extent of resection (gross total or subtotal) according to the criteria described by Juraschka et al. [9]. Endocrinological outcome was evaluated through postoperative hormonal assessment of the pituitary profile one month after surgery, with continued follow-up for patients with persistent hormonal abnormalities. Visual outcomes were assessed using visual acuity testing with Snellen charts and visual field examination using Humphrey perimetry during postoperative follow-up, and improvement in visual function was considered a favorable outcome. Postoperative complications including diabetes insipidus, cerebrospinal fluid (CSF) leakage, vascular injury, and infection were also recorded.

Statistical analysis

Statistical Package for the Social Sciences, version 26 (IBM Inc., Chicago, IL, USA) was used. A non-paired Student's t-test was used to compare quantitative data, which were displayed as means ± standard deviations (SD), among the various groups. Results for qualitative variables were examined with either Fisher's exact test or a Chi-square test, depending on whether they were given as numbers or percentages (%). The significance level was deemed to be $P < 0.05$.

Sample size calculation

The Epi Info™ version 2002 statistical tool, developed by the World Health Organization and the Centers for Disease Control and Prevention, was used to determine the sample size. The computation was done with a 95% confidence level and a ±20% margin of error, based on a prior study that reported a visual deficiency frequency of 69.4% [10]. A total of 25 patients were included in the study after four extra cases were included to account for possible dropouts, as was determined to be the minimum needed sample size.

RESULTS

We initially evaluated 31 patients for eligibility. Four patients were excluded due to the presence of microadenomas, while two patients declined to participate. A total of 25 patients were finally included in the study, with a mean age of 37.6 ± 13.1 years (range: 12–70).

Preoperative tumor invasion and clinical presentation

The extent of cavernous sinus invasion (Knosp classification) showed that the majority of tumors (n= 22, 88%) were non-invasive or minimally invasive. Specifically, 10 patients (40%) were Grade 0 while 8 patients (32%) were Grade I and 4 patients (16%) were Grade II. Higher-grade invasion was less frequent with Grade III in 2 patients (8%), and Grade IV in 1 patient (4%). Common presenting symptoms included headache in 10 patients (40%) and diplopia in 2 patients (8%). Visual impairment was the presenting feature in 20 of 25 patients (80%). These symptoms were not mutually exclusive and could occur in combination. One patient was identified incidentally and had no baseline headache, diplopia, or visual impairment, and was therefore excluded from visual outcome analysis. Ophthalmological evaluation revealed that visual field defects were present in 17 of 25 patients (68%), while decreased visual acuity was observed in 9 patients (36%). Among the 17 patients with visual field defects, the most common pattern was bitemporal hemianopia, observed in 8 patients (47%), followed by bilateral generalized field depression in 5 patients (29%), and unilateral generalized field depression in 4 patients (24%). Overlap between visual field defects and decreased visual acuity was observed in 6 patients, whereas visual field defects only were present in 11 patients, and decreased visual acuity only in 3 patients. Postoperatively, 16 of the 20 patients with visual impairment (80%) showed improvement. Improvement rates for each group were as follows: visual field only (11 patients), 9 improved (82%); decreased visual acuity only (3 patients), 2 improved (67%); overlap group (6 patients), 5 improved (83%), with 4 patients improving in both visual field and visual acuity and 1 patient improving in visual field only. One patient in

the overlap group showed no improvement. Patients in the overlap group typically demonstrated improvement in at least one affected domain, most commonly the visual field. These results indicate a high rate of visual recovery following endoscopic endonasal surgery, particularly among patients with visual field defects, and underscore the importance of subtype-specific ophthalmological assessment in pituitary macroadenoma patients. **(Table 1).**

Preoperative hormonal and radiological status

The mean preoperative hormonal levels were as follow: prolactin among PRL-secreting macroadenomas (n=7) was 689±260 ng/ml, GH among GH-secreting (n=3) was 51.7±7.6 ng/ml, and IGF-1 was 550±100 ng/ml. Non-functioning macroadenomas were excluded from the calculation. Among the 25 patients with pituitary macroadenomas, hormonal hypersecretion was observed in 11 cases. Prolactin-secreting adenomas were diagnosed based on markedly elevated serum prolactin levels (>200 ng/mL) in correlation with clinical and radiological findings. Immunohistochemical staining for prolactin was used for confirmation when available. In contrast, patients with prolactin levels <200 ng/mL in the presence of a macroadenoma were considered to have stalk effect or non-functioning adenomas. In our cohort, prolactin elevation occurred in 7 patients (28% of the total cohort, 64% of functional adenomas), growth hormone elevation was seen in 3 patients (12% of the total cohort, 27% of functional adenomas), and ACTH hypersecretion was observed in 1 patient (4% of the total cohort, 9% of functional adenomas). In terms of sphenoid sinus location, most tumors were centered in the sellar region (84%), with 4 tumors (16%) having a post-sellar location. Multiple sphenoid sinus septa were observed in 22 patients. All tumors showed homogeneous enhancement on MRI. Most tumors (68%) measured between 30-50 mm in height, with the remaining 8 (32%) between 10-30 mm **(Table 2).** Suprasellar extension was observed in 21 patients (84%). Sphenoid sinus mucosal thickening was observed in 18 of 25 patients (72%), corresponding to the high prevalence of suprasellar extension (21/25, 84%) in our cohort. Cavernous sinus invasion was present in only 3 cases (12%) and appeared to have minimal effect on mucosal changes. The mean operative time for the endoscopic endonasal approach was 2.2±0.48 hours. The mean duration between symptom onset and surgery was 4.7 ± 2.12 months.

Postoperative outcomes and complications

Gross Total Resection (GTR) was achieved in 19 patients (76%), while Subtotal Resection (STR) occurred in 6 patients (24%). **(Table 3).** "Postoperatively, clinical outcomes in our cohort of 25 patients undergoing endoscopic endonasal resection of pituitary macroadenomas were generally favorable. Among patients presenting with headache (10 patients), 8 patients (80%) experienced improvement, while 2 patients (20%) remained unchanged. Diplopia was observed in 2 patients; 1 patient (50%) improved, whereas the other (50%) remained unchanged. Diplopia in our cohort was primarily due to abducent (CN VI) palsy. The patient who improved had a tumor causing lateral and suprasellar mass effect and underwent gross total resection. The patient whose diplopia did not improve had tumor invasion into the cavernous sinus, limiting the extent of resection and resulting in persistent nerve compression.

Twenty patients with preexisting visual impairments had their visual function evaluated; 16 patients (80%) had an improvement, 4 patients (20%) had no change, and 0 patients had a worsening in vision.

Endocrine outcomes in 11 patients with functional adenomas demonstrated remission in 7 patients (64%), while persistent hyperfunction was mainly observed in cases of subtotal resection or tumors with cavernous sinus extension. It should be noted that absence of cavernous sinus invasion did not guarantee gross total resection (GTR), as some tumors were subtotal resected due to high suprasellar extension, firm adherence to the optic apparatus, or technical considerations aimed at preserving neurological and pituitary function. Postoperative complications in our cohort were generally infrequent. Cerebrospinal fluid (CSF) leak occurred in 2 patients (8%) during the first two postoperative days and was successfully managed conservatively without the need for lumbar drainage; no persistent CSF leak was observed. Transient diabetes insipidus was observed in 2 patients (8%). In one patient (4%), The classic triphasic reaction following pituitary surgery manifested as the progression from transitory to permanent diabetic insipidus. It appears that the patient went through both the temporary and permanent stages. Throughout the duration of the follow-up, there were no reports of meningitis, major epistaxis, death, or postoperative vision impairment. **(Table 4).**

Correlation between extent of resection and outcomes

A significant difference was found between the extent of resection and clinical outcome (P=0.001). Among patients who underwent gross total resection (GTR, n = 19), improvement among patients presenting with the symptom preoperatively was as follows: headache improved in 7 of 8 patients (87.5%), diplopia in 1 of 1 patient (100%), and visual function improved in 14 of 16 patients (87.5%). Among patients who underwent subtotal resection (STR, n = 6), improvement among patients presenting with the symptom preoperatively was: headache improved in 1 of 2 patients (50%), diplopia did not improve (0%), and visual function improved in 2 of 4 patients (50%). No significant difference was seen in the percentage of visual improvement between the GTR (87.5% improved) and STR (50% improved) groups (P = 0.21). Also, when comparing the two groups, neither the mean operating time (P = 0.579) nor

the distribution among Knosp invasion stages (P = 0.671) showed any statistically significant differences. However, Overall, tumor resection was shown to be less extensive at higher Knosp grades, suggesting that the capacity to accomplish gross complete resection is limited by larger penetration of the cavernous sinus. Both the unaltered and clinically better groups did not vary significantly in operational time (P = 0.497) **(Table 5).**

DISCUSSION

Findings summary

The endoscopic endonasal transsphenoidal technique was shown to be safe and effective in managing pituitary adenomas in 25 individuals in this investigation. Patients having subtotal resection (STR, 6/25, 24%) demonstrated lower rates of improvement compared to those attaining gross complete resection (19/25, 76%), and there was a statistically significant association between the degree of resection and clinical improvement (P = 0.001). Overall, 80% of patients had an improvement in visual function, and 64% of patients with functional adenomas were able to achieve remission of endocrine hyperfunction. When comparing the GTR and STR groups, we did not find any statistically significant differences in terms of operating time, visual improvement, or the stage of Knosp invasion. The endoscopic endonasal technique is highly effective and safe for controlling pituitary adenomas, according to these data.

Our results in the context of previous literature

Endocrinological assessment in our cohort revealed that 44% of patients had functional adenomas, with prolactin elevation being the most common hormonal abnormality (28% of the total cohort; 64% of functional adenomas). Other functional types included GH-secreting adenomas (12% of the total cohort; 27% of functional adenomas) and ACTH-secreting adenoma (4% of the total cohort; 9% of functional adenomas), while the majority of cases (56%) were non-functioning adenomas. This pattern reflects a predominance of tumors producing mass effect symptoms rather than overt hormonal syndromes, although functioning tumors still represent a significant surgical subset. The lower proportion of prolactinomas in this series compared to some reports may be explained by the high responsiveness of these tumors to medical therapy, particularly dopamine agonists, resulting in fewer surgical referrals. Maiter [11] noted that dopamine agonists remain the first-line therapy for most prolactinomas, with surgery typically reserved for resistant or intolerant cases. Surgical outcomes demonstrated a gross total resection rate of 76%, with the majority of patients experiencing clinical improvement postoperatively. Overall, visual function improved in 16 of 20 affected patients (80%), and endocrine hyperfunction remission was achieved in 7 of 11 patients with functioning adenomas (64%). Only a small proportion of patients had persistent deficits or required adjuvant medical therapy, indicating that both visual and endocrine outcomes were generally favorable.

Complications following surgery were uncommon. Of the individuals studied, 2 (or 8%) had transient diabetes insipidus and 1 (or 4%) had persistent diabetes insipidus. Two patients, accounting for 8% of the total, experienced minimally invasive management of CSF leak that did not need lumbar draining. Importantly, no cases of SIADH independent of the triphasic response, postoperative meningitis, significant epistaxis, mortality, or severe visual deterioration were recorded during the follow-up period. These findings indicate that the endoscopic endonasal approach can be performed with an acceptable morbidity profile, particularly when meticulous reconstruction techniques are applied. The observed CSF leak and DI rates are comparable to those reported in the literature, supporting the idea that careful perioperative management and handling of the pituitary stalk can minimize long-term endocrinological complications.

Analysis of surgical outcomes demonstrated that improvement in symptoms was significantly higher among patients who achieved gross total resection (GTR, 19/25, 76%) compared to those who underwent subtotal resection (STR, 6/25, 24%) (P = 0.001). Among affected patients in the GTR group, headache improved in 7 of 8 patients (87.5%), diplopia in 1 of 1 patient (100%), and visual function in 14 of 16 patients (87.5%). In the STR group, improvement among affected patients was lower: headache improved in 1 of 2 patients (50%), diplopia did not improve (0%), and visual function improved in 2 of 4 patients (50%). These findings underscore the direct relationship between completeness of tumor removal and postoperative functional recovery in our series, reinforcing the consensus in the literature that maximal safe resection is a key determinant of postoperative outcomes. Akinduro et al. [14] demonstrated in a meta-analysis that GTR is associated with superior visual and endocrine recovery compared to subtotal resection, although STR may be warranted in cases with high surgical risk or challenging tumor characteristics. When examining the relationship between operative time and clinical improvement, no statistically significant association was identified in our cohort. Mean operative times were similar in patients who improved and those whose symptoms remained unchanged (P = 0.497), suggesting that surgical duration alone is not a primary predictor of functional outcome. This indicates that factors beyond time efficiency, such as tumor characteristics, suprasellar extension, and the precision of resection, may play a greater role in determining recovery. A similar observation has been made in previous studies, where shorter operative times did not necessarily translate into better

results. Braddock et al. [15] demonstrated that the accuracy and thoroughness of surgical decisions are more important in determining results than the time spent in surgery.

Clinical implication
The findings support the idea that pituitary adenomas, particularly those presenting mass effect symptoms, are best surgically managed utilizing the endoscopic endonasal transsphenoidal procedure. The strong correlation between GTR and clinical improvement highlights the need of safely removing the tumor to its maximum extent as the main objective of the surgery. This is crucial for achieving positive patient outcomes. These findings support aggressive, yet careful, resection whenever feasible to achieve not only decompression but also symptomatic relief and endocrinological control.

Study limitations
The conclusions may not be applicable to other populations or surgical contexts due to the study's single-center design, the limited statistical power for subgroup analyses is possible due to the small sample size, and a thorough evaluation of tumor recurrence or long-term complications may not be possible due to the short-to-intermediate follow-up period.

CONCLUSION
The endoscopic endonasal transsphenoidal technique was a safe and effective surgical method that successfully removed pituitary adenomas. Patients had a good chance of seeing well and experiencing minimal side effects after the procedure. Future studies should focus on larger multicenter cohorts to improve statistical power and enhance the generalizability of findings, extend follow-up durations to evaluate long-term recurrence rates and late-onset complications, and incorporate standardized patient-reported outcome measures to assess quality of life and functional recovery.

Ethics approval and consent to participate:
The study protocol was approved by the university's ethical committee **(KFSIRB200-297)** and preregistered in the Pan African Clinical Trial Registry **(PACTR202512728520659).**
Written informed permission was obtained from all participants in the study.

Consent for publication: Not applicable.

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Author contributions:
1. **Ayman M. Ismail:** study design, data collection, statistical analysis, writing.
2. **Mohamed Adel Moustafa:** investigations, surgical interventions, resources, writing.
3. **Taha A. Ismail:** resources, surgical interventions, supervision, writing, reviewing.
4. **Mohammad Fathy:** investigations, surgical interventions, resources, writing.
5. **Nabil Amin Nasef:** resources, surgical interventions, supervision
6. **Mohamed A. Abbas:** resources, surgical interventions, writing, reviewing.

***Corresponding to Mohamed Adel Moustafa, MBBCh**, Neurosurgery Department, Faculty of Medicine, Kafr Elsheikh University, Kafr Elsheikh, Egypt. **Email:**
mohamedmoustafa451996@gmail.com, **Tele:** (+20) 100 933 9724

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Table 1. Clinical Presentation

Symptom	**Number of Patients**	**% of Total Cohort**
Headache	10	40%
Diplopia	2	8%
Visual impairment	20	80%
Incidentaloma	1	4%

Extent of Resection

Extent of Resection	**Number of Patients**	**%**
Gross Total Resection (GTR)	19	76%
Subtotal Resection (STR)	6	24%

Visual and Endocrine Outcomes (Overall)

Outcome	Number Affected	Improved / Remission	%
Visual function	20	16	80%
Endocrine hyperfunction (functional adenomas)	11	7	64%

Visual Function Details – Combined

Visual Deficit	Subtype / Pattern	Number of Patients	Improved	% Improved
Visual field defects	Bitemporal hemianopia	8	7	87.5%
Visual field defects	Unilateral generalized depression	4	3	75%
Visual field defects	Bilateral generalized depression	5	4	80%
Decreased visual acuity	–	9	6	67%
Overall visual impairment	–	**20**	**16**	**80%**

Visual Field Defects Only (Without Acuity Involvement)

Subtype	Number of Patients	Improved	% Improved
Bitemporal hemianopia	5	4	80%
Bilateral generalized field depression	4	3	75%
Unilateral generalized field depression	2	2	100%

Decreased Visual Acuity Only

Category	Number of Patients	Improved	% Improved
Decreased visual acuity only	3	2	67%

Overlap (Both Visual Field & Acuity Deficits)

Outcome	Number of Patients	Improved	%
Improved in both domains	4	4	100%

Outcome	Number of Patients	Improved	%
Improved in visual field only	1	1	100%
No improvement	1	0	0%
Total overlap patients	**6**	–	–

Cavernous Sinus Invasion (Knosp Grade)

Knosp Grade	Number of Patients	% of Total Cohort	Notes
Grade 0	10	40%	No invasion
Grade I	8	32%	Minimal invasion
Grade II	4	16%	Minimal invasion
Grade III	2	8%	True cavernous sinus invasion
Grade IV	1	4%	Complete cavernous sinus invasion
Total	**25**	**100%**	–
Summary	**Number of Patients**	**% of Total Cohort**	**Notes**
Knosp 0–2 (No / Minimal invasion)	22	88%	Mostly GTR
Knosp 3–4 (True cavernous sinus invasion)	3	12%	STR in most cases

Table 2. Radiological evaluation of the studied patients

Adenoma height	**10-30 mm**	**8 (32%)**
	30-50 mm	17 (68%)
Tumor extension	**Suprasellar**	21 (84%)
Tumor enhancement	**Homogeneous**	25 (100%)
Sphenoid sinus mucosal thickening		18 (72%)
CT paranasal sinuses		
Location of sphenoid sinus	**post sellar**	4 (16%)
	sellar	21 (84%)
Septa of sphenoid sinus	**Single**	3 (12%)
	Multiple	22 (88%)

Complication	Number of Patients	%
Transient diabetes insipidus	2	8%
Permanent diabetes insipidus	1	4%
CSF leak	2	8%
SIADH (independent)	0	0%
Meningitis	0	0%
Significant epistaxis	0	0%
Mortality	0	0%
Postoperative visual deterioration	0	0%

Table 3. Extent of Resection

Extent of Resection	Number of Patients	%
Gross Total Resection (GTR)	19	76%
Subtotal Resection (STR)	6	24%

Clinical Outcomes by Extent of Resection

Symptom	GTR (n affected)	Improved	Improved %	STR (n affected)	Improved	Improved %
Headache	8	7	87.5%	2	1	50%
Diplopia	1	1	100%	1	0	0%
Visual function	16	14	87.5%	4	2	50%
Overall clinical improvement	–	–	–	–	–	–

Note: Clinical improvement was significantly higher in the GTR group compared to the STR group ($p = 0.001$). Visual improvement showed a trend favoring GTR but did not reach statistical significance ($p = 0.059$).

Table 4. Postoperative Complications

Table 5. Operative Time and Associated P-values

Variable	Comparison	P-value	Interpretation
Clinical improvement	GTR vs STR	0.001	Statistically significant
Visual improvement	GTR vs STR	0.059	Not statistically significant
Operative time	Improved vs unchanged	0.497	Not significant
Knosp invasion stage	GTR vs STR	0.671	Not significant
Operative time	GTR vs STR	0.579	Not significant

Additional Tables (for reference)
Patient Demographics and Endocrine Types

Parameter	Number of Patients	% of Total Cohort	% of Functional Adenomas
Total patients	25	100%	–
Functional adenomas	11	44%	100%
Prolactinomas	7	28%	64%
GH-secreting adenomas	3	12%	27%
ACTH-secreting adenoma	1	4%	9%
Non-functioning adenomas	14	56%	–