International Journal of Neurology Sciences

ISSN Print: 2664-6161
ISSN Online: 2664-617X
IJNS 2025; 7(1): 23-32
www.neurologyjournal.in
Received: 06-11-2024
Accepted: 08-12-2024

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Image guided minimally invasive surgical approaches to tumors around sella

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DOI: https://www.doi.org/10.33545/26646161.2025.v7.i1a.33

Abstract

Background: Previously, conventional craniotomy techniques have been employed to reach lesions that affect the sellar and parasellar regions. In recent times, there has been a growing preference for minimally invasive methods, such as supraorbital and endonasal endoscopic approaches.

Objective: This study aimed to assess the efficacy, advantages, and limitation of minimally invasive approaches to tumors around sella with using of image guided system.

Methods: 25 patients with tumors around sella who underwent minimally invasive approaches were identified: 7 supraorbital keyhole and 18 endoscopic endonasal. Radiographic images, presenting complaints and outcomes, were analyzed. The safety of each approach was evaluated concerning lesions diameter, extension, encasement of neurovascular structures, and brain invasion especially malignant lesions are considered some contraindications for the transnasal approach and suitable for the supraorbital approach.

Results: According to surgical approaches used transnasal (16%), transclival (20%), and transsphenoidal (36%), which was the most common approach in this study. Gross total tumor removal, as assessed by postoperative magnetic resonance imaging, was possible in most patients (72%). Clinical improvement from 13 (52%) of patients post-operative increased up to 80% of patients after 6 months. Complications included cerebrospinal fluid leak in 6 patients (24%), meningitis in 1 patient (4%) and transient diabetes insipidus in (68%). There was one operative mortality, and two patients showed tumor regrowth after 6 months follow up.

Conclusion: meticulous planning and coordination with multiple specialists is necessary to provide the patient with optimal therapy while minimizing potential consequences.

Keywords: Lesions around sella, potential consequences, craniotomy techniques, surgical approaches

Introduction

Lesions around sella and anterior skull base include a wide variety of congenital, vascular and neoplastic lesions. Many lesions in this area are of a benign nature requiring fully adequate management to achieve complete cure. The anatomical location of these lesions lies in close proximity of critical neural and vascular structures [1].

Endoscopic skull base surgery has undergone rapid advancement in the past decade, moving from pituitary surgery to suprasellar lesions and now to lesions extending from the cribriform plate to C2 and laterally out to the infratemporal fossa and petrous apex. Evolution of technological advances, including understanding of endoscopic anatomy and the development of surgical techniques both in resection and reconstruction have fostered this capability. Continued advances in surgical technique, navigation systems, endoscopic imaging technology, and robotics assure continued evolution in this expanding field [2].

The introduction of endoscopic endonasal transsphenoidal surgery in the 1990s allowed for a broader field of view and improved visualization while preserving minimal invasiveness. The popularization of this new surgical technique, with which particularly good clinical results have been achieved, together with excellent anatomic studies in human cadavers that have enabled the limits of this approach to be explored and encouraged the extension of the approach beyond the limits of the microsurgical approach [3].

The objective of "keyhole" surgery is not merely to create a small incision and craniotomy for the sake of having a small orifice.

The objective of this strategy is to allow sufficient access to skull base lesions while minimizing damage to adjacent areas such as the skin, bone, dura, and, most significantly, the brain [4].
Image guided techniques have advantages over conventional planning and surgery in selected cases as they help to identify prominent vascular and neural structures associated with skull base and provide a visual warning that these structures are in the vicinity during an aggressive tumor resection [5]. One of the major concerns in endoscopic skull base surgery is the need for reconstruction of the dural defect. The techniques to create large defects in the cranial base have been available for quite some time. However, it is only recently that good options for reconstruction have been discovered [6].
The aim of the present study was to evaluate the outcome of minimally invasive approaches in the treatment of patients with lesions around sella, to evaluate its limitations, safety and efficacy in the treatment and the benefits of using image guided system.

Patients and Methods
This study included twenty-five patients presented with lesions around sella and anterior skull base and subjected to image guided minimally invasive approaches. The study was performed at Tanta University Hospital, Neurosurgery Department between July 2021 and August 2023. Ethical approval for conducting this study was obtained from the ethical committee in faculty of medicine, Tanta University, before the start of the study.

Surgical methods
1. Endoscopic Endonasal Approach
- **Inclusion criteria:** 1) Skull base lesions located at: a. Planum sphenoidale, b. *Tuberculum sellae* meningiomas, c. Sellar region with symmetrical suprasellar extension, d. Clivus, 2) eligibility criteria for general anesthesia.
- **Exclusion criteria:** Patients excluded from this study are those with 1. Encasement of critical neurovascular structures (internal carotid arteries, anterior cerebral arteries). 2. The main part of the lesion shows asymmetric upward and or lateral extension over the sellar region. 3. Wide dural and cerebral involvement. 4. Posterior extension into the infratemporal fossa with osteolysis of the greater wing of sphenoid. 5. Large *tuberculum sellae*/planum sphenoidale and olfactory groove region that have encased the anterior cerebral arteries, present with significant underlying brain edema suggesting breach of the pia-arachnoid planes and have a major lateral or parasellar extension. 6. When air cell not well pneumatized in CT paranasal sinuses. 7. Contraindications for general anesthesia.

2. Endoscopic assisted microscopic supraorbital keyhole approach
- **Inclusion criteria:** Patient with suprasellar and-or parasellar lesion.
- **Exclusion criteria:** Patients excluded from this study are those with: Invasive lesions with bilateral (both right and left) parasellar extensions, patient with large frontal air sinus. Contraindications for general anesthesia.

Preoperative evaluation
Clinical assessment
All patients in this study underwent detailed clinical assessment in the form of detailed history taking, through general examination, and comprehensive neurological examination. Special attention is made on the examination of the visual functions and endocrinal manifestation.

Symptoms of anterior skull base and sellar lesions
- **Visual manifestations:** Decrease visual acuity. Blurring of vision Field defect diplopia
- **Hypothalamic manifestation:** Fatigue Appetite change Sleep disturbance Polyuria.
- **Endocrinal manifestation:** Growth abnormality Amenorrhea Galactorrhea Loss of libido
- **ICP related manifestation:** Disturbed consciousness Headache vomiting
- **Other manifestation:** Cranial nerve affection Behavioral changes Motor or sensory deficit & seizure.

Laboratory work up: Routine laboratories work up including complete blood picture, liver and kidney functions, blood sugar level, and coagulation profile were performed in every patient.
Hormonal assay including prolactin level, 24-hour urinary cortisol level, T4 and TSH, growth hormone, FSH and LH were performed in patients presented with hypothalamic or endocrinal manifestations and in patients with lesions compressing hypothalamus or pituitary gland.

Neuroimages: Both CT scan and MRI of the brain with and without contrast were obtained in every patient. Special MRI sequences such as diffusion-weighted images were obtained in case of (epidermoid tumors), dynamic MRI sella with contrast. Navigation protocol was applied in both CT and MRI imaging.

Operative technique
Endoscopic assisted microscopic supraorbital keyhole approach
The supraorbital keyhole approach is a truly minimally invasive approach. The head of the patient is fixed in a May field head holder with the head only slightly rotated away from the side of approach (usually 20-30 degrees). A skin incision is made just lateral to the foramen of the supraorbital nerve extending to the lateral border of the eyebrow within the hairline of the eyebrow.
A small frontal muscle flap is created medial to the superior temporal line, while the temporal muscle is retracted 1 cm laterally. A burr hole is made lateral to the superior temporal line and a small supraorbital craniotomy with a diameter of 2.5 x 1.5 cm is made.
The side of the supraorbital approach is dictated by the tumor extension. Parasellar tumor extension or lateral to suprasellar space requires an ipsilateral approach. However, a suprasellar tumor part that is lateralizing within the suprasellar area may require a contralateral approach. In those cases, the preoperative MRI should be carefully studied for a prefixed chiasm that may hinder the approach. If the tumor is growing parasellarly into the middle cranial fossa one might opt for a small pterional approach instead of a supraorbital approach to improve the approach to the middle cranial fossa. The supraorbital approach allows the removal of the suprasellar tumor part, and tumor on the

tuberculum sellae and anterior skull base, as well as beyond the dorsum sellae.

Endoscopic Endonasal approach

The operation takes place with a patient in a supine position with the head fixed in a three-pin Mayfield holder. The head of the bed is elevated 30 degrees with the neck neutral or slightly extended and rotated toward the side of the surgeon. Intraoperative image guidance using navigation is used routinely. The video monitor is positioned behind the patient's head directly in front of the surgeon's line of vision. Both nostrils are prepared with a topical vasoconstrictor. The endonasal approach is begun by exploring the right and left nostrils.

The initial steps include resection or lateralization of the middle turbinate. Next, one attempts to locate the sphenoid ostia. A large sphenoidotomy is performed, with exposure of the sellar floor from carotid prominence to carotid prominence and craniocaudally from the planum to the clivus.

We routinely visualize both the medial and lateral opticocarotid recesses. To maximize the advantages of the endoscopic approach, we advocate a binostril bimanual technique for pituitary exploration and tumor removal in all cases. This requires the resection of a small part of the posterior nasal septum.

This technique significantly increases the maneuverability of instruments, augments the efficacy and safety of the endoscopic surgery by improving access to the tumor, and helps to deal with any bleeding in the same manner as with microsurgery.

The drilling of the base of the sphenoid is an important step that helps expose the clivus and the inferior sellar floor and the exposure of the sellar floor. This and the remaining part of the procedure are performed using a bimanual technique, with the assistant surgeon holding the endoscope.

At the completion of the sphenoidotomy, the clival and sellar carotid prominence, medial and lateral opticocarotid recesses, planum, and clivus should be clearly seen. Image guidance and a micro-Doppler probe are used to identify and confirm the trajectory of both carotid arteries and the medial cavernous sinus wall.

The sellar floor is initially opened with a drill and is then resected with various angled punches to visualize the medial wall of the cavernous sinus bilaterally. The dural opening is then made from the medial cavernous sinus walls and from the superior intercavernous sinus to the clivus.

The rationale for opening from lateral to medial and superior to inferior is to promote safer control of any false maneuver of the telescopic knife, which would be more hazardous by going in the opposite direction toward the cavernous, carotid, or superior cavernous sinus.

However, the starting point should be carefully inspected and checked with the Doppler probe to ascertain the trajectory of the carotid arteries, and the incision should be made a few millimeters medial to that. Additional lateral opening of the dura can be accomplished using micro scissors under direct visual control.

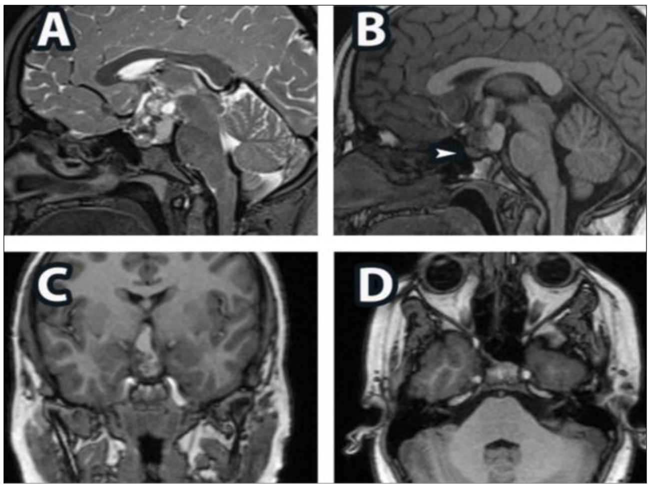
Using the binostril bimanual technique, tumor removal is performed using the same principles as with the microscopic technique.

In patients with focal compression toward the cavernous sinus, additional resection of the sellar floor over the carotid prominence can be done. This allows for retraction of the medial wall laterally, and, under endoscopic visualization, resection of the tumor by careful dissection from the medial wall of the cavernous sinus, although rarely can the tumor be followed and resected from within the cavernous sinus. We favor a subtotal resection policy for tumors with direct intracavernous invasion.

The closure is completed in a multilayer fashion using Surgicel © (Johnson & Johnson, USA), fibrin glue, and Gelfoam © (Pfizer, USA) and in case of a significant perioperative cerebrospinal fluid (CSF) leak, a fascia lata and fat graft are harvested and also used.

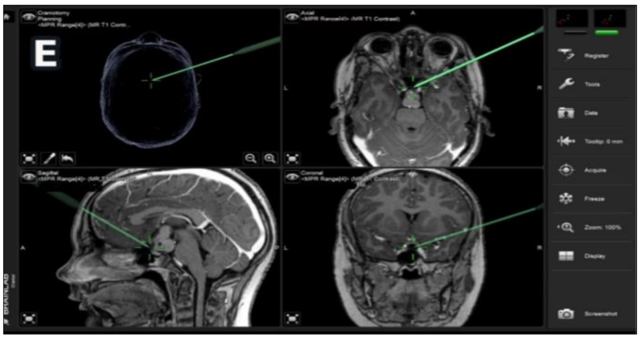
Patients are not routinely given corticosteroids before the surgery. Antibiotic administration is continued for 24 hours. All patients are admitted to a stepdown unit for overnight monitoring, although more recently, some patients have gone directly to the hospital ward.

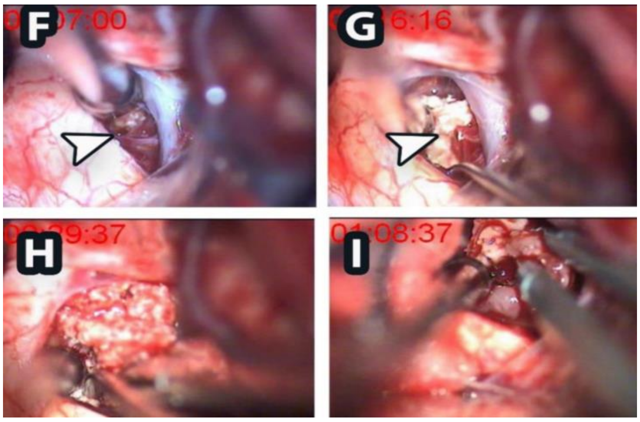
Case 1

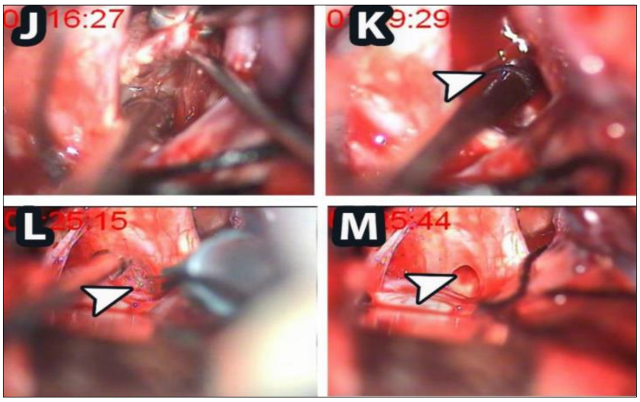


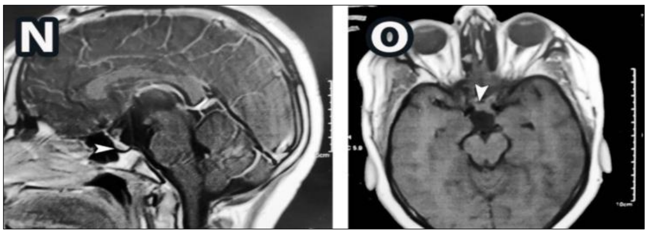
A-D are all MRI images before surgery. A: preoperative sagittal T1 weighted MR image showing mixed tumor intensity. B: preoperative sagittal T1 weighted MR image showing suprasellar exclusive growth of the tumor above the normal pituitary gland (arrowhead). C: a coronal T1 weighted MR image showing the upper part of the tumor extending partially into the cavity of the third ventricle. D: and axial T1 weighted MRI image showing the sella is not dilated and the normal pituitary resides in E, is intraoperative image guided (optical navigation) surgical verification images F-I are all intra-operative live microscopic images during surgery. F: accessing the tumor through the optico-carotid triangle (arrowhead) G: removal of solid cholesterol containing parts. H: Further completion of solid part removal. I: challenging the removal of the soft tissue wall through the optico-carotid triangle.

Images J-M are all intra-operative live microscopic images during surgery. J: Further removal of the amenable parts of the wall of lesion K: A suction tube inside the empty corridor. L: Lamina Terminalis is sharply open using an insulin syringe (arrowhead). M: The Lamina Terminalis is clear after descent of the tumor during resection (arrowhead) N&O are late postoperative images showing complete removal of the lesion. N: sagittal T1MR image showing normal pituitary gland and stalk (arrowhead). O: axial cut showing normal position of the chiasm.









Case 2

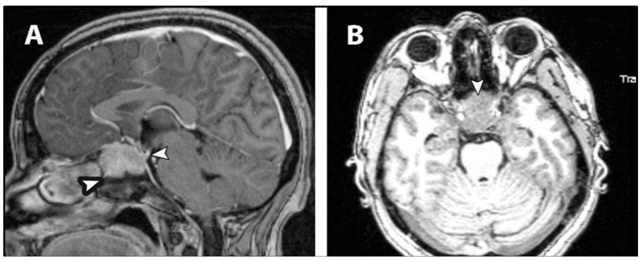


Fig 1: A&B are all MR images before surgery. A: sagittal T1 weighted MR image showing a *tuberculum sellae* meningioma with downward extension into the sphenoid and ethmoid sinuses (arrowhead larger) and backward pushing of the normal pituitary gland (arrowhead small). B: axial T1 weighted MR image showing is filling the sphenoid sinus (arrowhead).

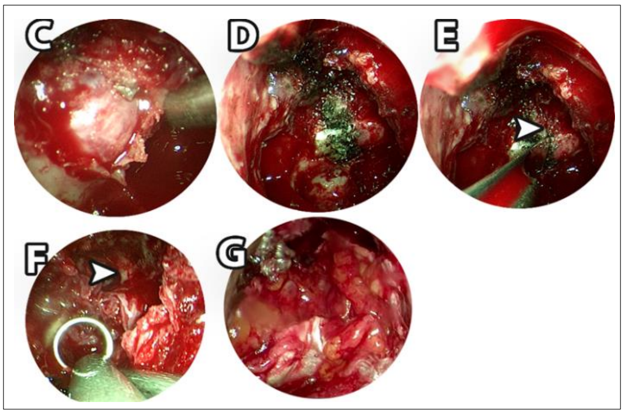


Fig 2: C-G. C: an intraoperative expanded endoscopic access to the lesion with bony decompression to expose the affected dura. D: quantization of the dura to devascularize the lesion and facilitate removal. E: The durotomy is performed using a knife (arrowhead). F: further removal of the lesion allowed for visualization of the left optic nerve (arrowhead). G: following a maximum possible recession a graft fascia lata is used to close the dural defect

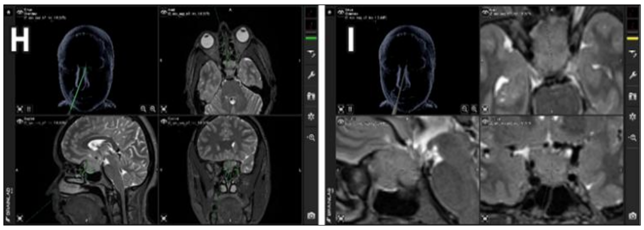


Fig 3: H&I are intraoperative navigation confirmation of reaching both the tumor surface and depth

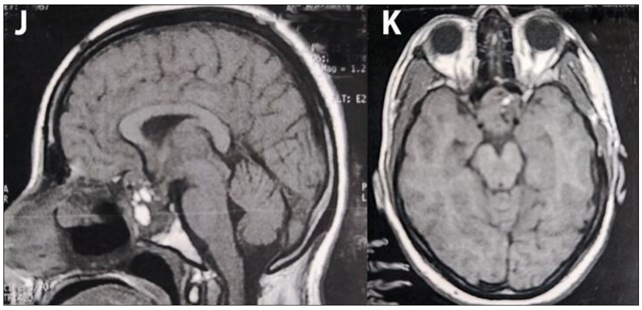


Fig 4: J & K are all post MR images. J: sagittal T1-weighted image showing the tumor bed largely replaced by fat graft above, which is small tumor residual. K: Axial T1-weighted image showing the summit of the tumor with partial residual component.

Postoperative course and follow up

All patients were discharged from the operating room to the ICU for 24 hours. Patients were maintained on antibiotic (ceftriaxone one gram/12hours) and steroids in gradual tapering doses. Patients receiving preoperative hormone supplementation were continued postoperatively.

Complete neurological evaluation was performed immediately after recovery from anesthesia for evaluation of consciousness level, visual functions, cranial nerve affection, and motor power. Early morbidities were recorded and treated appropriately. Urine output and any endocrinopathies were recorded.

Patients were discharged on the 3rd to 5th postoperative day unless their clinical condition required staying more like transient CSF leakage, meningitis, electrolyte disbalance, polyuria and seizures. Post discharge outpatient clinic visits were scheduled two weeks following surgery, then monthly for 3-6 months period.

Outcome assessment

- **Perioperative Data:** Operative time, blood loss, Intraoperative complications and percentage of lesion resection and its accessibility.
- **Post-Operative Data:** CT Brain was done within 24 hours to detect early complications, such as hematoma or pneumocephalus. Contrasted MRI Brain was done within the first 3 months postoperatively. Hormonal Profile was done on the one month, three months and six months post-operatively. Incidence of Cerebrospinal Fluid (CSF) leakage was followed. Intracranial infection was followed clinically and laboratory. Nasal functional (Smelling, Aeration and Nasal Crusts) assessment for the smell was followed by fellow otorhinolaryngologist. Endocrinological and visual follow-up. Any remote cranial complications.

Follow up evaluation

- The outcome is assessed in every post-operative visit according to three criteria which include clinical and functional state, cosmetic result, and achievement of surgical goal. Contrasted MRI Brain was done 3 and 6 months later to assess the gross total resection ratio. Hormonal Profile one month, three months, six months later.
- Pre-Operative and Post-Operative assessment: performance Outcome was assessed by Karnofsky scoring [7], papilledema as a sign of increased intracranial pressure assessed by fundus examination, headache as symptom of increase intracranial pressure was evaluated by visual analogue score from zero, which indicates no pain to ten. Scott kraft scale was used to assess the sixth nerve palsy state [8]. Each patient's score was evaluated preoperatively, immediately post operation, and 3 and 6 months postoperatively.

Results

Table 1: Patient data

Category	Value
Total number	25
Gender (M/F)	Aug-17
Age (Mean ± SD, years)	44.28±11.96
Pathology: Number (percent)	
Chordoma	3 (12%)
Craniopharyngioma	5 (20%)
Epidermoid	1 (4%)
Meningioma	8 (32%)
Adenoma	8 (32%)
Macroadenoma	5 (20%)
Microadenoma	3 (12%)
Location: Number (percent)	
Clival	3 (12%)
Petroclival	1 (4%)
Suprasellar	7 (28%)
Sellar	7 (28%)
Tuberculum sella	7 (28%)
Extension of tumor: Number (percent)	
Suprasellar	13 (52%)
Sellar	3 (12%)
Parasellar	9 (36%)
Approach: Number (percent)	
Supraorbital	7 (28%)
Transclival	4 (16%)
Transplanum	5 (20%)
Transsphenoidal	9 (36%)
Intraoperative removal: Number (percent)	
Subtotal	7 (28%)
Total	18 (72%)

Table 2: Distribution of the studied cases according to preoperative presenting symptoms and signs

Presenting Neurological Symptoms		
Symptom	**Frequency**	**Percentage (%)**
Sixth nerve palsy	4	16
Hypothalamic manifestation	15	60
Increased intracranial pressure	23	92
Seizures	6	24
Visual affection	21	84
Hormonal disturbance	8	32
Headache Visual Analogue Score (VAS)		
AS Score	**Frequency**	**Percentage (%)**
VAS > 5	23	92
VAS < 5	2	8
Sixth Nerve Palsy (Scott-Kraft Scale)		

Score	Frequency	Percentage (%)
6 (= normal)	21	84
2-4	3	12
0-2	1	4
Grading of Papilledema		
Grade	**Frequency**	**Percentage (%)**
No papilledema	13	52
Grade 1	1	12
Grade 2	6	4
Grade 3	2	24
Grade 4	-	8
Presenting Visual Affection		
Type of Affection	**Frequency**	**Percentage (%)**
No affection	3	12
Right side affection	6	24
Left side affection	4	16
Bilateral (more on left)	3	12
Bilateral (more on right)	2	8
Bitemporal hemianopia	7	28

Table 3: Relation between extensions of surgical removal with tumor characteristics

	Extension of surgical removal				FEP
	Subtotal (7)		Total (18)		
	Number	Percent	Number	Percent	
Location					
Clivus Petro	3	42.9	0	0	0.015*
clival	1	14.3	0	0	0.280
Suprasellar	0	0	7	38.9	0.133
Sellar	0	0	7	38.9	0.133
Tuberclum sella	3	42.9	4	22.2	0.355
Pathology	3	42.9	0	0	0.015*
Chordoma Craniopharyngioma	1	14.3	4	27.8	0.274
Epidermoid Meningioma	1	14.3	0	0.0	0.280
Adenoma	2	28.9	5	27.8	0.640
	0	0	0.0	44.4	
Extension of tumor growth					
Suprasellar	2	28.6	11	61.1	0.057
Sellar	0	0	3	16.7	
Parasellar	5	71.4	4	22.2	

The descriptive analysis of the cases under study based on the duration of the operation, the time taken to reach the tumor, and the amount of blood lost during the operation. During the operation, the time taken ranged from 120 to 285 minutes, with an average of 198.2±55.99 minutes and a median of 230 minutes. The average time taken to reach the tumor was 66.0±13.99 minutes, with a range of 40 to 90 minutes. The utilization of image-guided systems such as optical neuronavigation and electromagnetic navigation has played a vital role in reducing the duration required to reach the tumor. The amount of blood lost during the operation ranged from 150 to 500 milliliters, with an average of 280.0±109.9 milliliters and a median of 300 milliliters.

Table 4: Comparison between the three studied periods according to Lesion diameters

	Preoperative (Mean ± SD)	After 1 Month (Mean ± SD)	After 6 Months (Mean ± SD)	Fr	P-Value
Height of lesion (cm)	3.54±1.41	0.38±0.75	0.42±0.91	49.368*	<0.001*
Width of lesion (cm)	3.57±1.47	0.4±0.8	0.44±0.95	49.368*	<0.001*
Depth of lesion (cm)	3.70±1.89	0.36±0.68	0.4±0.8	49.368*	<0.001*

Table 5: Comparison between preoperative and postoperative patient's outcome

Parameter	Preoperative (Mean ± SD)	After 1 Month (Mean ± SD)	After 6 Months (Mean ± SD)	P-Value
6^{th} nerve palsy (Scott-Kraft scale)	5.36±1.52	5.44±1.36	5.44±1.39	0.497
Headache (VAS Score)	7.04±1.24	3.2±1.38	1.64±1.38	<0.001*
Functional outcome (Karnofsky score)	62.0±7.07	—	82.61±12.51	<0.0001*
Postoperative Visual Function				
Outcome	**Frequency (N=21)**	**Percentage (%)**		
No change	1	4.07		
Improved	18	85.7		
Deteriorated	2	9.3		
Hormonal Levels (Median Values, N=3)				
Hormone	**Preoperative**	**After 1 Month**	**After 6 Months**	
ILGF (ng/ml)	520	190	95	
ILGF (ng/ml)	520	190	95	
Prolactin level (ng/ml)	700	125	45	
24h Urinary Free Cortisol (ng/ml)	192	55	45	

The most common immediate post-operative complication in the present study is transient post-operative diabetes insipidus representing 17 patients (68%) of the patients controlled with desmopressin, the following complications each represented 24%: periorbital ecchymosis in supraorbital approach, transient C S F leakage manage it conservatively in transnasal approach and one case with transient post-operative meningitis managed with antibiotics.

Discussion

Various methods had been established to reduce the size of the craniotomy, minimize brain displacement, and provide sufficient visualization of the cranial base. As technology progresses, cerebral techniques are also developing. Neurosurgeons now have access to improve lighting, advanced surgical microscope optics, precise navigation systems, and the ongoing progress in microsurgical instruments. These technologies enabled carrying out surgeries that are characterized by precision, delicacy, and safety [9].

These procedures include advanced anesthetic methods, precise patient positioning, the utilization of lumbar drains and specialized brain retraction systems [10]. With better microsurgical techniques, instruments, surgical navigation, and endoscopy, tumors in the anterior cranial fossa and parasellar region can now be treated with minimally invasive methods and through smaller surgical pathways [11].

The development of the trans-sphenoidal approach to the sellar and parasellar region was driven by the dedication of surgical pioneers, advancements in technology; and finally, its integration into standard surgical practice. This applies to the utilization of the endoscopic method in the field of skull base surgery. The primary benefits of the endoscopic procedure include a minimally invasive approach that avoids any visible scarring, a clear and comprehensive view of the surgical area, and the ability to effectively address lesions located on the sides, top, or bottom, resulting in a more thorough treatment with fewer issues during the recovery period [12].

In this study, our patients had heterogenous skull base lesions with majority of adenomas and meningiomas. The lesions in our study were not uniformly distributed in terms of location and size. Specifically, 12% of the cases originated from the clival region, 4% from the petro-clival region, 28% from the suprasellar region, 28% from the sellar region, and 28% from the tuberculum sella. In terms of tumor extension, 52% of cases had extension above the sella turcica, 36% had extension lateral to the sella turcica, and 12% had extension within the sella turcica. Among the patients, 72% underwent surgery using the endoscopic endonasal approach, with various corridors utilized. Many cases (36%) were approached transsphenoidally, followed by 20% through the transplanum corridor, and 16% through the transclival corridor. Additionally, 28% of patients underwent surgery using the endoscopic assisted microsurgery supraorbital approach. The main objective of the various surgical techniques employed in this study was to achieve tumor debulking, namely by extending the removal process during the operation. 72% of the instances involved complete removal, whereas 28% involved partial removal. The subtotal removal was primarily performed in cases with chordoma due to the existence of significant neurovascular structures and brain stem invasion.

In accordance with our study, Seaman *et al*. 2022, studied a total of 32 patient who underwent minimally invasive approaches were identified: 20 supraorbital and 11 endoscopic endonasal. They decided the approach according to algorism include lateral extension beyond the ICA, optic nerve, lamina papyracea, olfactory grove and involvement of cribriform plate a supraorbital approach was more frequently selected if the tumor extended lateral to and/or capped the optic nerve, as satisfactory decompression via a transnasal approach in such instances would be unlikely. They found that anterior skull base lesions can be successfully managed by both supraorbital and endoscopic endonasal approaches. Both approaches provide excellent direct access to tumor in carefully selected patients and are safe and efficient, but patient factors and symptoms should dictate the approach selected [10].

Dehdashi *et al*., studied 22 patients with different pathologies 6 craniopharyngiomas, 4 esthesioneuro blastomas, 3 giant pituitary macroadenomas; 2 suprasellar Rathke's pouch cysts; 2 angiofibromas; and 1 each of suprasellar meningioma, germinoma, ethmoidal carcinoma, adenoid cystic carcinoma, and large suprasellar arachnoid cyst operating by expanded endonasal approach, They concluded that the expanded endoscopic endonasal approach is a promising minimally invasive alternative to open transcranial approaches for selective lesions of the midline anterior cranial base. The avoidance of craniotomy and brain retraction and reduced neurovascular manipulation with less morbidity are potential advantages [13].

In this current study the mean operative duration was 198.2±55.99 minutes and a median of 230 minutes. The average time taken to reach the tumor was 66.0±13.99 minutes. The utilization of image-guided systems such as optical and electromagnetic navigation has played a vital role in reducing the duration required to reach the tumor. The endoscopic transsphenoidal approach was shown to have the shortest duration of surgery (median=120 minutes), the quickest time to reach the tumor (median=55 minutes), and the lowest quantity of blood loss (median=150 milliliters). This was attributed to the fact that the corridor was considered the simplest, and most surgeons were familiar with that approach. Conversely, the transplanum method had the longest duration, taking around 85 minutes to reach the tumor. This was owing to the extensive exposure and the utilization of various angles of the endoscopic lens, and this duration decreased by the time by the progress in the learning curve. The supraorbital approach resulted in the longest surgical duration, with a median of 240 minutes and a mean of 240±10 minutes because of the time spent in limited corridor craniotomy. There were no studies before talking about the time to reach the tumor. The transclival procedure had the highest incidence of blood loss (median=375 milliliters) due to the frequent necessity to do middle turbinectomy to enhance visualization and unavoidable violation of the terminal branches of the sphenopalatine artery and clival plexus of veins, as well as the highly vascularity characteristics of tumors in this region.

This result is acceptable in accordance with Song *et al*. team, the operation time was 257±98 minutes [14]. With Felisati *et al*. team, intraoperative blood loss had never been significant with different pathologies and approaches [15].

In our study, arterial bleeding stops spontaneously in most cases or could be controlled by coagulation with bipolar cautery. Venous bleeding mainly originates from the cavernous sinus could be easily controlled by compression or gelatin sponge. The use of the neuronavigation and the micro-doppler provide important support for determining the site of abnormally located great vessels because of the tumor pattern of growth that's have the potential to reduce the possibility of profuse bleeding from great vessels also an accurate preoperative radiological study is mandatory to prevent this complication.

Emanuel *et al*., [16] and Valentine *et al*. [17] had reported possible complication was bleeding, generally from the posterior septal branches of the sphenopalatine artery, more frequently in macroadenomas and during extended approaches. The accidental damage of ICA during the transsphenoidal approach for pituitary adenomas was reported to be in the range of 0-1, 4% in the literature.

AL Qahtani *et al*. [18] distinguished the risk factors for ICA damage in: anatomical factors (thinning or thickening of the ICA bone canal in the lateral wall of the sphenoid sinus, the distance between the two intracavernous tracts, possible presence of aneurysms, pseudoaneurysm or arterio-venous malformations, dislocation of the ICA), factors related to the pathology (tumors in close contact or invading the artery, previous treatments), surgeon-depending factors (the surgeon's experience). Emergency treatment in case of vascular damage consists of blood transfusion and plasma expanders infusion to avoid hypovolemic shock, the use of hemostatic materials or vascular clips and, once the bleeding had been controlled, the endovascular treatment.

Extent of resection

The tumor size was assessed using radiological techniques by calculating the volume, which was obtained by multiplying the length, width, and depth in cubic centimeters (cm3). These measurements reduced after one month and further decreased after six months. The tumor removal was considered complete when there were free margins on the postoperative MRI findings documented no evidence of tumor. Total tumor resection was successfully performed in 72% of individuals, as confirmed by postoperative radiological assessments, while there was incomplete resection in 28% of patients due to invasion of important neurovascular structures and brain stem invasion. Unfortunately, eight percent of patients experienced tumor regrowth. One of them was chordoma due to presence of intradural invasion and the patient had not received the appropriate radiation therapy (proton beam), and the other was craniopharyngioma, because of the nature of pathology and presence of dense calcifications adherent to important structures and reoperated for tumor debulking.

Dehdashti, *et al*., [13] his team reviewed their experience in expanded endoscopic endonasal approach in 22 patients with the following pathologies: Six craniopharyngiomas four esthesioneuroblastomas three giants pituitary macroadenomas; two suprasellar Rathke's pouch cysts two angiofibromas and one each of suprasellar meningioma, ethmoidal carcinoma, adenoid cystic carcinoma, and large suprasellar arachnoid cyst. This study had focused on the surgical indications and approaches to these lesions and the surgical results, complications, and limitations associated with this technique. Gross total tumor removal, was assessed by postoperative MRI, was possible in most patients (73%), apart from the craniopharyngioma group, in which only 1 lesion was completely removed. They reported that the reasons for incomplete removal in this group of patients included the presence of significant adhesions to neurovascular structures from previous surgery in 2 patients and/or the presence of dense calcification and firm adherence to the carotid artery in 4 patients. In 3 patients, the decision was made preoperatively not to attempt complete removal based on normal endocrine function and the patient's own wish to avoid any risk of injury to the pituitary stalk and the development of cystic carcinoma and ethmoidal carcinoma) had gross total resection with free margins.

Seaman *et al*. [10], stated that the primary goal of minimally invasive approaches to anterior skull base meningiomas in their series was tumor debulking and decompression of the optic apparatus to preserve vision. Complete resection of tumors is challenging, particularly when tumors extend laterally to the optic nerves and carotid arteries [19] as such subtotal resection is often the preoperative oncologic goal but still achieving goals of optic apparatus decompression. In their series, these lateral limits, set by the orbit and important neurovascular structures, including the optic nerves, dictated choice of approach. In some cases of anterior skull base meningiomas, they found the interface of the tumor and optic apparatus can be densely adherent precluding safe resection, whereas others have an identifiable and dissectible arachnoid plane [20].

In this study, the cases of clival lesions had subtotal resection due to intradural invasion, adhesion to brain stem and extensive parasellar extension. In correspondence to our study, Culebras *et al*., [21] had a retrospective analysis of a series of 14 patients with clival chordoma or chondrosarcoma who had extended endoscopic endonasal surgery from 2008 to 2016 performed by the same multidisciplinary team. They had fourteen patients for chordoma and 32 for chondrosarcoma. In addition, invasion of at least two-thirds or more of the clivus was found in 81% of the cases; in 57.1% there was intradural invasion, and in 35.7% invasion of the sella turcica. In 42.8% of cases, the degree of resection was total and in 21.5% subtotal. Adjuvant treatment with Proton Beam was performed in 35.7% of cases and with conventional radiotherapy in 21.5%. Mean follow-up was 53.5 months and tumor recurrence or progression was found in 21.5% of the cases, two of which had not received adjuvant treatment. There were no deaths. They concluded that the extended endoscopic endonasal approach (EEEA) performed by an experienced team is a good alternative for the management of these lesions. Intradural invasion may be related to an increased risk of complications and worse clinical presentation, in addition to a lower rate of total resection.

Visual presentations

Our study includes 21 cases having visual manifestations. Fortunately, (85.7%) showed improvement in visual acuity after 3 months. In two cases, there was no change in visual manifestation after three months. Unfortunately, one patient with clival chordoma experienced a decline in visual acuity after three months due to regrowth of the lesion, requiring a second tumor attack. Additionally, two cases with meningioma did not experience any change in visual manifestation. One of these cases had incomplete tumor resection after using an extended endonasal approach and deteriorated after six months, leading to reoperation with a supraorbital approach. The other case did not show improvement due to preoperative optic atrophy.

Dehdashti *et al*. [13] stated that among the 80 patients with visual deficit before surgery, 40 patients (50%) had complete normalization of their visual disturbance, 31 patients (39%) had moderate to marked improvement, and 9 patients (11%) had no improvement. No patients experienced visual worsening after the surgery.

Emanuel *et al*. [16], reported that sixteen patients presented with visual impairment such as homonymous or bitemporal hemianopsia or decrease in visual acuity (usually unilateral): in 12 cases the post-surgical visual recovery was complete while in 2 cases it was partial in 2 patients there was no improvement.

Sixth nerve palsy

Study there were 16% of patients had sixth nerve palsy from parasellar extension of tumors and, accordance to Scott-Kraft scale, there were mild postoperative improvement in abducent nerve however there was a deterioration in one case with chordoma due to regrowth of the tumor.

In accordance with our study, Shono *et al*. [22] examined 240 patients with various skull base tumors underwent surgery, among them, nine patients presented with abducens nerve palsies. The lesions included two pituitary adenomas, two trigeminal schwannomas and five meningiomas. They evaluated the function of the abducens nerves in these patients on admission, at discharge, and periodically in the outpatient clinic. Four of the abducens nerve palsies already existed prior to surgery, and six of them developed post-operatively. In the four patients with pituitary adenomas and trigeminal schwannomas, all nerves were anatomically preserved and showed complete recovery of function within 6 months after surgery. In contrast, only two of the six palsies in patients with skull base meningiomas showed complete recovery. In three patients with petro-clival meningiomas, the abducens nerves were completely transected during surgery, and one was reconstructed using fibrin glue. This patient remarkably recovered from the abducens nerve palsy within 2 years.

Yoo *et al*., [8] analyzed 70 patients who underwent surgery for petroclival meningiomas between May 2010 and December 2019, divided into gross-total resection (GTR) and subtotal resection (STR) groups. The relationship of preoperative clinical factors with the incidence and recovery of postoperative abducent nerve palsy was analyzed according to Scott-kraft scale, they concluded that recovery of the abducens nerve function after surgery was observed more frequently in the STR group than in the GTR group.

Complications

The most common immediate post-operative complication in this present study was transient diabetes insipidus representing (68%) of patients most of them operated by endonasal approaches that resolved in all cases before three months, especially in craniopharyngioma because of invasion and compression on neurohypophysis or surgical manipulation on pituitary stalk. Transient periorbital ecchymosis occurred in supraorbital approach resolved spontaneously after a maximum two weeks with medications (24%). Also, transient CSF leakage representing 24% was managed conservatively and transient post-operative meningitis in 4% was managed with antibiotics.

There was one mortality rate female patient 55 years old that had sellar and suprasellar craniopharyngioma. She underwent total excision through supraorbital eyebrow skin incision. Post operatively patient fully recovered from anesthesia without any salient deficit. A few hours, she developed severe diabetes insipidus and electrolyte disturbance that led to disturbed conscious level urgent CT scan was done to exclude surgical bed hematoma, but there was no hematoma or tumor residual. The patient died on the one-week postoperative day from severe electrolyte disbalance and cardiac tachyarrhythmia.

Cavallo *et al*. in 2014 published retrospectively analyzed data from a series of 103 patients who underwent the endoscopic endonasal approach at two institutions 48.1% of them experienced diabetes insipidus [23], Ceylan *et al*. [24] had post-operative transient diabetes insipidus in 23.1% of their patients, however none of them persisted. While with Song *et al*. [14] team, they have transient diabetes insipidus in 2.6%, permanent diabetes insipidus in 1.9% and postoperative panhypopituitarism in 3.3%.

In accordance with our study Emanuel *et al*., [16] team used endoscopic endonasal approach in 153 patients with sellar and parasellar lesions, reported that most common surgical complications were cerebral spinal fluid leak (9), bleeding (2), pituitary abscess (2). Among Endocrinological complications, the most important were diabetes insipidus (23) and panhypopituitarism (3). Two of their patients had meningitis.

All patients in our study underwent surgery with the assistance of optical or electromagnetic neuronavigation, a technique that enhances the accuracy of lesion localization and identifying tumor boundaries. Additionally, it significantly reduces operation time, time to reach lesion and minimizes the risk of neurovascular damage. Overall, the avoidance of complications in this present series depended on several factors. A well-learned sphenoidal sinus and sellar anatomy with the help of ENT surgeon, especially in the learning curve period, detailed preoperative planning with the paranasal sinus CT and MRI scans were considered in all cases. The use of neuronavigation system further aided localization of tumor. A multidisciplinary teamwork with post-operative endocrinologist and steam sterilization of different tools contributed to low infection rate.

Conclusion

- Sellar and parasellar lesions pose a difficulty because of their diverse characteristics and the need for understanding the anatomy of this area, which is crucial for achieving enhanced resections with reduced morbidity.
- The supraorbital and endonasal endoscopic procedures offer secure minimally invasive methods for removing sellar and parasellar lesions. These procedures should not be regarded as a substitute for the conventional open approaches, but as supplementary alternatives that a skull base surgeon might skillfully employ in carefully chosen patients.
- The image guided system plays an important role in decreasing the time required to reach the tumor, decreasing the incidence of neurovascular injury, and achieving the limitations of the lesion.
- Treatment planning that involves multiple specialists (Otolaryngologist, neurosurgeon, neuroradiologist, endocrinologist, and ophthalmologist) reduce the occurrence of complications and provide the patient with the most effective therapy and a superior quality of life.

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