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Endoscopic Endonasal Approach for Rare Skull Base Pathologies: Insights from a Neurosurgical Perspective

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Simple Summary

This study presents our surgical experience with 41 patients harboring extremely rare skull base tumors treated via the endoscopic endonasal approach (EEA). Although EEA is well-established for common lesions, rare pathologies often defy preoperative expectations and require flexible intraoperative decision-making. Our findings highlight the importance of tailoring surgical strategies in real time and underscore the need for comprehensive anatomical knowledge and multidisciplinary collaboration when managing these uncommon cases. Even in high-volume centers, rare skull base tumors remain a significant challenge that demands careful planning and adaptability.

Abstract

Background: Endoscopic endonasal approach (EEA) has become a well- established approach for skull base pathologies, providing a minimally invasive corridor to access various lesions. While the technique has been extensively studied for common skull base tumors, data on extremely rare pathologies remain limited. Our study aims to present our experience with rare skull base lesions managed via the endoscopic endonasal approach, highlighting the challenges associated with preoperative diagnosis, intraoperative decision-making, and surgical strategy modifications. **Methods:** A retrospective analysis was conducted on patients who underwent endoscopic endonasal surgery at the tertiary center up to January 2025. Among 6,225 endoscopic endonasal procedures performed, 41 patients with exceptionally rare skull base pathologies were identified. Each tumor type was separately evaluated for differences in resection rates, complication rates, and recurrence patterns. **Results:** These included 6 pituitary pituicytomas, 5 plasmacytomas, 5 xanthogranulomas, 4 granular cell tumors, 3 giant cell tumors and others. Gross total resection was achieved in 68% of cases, with subtotal resection in vascular or malignant tumors. Intraoperative challenges included unexpected vascularity and fibrotic adhesions. Postoperative CSF leakage occurred in 7%, and recurrence was observed in 17%, mostly in malignant or partially resected tumors. No intraoperative mortality was recorded. Tailored adjuvant treatments ensured durable disease control in most patients. **Conclusions:** Even in highly experienced centers, rare skull base pathologies pose unique diagnostic and surgical challenges. The discrepancy between preoperative and intraoperative findings often necessitates real-time strategic adaptations. In these rare cases, for optimizing patient outcomes requires a comprehensive understanding of skull base anatomy, flexibility in surgical planning, readiness for sudden strategy modifications, and a multidisciplinary approach.

Keywords: skull base; endoscopic endonasal approach; pituitary; rare cases; pituicytomas; xanthogranulomas

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1. Introduction

The endoscopic endonasal approach (EEA) has become a pivotal advancement in skull base surgery, offering a minimally invasive route to address a wide range of lesions that once required extensive open procedures [1,2] The EEA avoids brain retraction, offers excellent visualization, and is associated with reduced morbidity and shorter hospital stays. [1,3] While its efficacy for common skull base lesions (SBLs), such as pituitary adenomas (PA), craniopharyngiomas, and meningiomas, is well established [4,5], experience and literature regarding the use of EEA for rare SBLs remain limited.

Recent reports suggest that EEA can be safely and effectively applied to a variety of uncommon SBLs, including primary central nervous system lymphomas involving the skull base [6], giant cell tumors of the clivus [7,8], plasmacytomas [9], and rare pituitary region neoplasms, such as pituicytomas and spindle cell oncocytomas [10,11]. Many of these rare lesions mimic more common entities in their clinical presentation and imaging characteristics, posing significant preoperative diagnostic challenges [10–12]. Moreover, intraoperative findings often necessitate sudden alterations in surgical strategy, particularly when faced with unexpected vascularity, invasiveness, or malignant pathology [13].

Despite technical advancements, the literature regarding outcomes, complications, and optimal management strategies for rare SBLs treated endonasally remains limited [4,6]. Our study contributes to this limited body of evidence by presenting a single-center experience involving 41 patients harboring exceptionally rare SBLs treated via the EEA. We aim to share insights into diagnostic challenges, intraoperative decision-making, surgical outcomes, and postoperative management to assist neurosurgeons in managing such complex cases.

2. Materials and Methods

This retrospective study was conducted at the tertiary center and included patients who underwent EEA between 1997 and January 2025. The institutional surgical databases were systematically reviewed to identify patients diagnosed with rare SBLs, defined as lesions accounting for less than 1% of the total EEA cohort during the study period. A total of 6,225 EEA procedures were performed during this period. Patients with common SBLs, such as PA, meningiomas, craniopharyngiomas, chordomas, and sinonasal carcinomas, were excluded from the analysis.

Data were retrospectively obtained from electronic medical records and operative reports. The variables assessed included demographic information, including age and sex, and clinical presentation, such as visual disturbances, headache, hormonal dysfunction, nasal obstruction, and cranial nerve deficits. Further assessment included radiological findings derived from magnetic resonance imaging (MRI) and computed tomography scans; tumor characteristics, such as size, location, and radiological indicators of vascularity or fibrotic nature; and intraoperative observations regarding tumor consistency, degree of vascularity, and intraoperative bleeding. Surgical details, extent of resection, histopathological results, postoperative complications, and follow-up outcomes were also documented. The extent of resection was determined based on operative notes and postoperative imaging. Follow-up evaluations were conducted at regular intervals, typically every 3 months during the first year and every 6—12 months thereafter, and included clinical examinations and imaging studies.

All surgical procedures were performed with the aid of image-guided neuronavigation systems. In most cases, the standard EEA was employed. Nevertheless, alternative endoscopic techniques were employed as necessary, depending on the extent and direction of tumor growth. For lesions extending into the anterior cranial fossa, an extended EEA was utilized. Detailed descriptions of these surgical techniques have been documented in prior studies. Dural reconstruction was performed using a galeal graft to minimize the risk of cerebrospinal fluid (CSF) leakage. For reconstruction of

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the sellar region, a multilayer technique was employed, incorporating fascia lata grafts, adipose tissue, and a nasoseptal flap to ensure robust closure and support of the skull base. In selected patients, lumbar drainage was instituted and maintained for 96 hours postoperatively when deemed beneficial to reduce the likelihood of CSF leakage and promote healing. [14–18]

Descriptive statistical methods were employed to summarize the data. The study protocol was approved by Bahcesehir University(2025, 03/09), and due to its retrospective design, the requirement for individual informed consent was waived.

3. Results

Of the 6,225 patients who underwent endoscopic endonasal surgery during the 27-year study period, 41 patients, accounting for 0.7% of the cohort, were identified as having rare SBLs. The mean age of these patients was 34.7 years (range: 4—67 years), with a slight male predominance, as 24 patients (58.5%) were male, while 17 (41.5%) were female. The most frequent presenting symptoms in this group included headache in 21 patients (51%); visual disturbances in 19 patients (46%); hormonal dysfunction, such as hypopituitarism, diabetes insipidus(DI), or hyperprolactinemia, in 13 patients (32%); nasal obstruction or epistaxis in 8 patients (20%); and cranial nerve deficits in 3 patients (7,3%). In 48% of cases, the initial imaging impressions differed from the eventual pathological diagnosis, with nonfunctioning PA being the most frequent preoperative misdiagnosis, particularly in sellar or parasellar tumors (Figure 1)(Table 1).

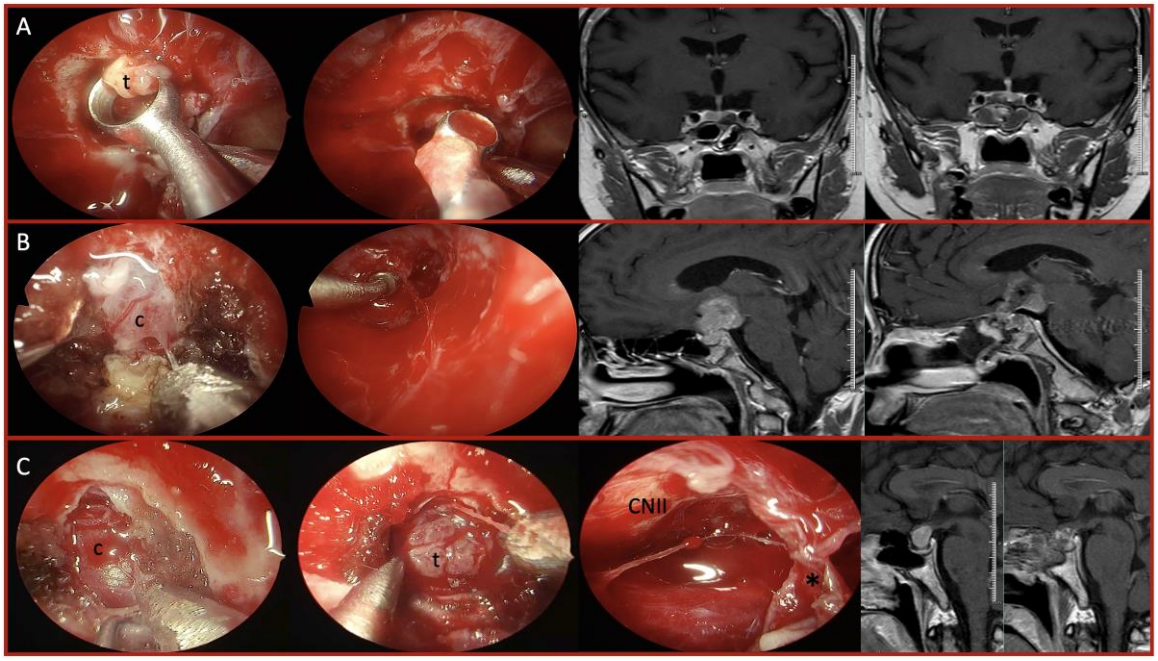

Figure 1. A Intraoperative view and preoperative/postoperative MRI images of a patient operated via EEA for a presumed PA. Although the tumor appeared macroscopically soft and adenoma-like, histopathological analysis revealed a diagnosis of granular cell tumor. B. Intraoperative view of a young female patient operated under the initial diagnosis of optic pathway glioma. A highly vascular capsule and a soft but hemorrhagic mass were encountered during internal debulking. Final histopathological diagnosis revealed a germinoma. C. Intraoperative and radiological findings of a patient operated via EEA for an isolated infundibular lesion. A firm, hemorrhagic mass with a highly vascular capsule was encountered. The lesion was gross totally resected with preservation of the infundibulum. Histopathological diagnosis confirmed a pituicytoma. (* infundibulum, c capsule, t tumor).

Table 1. Demographic and Clinical Characteristics of Patients with Rare Skull Base Tumors.

Characteristic	Total (n=41)	Fibrotic/Adherent Tumors	Hypervascular Tumors

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Mean age (years)	34.7 ± SD	—	—
Sex (M/F)	24 / 17	—	—
Most common symptoms	Headache (51%), visual deficit (46%), hormonal dysfunction (32%)	DI, cranial nerve deficits	Epistaxis,nasal obstruction
Misdiagnosis rate	48% Nonfunctioning pituitary adenoma	Frequently misdiagnosed as PA and craniopharyngioma	Frequently misdiagnosed as PA and meningioma
Most frequent misdiagnosis	Nonfunctioning pituitary adenoma	Craniopharyngioma	Pituitary adenoma
Lesion location	Sellar/Parasellar dominant	Sellar/suprasellar	Clival, sphenoid sinus and nasal passage extensions
Preoperative imaging findings	Heterogeneous	Solid, low contrast enhancement	Intense contrast enhancement

This study identified a range of rare SBLs, including 6 cases of pituitary pituicytomas, 5 plasmacytomas, 5 xanthogranulomas, 4 granular cell tumors, 3 giant cell tumors, and 2 cases each of germinoma, hemangiopericytoma (HPC), Langerhans cell histiocytosis, malignant epithelial tumors, and spindle cell oncocytomas. Additionally, there was one case each of aneurysmal bone cyst, juvenile nasopharyngeal angiofibroma, ependymoma, Hodgkin lymphoma, B-cell acute lymphoblastic leukemia, neurinoma, osteosarcoma, and teratoma.

Intraoperative findings varied considerably depending on tumor type. Highly vascular lesions such as pituicytomas, spindle cell oncocytomas (3/6), HPC, plasmacytomas (3/5), giant cell tumors, and juvenile nasopharyngeal angiofibromas frequently exhibited significant intraoperative bleeding, which was rated as moderate to severe in 14 patients (34,1%). In some cases, substantial intraoperative hemorrhage necessitated blood transfusion and limited the extent of resection achievable.(Figure 2B) Conversely, tumors such as xanthogranulomas, Langerhans cell histiocytosis, malignant epithelial tumors, and Hodgkin lymphoma presented with a firm and fibrotic consistency(Figure2A), complicating surgical dissection due to dense adhesions to surrounding structures. Meanwhile, lesions such as germinomas, granular cell tumors and ependymomas were generally soft and nonvascular, facilitating relatively straightforward resection (Table 2).

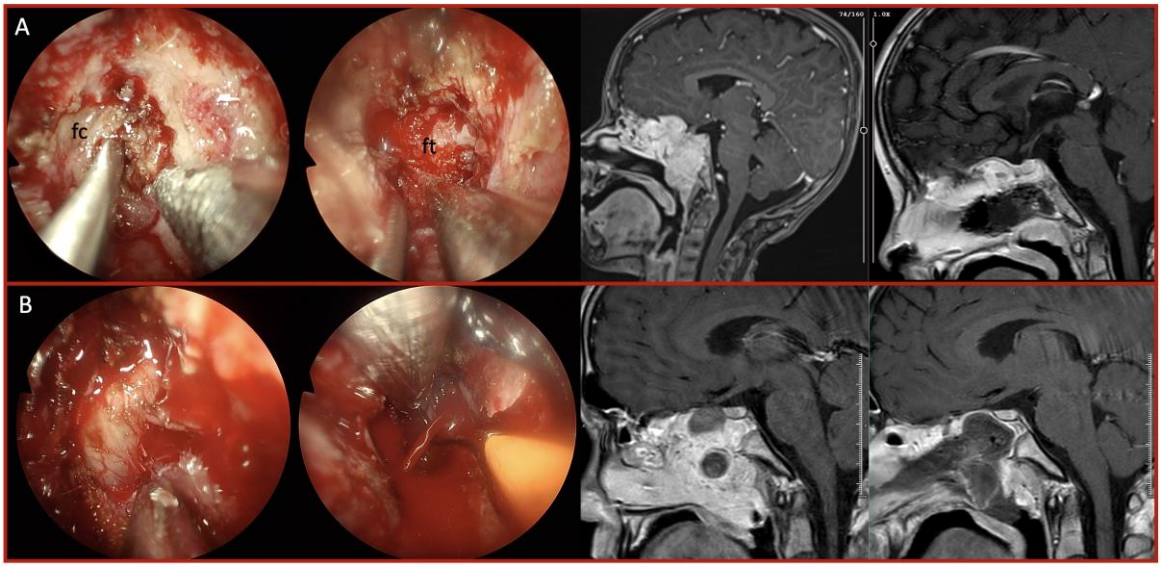

Figure 2. A. EEA in a 4-year-old patient with a predominantly sinus-based lesion. Intraoperatively, a very firm and fibrotic mass was encountered. STR was achieved with the assistance of an ultrasonic aspirator.

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Histopathological examination confirmed the diagnosis of Langerhans cell histiocytosis. B. A 13-year-old patient presenting with epistaxis was found to have a mass filling the sphenoid sinus and nasal passage. EEA revealed a highly hemorrhagic tumor. Intraoperative bleeding necessitated blood transfusion. After achieving temporary hemostasis, preoperative embolization was planned. The patient subsequently underwent a second surgery, during which STR was accomplished. (fc fibrotic capsule, ft fibrotic tumor).

Table 2. Tumor-Specific Characteristics, Surgical Findings, and Outcomes.

Tumor Type	No. of Cases	Consistency / Vascularity	Extent of Resection	Adjuvant Therapy / Recurrence
Pituicytoma	6	Firm, highly vascular capsule	GTR/STR (5/1)	No recurrence, no adjuvant
Plasmacytoma	5	Soft, moderately vascular	GTR/STR (3/2)	RT + chemo; 2 recurrences
Xanthogranuloma	5	Fibrotic, adherent	GTR	No recurrence
Granular cell tumor	4	Soft intense	GTR	Gamma Knife (case-based)
Giant cell tumor	3	Highly vascular	GTR Pre-operative embolization	Denosumab Fully controlled
Germinoma	2	Soft, Vascular capsule	STR	Chemo + RT; 1 recurrence
HPC	2	Hypervascular	STR	RT; 1 recurrence
LCH	2	Firm, fibrotic	GTR/STR (1/1)	Systemic chemo; stable
Malignant epithelial	2	Adherent, fibrotic	STR	1 Recurrence
Spindle cell oncocytoma	2	Firm, vascular	GTR/ STR 1/1	1 Gamma Knife
Others (each 1)	10	Varied	Varied	Case-specific

Gross total resection (GTR) or near-total resection was achieved in 28 patients (68%), predominantly in benign tumors. Subtotal resection (STR) was performed in 13 patients (32%). This was typically done when significant intraoperative bleeding prevented further resection, as seen in HPC and other vascular tumors, or when the pathology was malignant and required only tissue sampling for diagnosis before planned adjuvant therapy, such as in lymphomas and germinomas. Postoperative complications occurred in several patients, including CSF leaks in 3 patients (7%), new cranial nerve deficits in 1 patient (2,4%) and transient DI in 4 patients (9,7%). Of these, 1 patient (2,4%) developed permanent DI. Importantly, no perioperative mortalities occurred in this series.

During a mean follow-up period of 48 months (range: 6—180 months), recurrence was observed in seven patients (17%). Recurrences were most commonly observed in tumors with malignant potential or those that had undergone STR. Tumor-specific recurrences included 2 cases of plasmacytoma, 1 case of germinoma despite adjuvant therapy, 1 case each of HPC and juvenile nasopharyngeal angiofibromas where residual tumor was intentionally left for bleeding control, and 1 case each of osteosarcoma and malignant epithelial tumor. Adjuvant therapy, including radiotherapy, Gamma Knife, and/or chemotherapy, was administered to 16 patients (39%), depending on tumor type, extent of resection, and pathological characteristics (Figure 3)(Table 3).

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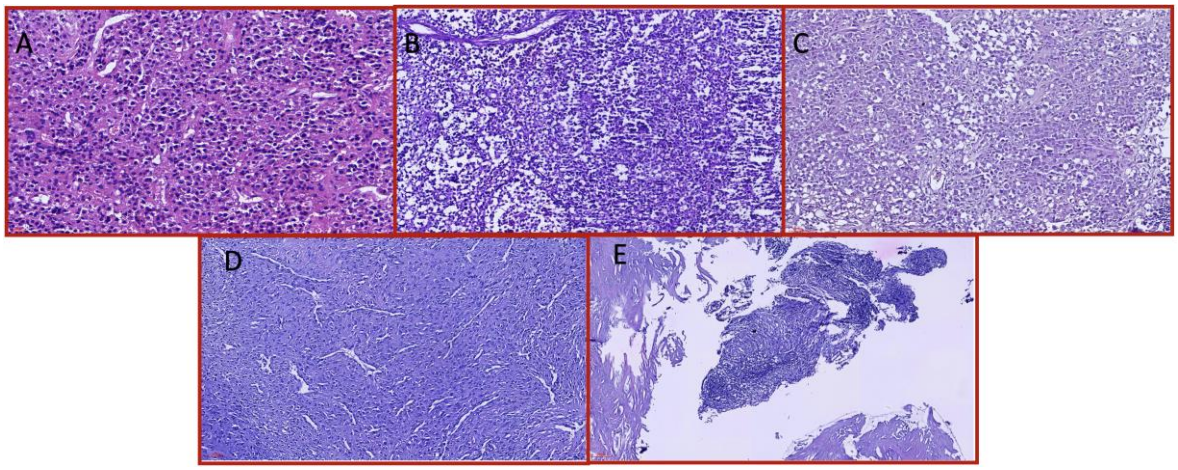

Figure 3. Histopathological evaluation of the tumor A. Hematoxylin and eosin (H&E) staining at ×400 magnification reveals sheets of atypical plasma cells with eccentric nuclei and basophilic cytoplasm.(Plasmacytoma) B. H&E staining at ×200 magnification demonstrates clusters of Langerhans cells with characteristic grooved nuclei, admixed with numerous eosinophils.(LCH) C. H&E staining at ×200 magnification reveals nests of epithelioid tumor cells separated by thin fibrous septae, with scattered infiltrating lymphocytes.(Germinoma) D. H&E staining at ×200 magnification demonstrates a fibrovascular neoplasm composed of slit-like vascular channels embedded within a cellular fibroblastic stroma.(Angiofibromas) E. H&E staining at ×100 magnification reveals dense infiltration of inflammatory cells within the adenohypophysis accompanied by fibrosclerosis, particularly in the left and inferior regions of the section.(Pituicytoma).

Table 3. Surgical and Postoperative Outcomes According to Tumor Characteristics.

Variable	Total (n=41)	Fibrotic/Adherent Tumors	Hypervascular Tumors
Extent of Resection: GTR / STR	28 (68%) / 13 (32%)	STR(8 patients)	STR(5patient)
Intraoperative bleeding (moderate-severe)	14 (34.1%)	Rare	Frequent
Blood transfusion needed	3	0	3
CSF leak	3 (7%)	2	1
New cranial nerve deficit	1 (2.4%)	1	0
Transient DI	4 (9.7%)	3	1
Permanent DI	1 (2.4%)	1 (LCH)	—
Recurrence rate	7 (17%)	4	3
Adjuvant therapy needed	16(39%)	Systemic therapy (LCH, lymphoma)	RT/Gamma Knife for HPC, plasmacytoma

4. Discussion

This single-center series highlights the novelty and clinical value of examining rare SBLs managed via the EEA. With 41 cases, it represents one of the largest cohorts to date of these rare lesions, which have otherwise been documented only in small series or individual case reports. For instance, pituicytomas are tumors arising from the pituicytes of the neurohypophysis and pituitary infundibulum, with only approximately 119 cases reported in the literature by 2020. [19] Similarly, HPCs of the cranial base are so infrequent that they may be overlooked in the differential diagnosis. [20] By aggregating outcomes across diverse pathologies, this study provides comparative insights

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that enhance the understanding of how tumor subtype influences EEA surgical strategies and outcomes.

Our findings for each tumor category align with and contribute to the existing literature. In our series, pituicytomas were frequently misdiagnosed as PAs, reflecting the diagnostic challenges associated with these tumors. This pattern is consistent with previous reports, including a study in which all 11 cases were misdiagnosed preoperatively. [19] We observed that pituicytomas are often highly vascular tumors, sometimes exhibiting a firm, fibrous consistency, which aligns with prior reports describing an "abnormally abundant" blood supply as a hallmark of this entity. Marked vascularity may complicate GTR, rendering tumor progression unavoidable in some cases. Cheng et al. [19] reported an approximate 36% progression rate following STR. However, in selected cases of pituicytomas, GTR significantly prolongs progression-free survival, reinforcing the view that complete resection offers the best opportunity for long-term disease control. [21,22] In our series, plasmacytomas located in the sellar or skull base region often mimicked PA in imaging characteristics and clinical manifestations. Similarly, DiDomenico et al. [23] reported that nearly half of sellar plasmacytomas were initially pituicytomas misdiagnosed as PAs. Intraoperatively, plasmacytomas appeared soft and moderately vascular, and they responded favorably to adjuvant therapies following maximal resection via the EEA. [24,25] Our cases of Langerhans cell histiocytosis (LCH) and other histiocytic lesions highlight the diagnostic ambiguity and variable surgical role associated with these entities. Skull base LCH may closely mimic chordomas and meningiomas radiologically and is characterized by a high invasive potential. Due to the absence of distinctive imaging features, establishing a definitive histopathological diagnosis following STR is essential. [26,27] Moreover, surgery for LCH is generally aimed at relieving symptoms or obtaining a biopsy for confirmation rather than achieving extensive resection, as these disorders are primarily managed with systemic therapy, including steroids, chemotherapy, or targeted agents. [28,29] Notably, one of our histiocytic lesions exhibited extensive fibrosis and adherence to critical structures, permitting only STR. The patient subsequently received systemic treatment, with no evidence of tumor progression during follow-up. Xanthogranulomas often closely mimic craniopharyngiomas in radiological appearance and intraoperative characteristics, making differential diagnosis particularly challenging. The primary surgical objective is GTR to alleviate mass effect and associated symptoms. Consistent with our experience, Rahmani et al. reported a series in which all patients underwent GTR, with no recurrences observed during long-term follow-up without the need for adjuvant therapy. Therefore, in managing sellar xanthogranulomas, surgical excision serves both diagnostic and curative purposes, with a notably low risk of recurrence on long-term follow-up. [30]

A key finding of this study was the remarkable intraoperative variability in bleeding risk and tumor consistency across different rare tumors. In particular, vascularity emerged as a decisive factor contributing to surgical complexity. Pituicytomas, juvenile nasopharyngeal angiofibromas, and giant cell bone tumors were highly vascular, demonstrating intense arterial intraoperative hemorrhage. [8,31,32] Blood transfusion proved to be potentially lifesaving in these patients. [19] We encountered similar challenges, including a case of HPC that caused profuse intraoperative bleeding, necessitating meticulous hemostasis. These hypervascular tumors occasionally necessitated staged resections or preventive measures. Skull base surgeons have advocated for preoperative embolization or staged surgery, particularly when tumors approached via the EEA encase the internal carotid artery or possess extensive vascular feeders. [33–35] Conversely, some lesions exhibited fibrosis or adherence to surrounding structures, making dissection and resection challenging despite minimal intraoperative bleeding. For instance, fibrous histiocytic lesions and chondroid tumors typically presented as firm masses that were inseparable from adjacent nerves or vessels. [36–39] In one of our LCH cases, extensive fibrosis and adherence to the optic chiasm implied that aggressive resection would have posed undue risks; therefore, subtotal debulking was performed. The broad spectrum of consistencies (from soft and easily aspirated to fibrous and calcified) and the variability in vascularity (from avascular to hypervascular) encountered the need to tailor the EEA technique intraoperatively. Surgeons must be equipped with a variety of instruments (e.g., ultrasonic aspirators, bipolar

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coagulation, skull base diamond drills) and strategies (e.g., early tumor devascularization, staged resection) to effectively address these differences.

As previously noted, many of these rare lesions are initially mistaken for more common SBLs, particularly PA. Sellar plasmacytomas and metastases, similar to pituicytomas, are notoriously challenging to distinguish radiologically and are often described as imaging "mimics" of PA. [19] In our clinical practice, such misdiagnoses can lead to an underestimation of surgical complexity. A lesion presumed to be a routine PA may be a highly vascular metastasis or plasmacytoma, potentially leaving the surgeon unprepared for its invasive behavior or substantial intraoperative bleeding. Pituitary metastases more commonly present with DI and cranial neuropathies. [40,41] Additionally, on MRI, they are more likely to invade the pituitary stalk or cavernous sinus compared to PA. [42,43] Additionally, intraoperatively, these metastases often appear as firm, hemorrhagic lesions, a finding consistent with our own experience in a case of renal cell carcinoma metastasis, which was significantly firmer and more vascular than a typical adenoma. When an unusual tumor is suspected, our current practice involves planning for potential STR following a diagnostic biopsy—particularly for lesions primarily managed medically, such as lymphomas or certain metastases—and ensuring the immediate availability of blood products and specialized vascular instruments for hypervascular tumors. This adaptive approach, guided by heightened diagnostic vigilance, may help prevent surgical morbidity. Ultimately, our experience underscores the importance of multidisciplinary collaboration among endocrinologists, radiologists, and surgeons, emphasizing the need to maintain a broad differential diagnosis for sellar masses.

Overall, the EEA proved to be a safe surgical corridor in our series, with no intraoperative mortality, and the complication profile was comparable to that reported in large published series on endoscopic skull base surgery. A CSF leakage rate of approximately 7% was observed, primarily in cases involving extensive dural resection. This rate aligns with the 10–15% leakage rates reported in the literature for extended EEA procedures [44,45] For instance, Chen et al. [46] reported a 12% CSF leakage rate in their series of EEA for clival chordomas. In our cohort, all CSF leakages were successfully managed with multilayer reconstruction and, when necessary, lumbar drainage, without long-term sequelae. Endocrinological complications were relatively common following resection of lesions involving the sellar region. New-onset transient DI occurred in several patients, particularly in cases involving stalk-infiltrating LCH and xanthogranulomas. Additionally, one patient with a granular cell tumor requiring extensive gland manipulation developed transient hypopituitarism, while another with a pituicytoma developed permanent DI. These outcomes are consistent with previous reports, where nearly half of the patients in a published series on pituicytomas experienced postoperative hypopituitarism or DI. Notably, despite the complexity of these cases, we observed no major vascular injuries or neurological decline, reinforcing the feasibility of EEA for atypical tumors when performed by experienced skull base surgeons. In one case of a giant cell bone tumor, a minor bleed from the paraclival segment of the internal carotid artery was successfully controlled with hemostatic agents. [47] This incident underscores the importance of careful postoperative vascular imaging and follow-up in tumors encasing major arteries.

Long-term tumor control in our cohort varied by pathology, largely reflecting the intrinsic biological behavior of each lesion. Indolent tumors, such as pituicytomas, exhibited minimal recurrence when GTR was achieved. Notably, none of the pituicytomas that underwent GTR in our series have recurred to date—consistent with other reports suggesting that complete excision may be curative in selected cases. [48] Granular cell tumors typically exhibit nonspecific radiological features and are frequently misdiagnosed as PA. Due to their firm adherence to the posterior pituitary and infundibulum, GTR is often not feasible; nevertheless, maximal safe resection should remain the primary surgical goal. In cases where recurrence is identified during follow-up, fractionated Gamma Knife radiosurgery may serve as an effective adjuvant treatment. In contrast, more aggressive tumors, such as HPC, demonstrated a higher propensity for recurrence and even metastasis. This supports the current understanding of HPC as neoplasms requiring multimodal oncologic management. In our series, sellar plasmacytomas were effectively controlled with surgery followed by radiotherapy,

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with patients subsequently referred for hematological evaluation and systemic chemotherapy. Langerhans cell histiocytosis (LCH), being part of a systemic disease, did not demonstrate local recurrence in the conventional sense. Instead, disease activity was primarily managed through systemic therapies. Two patients with multisystem LCH required escalation to second-line chemotherapy after initial treatment, highlighting the fact that neurosurgical intervention typically represents just one component of a broader oncological strategy for such diseases. [49] Plasmacytoma management universally included postoperative radiotherapy to the lesion site in our center, in line with the ~81% rate of adjuvant radiotherapy reported in the literature. Systemic therapies played a crucial role in managing nonsolid tumor entities: patients with confirmed LCH received systemic chemotherapy (e.g., cytarabine or targeted BRAF inhibitors for V600E-mutant cases), while those with pituitary metastases were referred for appropriate oncologic management. Finally, it is important to highlight rare pituitary tumor subtypes—pituicytoma, granular cell tumor, and spindle cell oncocytoma. These benign lesions currently lack established medical adjuvant therapies; however, in cases of residual tumor, Gamma Knife radiosurgery was considered on a case-by-case basis. In our series, one case of residual spindle cell oncocytoma was treated with fractionated Gamma Knife radiosurgery and has remained radiologically stable 1 year posttreatment.

5. Conclusions

This study represents one of the largest single-center cohorts focused on rare SBLs managed via the EEA, offering novel insights into the diagnostic, surgical, and postoperative nuances of these uncommon entities. By analyzing a range of diverse pathologies, our findings highlight the adaptability and safety of EEA in treating tumors with highly variable vascularity, consistency, and biological behavior. GTR was feasible for most benign lesions, while maximal safe debulking enabled histological diagnosis and symptom relief in more aggressive or systemic pathologies. Despite intraoperative challenges, complication rates were comparable to those seen with more common SBLs, and long-term control was achievable with tailored adjuvant therapies. These results underscore the importance of multidisciplinary evaluation and individualized surgical planning in rare SBLs. They further support the EEA as a viable and effective strategy, even in diagnostically complex and surgically challenging scenarios.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Figure S1: title; Table S1: title; Video S1: title.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, Atakan Emengen, Savas Ceylan. Methodology Eren Yilmaz, Aykut Gokbel; software, Ayse Uzuner, Ozlem Yapıcıer validation, Atakan Emengen, ,Melih Caklili..; formal analysis, Burak Cabuk data curation, Atakan Emengen; writing—original draft preparation, Atakan Emengen, , Savas Ceylan ; writing—review and editing, Atakan Emengen, ,Ihsan Anik, Savas Ceylan ; visualization, Atakan Emengen; supervision Savas Ceylan All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: This study was conducted in accordance with the approval provided by the relevant ethics committee.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

SBL	Skull Base Lesions
PA	Pituitary Adenom
EEA	Endoscopic endonasale approach
GTR	Gross-total Resection
STR	Subtotal Resection

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DI:	Diabetus Insipitus
CSF	Cerebrospinal Fluid
HPC	HEmangiomapericytoma

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