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A Structured Multi-Domain Clinical Algorithm for Sellar and Parasellar Tumors Integrated into a Unified Neurosurgical Framework

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Abstract

A Background/Objectives: *Sellar and parasellar tumors constitute a heterogeneous group of lesions whose management requires complex synthesis of radiological anatomy, endocrine dynamics, symptom evolution, and patient physiology. Although authoritative guidelines exist—such as those of the Congress of Neurological Surgeons (CNS) for pituitary adenomas [1], the European Association of Neuro-Oncology (EANO) for meningiomas [2], the European Society of Endocrinology (ESE) [3], and the Pituitary Society [4]—these recommendations remain domain-specific and do not provide a unified structure for real-world decision-making. We propose a clinically oriented six-node algorithm designed to integrate these domains into a coherent, sequential logic.*

Methods: *A narrative review of neurosurgical, endocrine, and radiological literature from 2010–2025 was performed. Guidelines from CNS, EANO, ESE, and the Pituitary Society were analyzed in depth. A structured algorithm was derived, comprised of six nodes: (A) urgency of presentation, (B) patient physiological profile, (C) radiological determinants, (D) endocrine characterization, (E) therapeutic pathway selection, and (F) risk-adapted follow-up. Three representative clinical cases—a planum sphenoidale meningioma requiring transcranial resection, an elderly patient with incidental NFPA followed for years before progression, and a young patient with stable asymptomatic NFPA—were integrated directly into the narrative to illustrate algorithmic reasoning.*

Results: *The algorithm captured the full clinical trajectories of all three cases, demonstrating concordance with CNS, EANO, and endocrine guidelines while offering enhanced granularity. Case 1 highlighted the primacy of radiological anatomy in determining surgical approach. Case 2 illustrated the validity of extended surveillance in elderly asymptomatic NFPA, followed by necessary transition to surgery upon radiological progression. Case 3 exemplified long-term observation in young asymptomatic NFPA lacking invasive features. In each case, the algorithm resolved ambiguities inherent in guideline documents and provided a structured*

rationale for management.

Conclusions: *The proposed six-node model offers a comprehensive framework for sellar tumor management. Integrating urgency, physiology, radiology, endocrine evaluation, treatment feasibility, and follow-up strategy into a unified sequential algorithm enhances clarity, supports multidisciplinary coherence, and aligns with but refines existing guidelines. Embedded clinical cases demonstrate its applicability in diverse scenarios.*

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Introduction

Sellar and parasellar tumors represent a complex intersection of neurosurgical, endocrine, and visual pathway pathology. Their management requires refined interpretation of MRI anatomy, assessment of hypothalamic–pituitary function, evaluation of visual compromise, and selection among observation, endocrine therapy, endoscopic surgery, transcranial skull-base surgery, and radiosurgery. Despite the availability of robust guideline documents—CNS guidelines for nonfunctioning pituitary adenomas (NFPA), EANO recommendations for meningiomas, ESE endocrine guidelines, and Pituitary Society consensus standards—their compartmentalized structure does not reflect the sequence of reasoning employed during real multidisciplinary evaluation [1-4].

The resulting gap is especially evident in cases where multiple parameters interact. For example, elderly patients with incidental macroadenomas, lesions with subtle radiological progression, or tumors abutting but not compressing the optic chiasm often fall into "gray zones" where guidelines permit wide latitude. To address this, we propose a six-node clinical logic algorithm that unifies these domains into a consistent decision pathway. Each node corresponds to a step typically taken in real clinical practice, thereby mirroring the cognitive structure of interdisciplinary skull-base evaluation.

To illustrate the algorithm's practical relevance, three representative cases are integrated into the narrative. Case 1 demonstrates radiology-dominated decision-making in planum sphenoidale meningioma. Case 2 illustrates extended surveillance and late transition to surgery for NFPA. Case 3 shows stable incidental NFPA in a young patient, emphasizing safe conservative management. The combination reflects the full spectrum of clinical scenarios encountered in sellar tumor management.

Materials and Methods

A narrative literature review was conducted using PubMed, Scopus, and Embase, covering publications from 2010 to 2025. Search terms included "pituitary adenoma," "planum sphenoidale meningioma," "optic chiasm compression," "skull-base surgery," "endoscopic endonasal approach," "cavernous sinus invasion," "nonfunctioning pituitary adenoma follow-up," and "parasellar tumor radiology." Guideline documents from the CNS, EANO, ESE, and the Pituitary Society were analyzed in detail [1-4].

The six-node algorithm was constructed by mapping existing guideline statements to real-world diagnostic workflow. Radiological determinants were informed by classifications such as Hardy [5] and Knosp [6] as well as skull-base surgical series [7-11]. Follow-up recommendations were drawn from NFPA natural-history studies [10,12,13]. The three clinical cases were chosen because they illustrate essential points of divergence

and concordance with guideline-permissible options.

Results

The Six-Node Clinical Logic Algorithm

Node A — Urgency of Presentation

Urgency determines the tempo of evaluation. Acute visual decline, apoplexy, or deteriorating consciousness require immediate decompression [1,14]. In contrast, asymptomatic lesions or slowly progressive symptoms allow comprehensive multidisciplinary evaluation.

Case 1 presented with a year-long history of progressive headaches without objective visual deficits. Although not emergent, the constellation justified prompt evaluation(Figure 1). Case 2, a 72-year-old patient with an incidental macroadenoma, clearly satisfied criteria for non-urgent assessment (Figure 2), concordant with CNS guidance for asymptomatic NFPA [1] . Case 3 similarly exhibited no symptoms apart from mild intermittent headaches, enabling full evaluation before deciding on management. Node A thereby establishes the temporal framework for subsequent decisions.

Node B — Patient Physiological Profile

Patient biology is essential yet under-formalized in guideline documents. Factors including age, comorbidities, functional reserve, and projected life expectancy impact the appropriateness and timing of intervention. Although CNS and ESE guidelines acknowledge such considerations [1,3], they do not offer a structured integration.

Case 2 illustrates this principle effectively. Despite a 20-mm NFPA, the patient's age and absence of symptoms favored surveillance over surgery. Studies confirm that asymptomatic NFPA in elderly populations may remain stable for years without adverse consequences [10,11]. Case 3, although younger, had a stable lesion lacking high-risk features; however, longer life expectancy necessitated a more prolonged and systematic follow-up. Case 1, at age 50, was an optimal surgical candidate. Node B ensures that physiological reserve tempers anatomical considerations.

Node C — Radiological Determinants

MRI anatomy is the structural foundation of decision-making. Radiological findings guide diagnosis, predict endocrine or visual risk, and determine surgical feasibility. Features such as ICA encasement, cavernous sinus invasion, suprasellar extension, optic chiasm compression, and dural implantation must be evaluated systematically.

Case 1 exhibited a 14 × 8 mm suprasellar extra-axial lesion with planum sphenoidale implantation, ICA contact, and chiasmal compression. (Figure 1) This constellation is characteristic of planum sphenoidale meningioma [21–23]. EANO guidelines advise transcranial approaches in such cases, particularly when lateral ICA surfaces must be decompressed [2].

Case 2 initially demonstrated a 20-mm NFPA with no cavernous sinus invasion and mild chiasmal elevation, permitting surveillance [1]. Four years later, the lesion enlarged to 24 × 25 × 16 mm with new cavernous sinus invasion and displaced optic chiasm—crossing the CNS threshold for surgical intervention [1]. (Figure 2) .

Case 3 presented with a 23 × 16 × 21 mm homogeneous macroadenoma lacking chiasmal distortion, cavernous invasion, or atypical radiological features (Figure 3). Studies confirm that such lesions often remain stable with observation [10,15]. Node C thereby converts anatomical data into operative feasibility.

Node D — Endocrine Characterization

Endocrine evaluation differentiates functioning adenomas from NFPA, identifies hypocortisolism or hypothyroidism requiring correction, and determines suitability for surgery. ESE and Pituitary Society recommendations mandate a full hormone panel including cortisol, ACTH, TSH, free T4, IGF-1, LH, FSH, sex steroids, and prolactin [3,4]. In Case 1, completely normal endocrine function supported an extra-axial etiology.

Case 2 maintained a stable endocrine profile for years; the mild prolactin rise during progression was consistent with stalk effect rather than prolactinoma. Case 3 exhibited a fully normal endocrine evaluation. Node D ensures functional lesions are identified before anatomical decisions dominate.

Node E — Selection of Therapeutic Pathway

By the time Nodes A–D are integrated, therapeutic selection becomes self-evident. Observation, medical

therapy, endoscopic endonasal surgery, transcranial surgery, and radiosurgery each have defined indications [1,2,16-18].

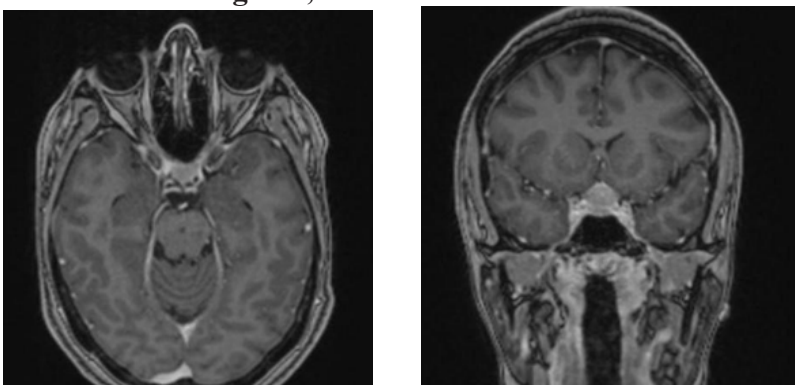
Case 1 required transcranial resection due to planum sphenoidale implantation and ICA contact [2,19]. Case 2 remained under surveillance for four years until radiological progression and cavernous sinus invasion necessitated endoscopic endonasal resection [14,20]. Case 3 remained under long-term surveillance with stable imaging over multiple years [10]. Node E thereby reflects a conclusive synthesis of prior nodes.

Node F — Risk-Adapted Follow-Up

Follow-up must be individualized to pathology, residual tumor, and risk of recurrence. EANO recommends surveillance schedules for meningiomas based on WHO grade [2], whereas CNS recommends tailored MRI intervals following NFPA resection or observation [1]. Endocrine follow-up ensures hormonal recovery or detection of hypopituitarism [3,4].

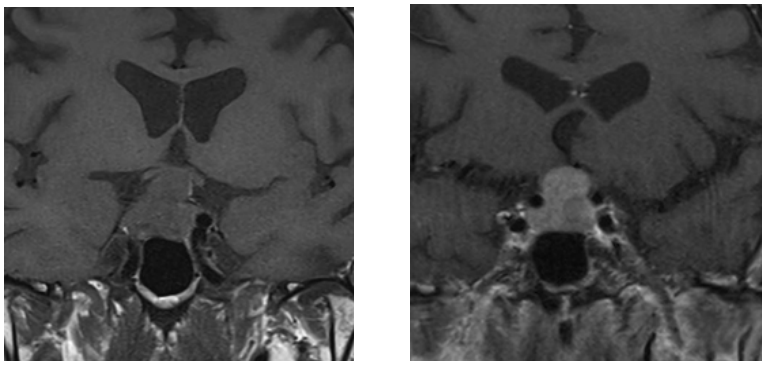
Case 1 followed EANO-consistent postoperative imaging. Case 2 shifted from a conservative NFPA follow-up schedule to postoperative surveillance after surgery. Case 3 continued annual MRI with stable findings. Node F formalizes longitudinal management based on risk categories.

Figures, Tables and Schemes



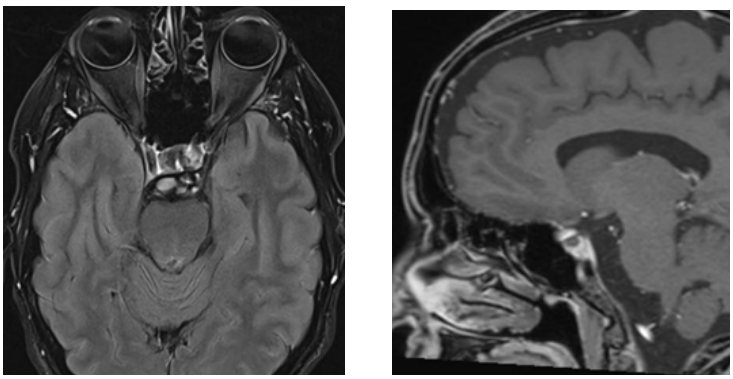
(A) **(B)**

Figure 1: Preoperative MRI Assessment. (A) Axial T1-weighted Sequence and (B) Coronal T1-Weighted Sequence Confirming a Planum Sphenoidale Meningioma with Superior Extension and Compression of the Optic Chiasm.



(A) (B)

Figure 2: Coronal T1-weighted MRI Comparison Over Time.(A) Initial Scan Demonstrating a Pituitary Macroadenoma. (B) Three-Year follow-up Showing Interval Enlargement to 24 × 25 × 16 mm (Previously 20 × 25 × 16 mm), Indicating Slight Progression along the Craniocaudal Axis.



(A) (B)

Figure 3: Axial and Sagittal MRI Characterization of a Suspected Meningioma. (A) Axial T1-Weighted Sequence and (B) Sagittal T1-Weighted Sequence Demonstrating a 23-mm Right Frontal Paramedian/Sellar Mass, with Imaging Features Suggestive of Meningioma as the Leading Diagnosis.

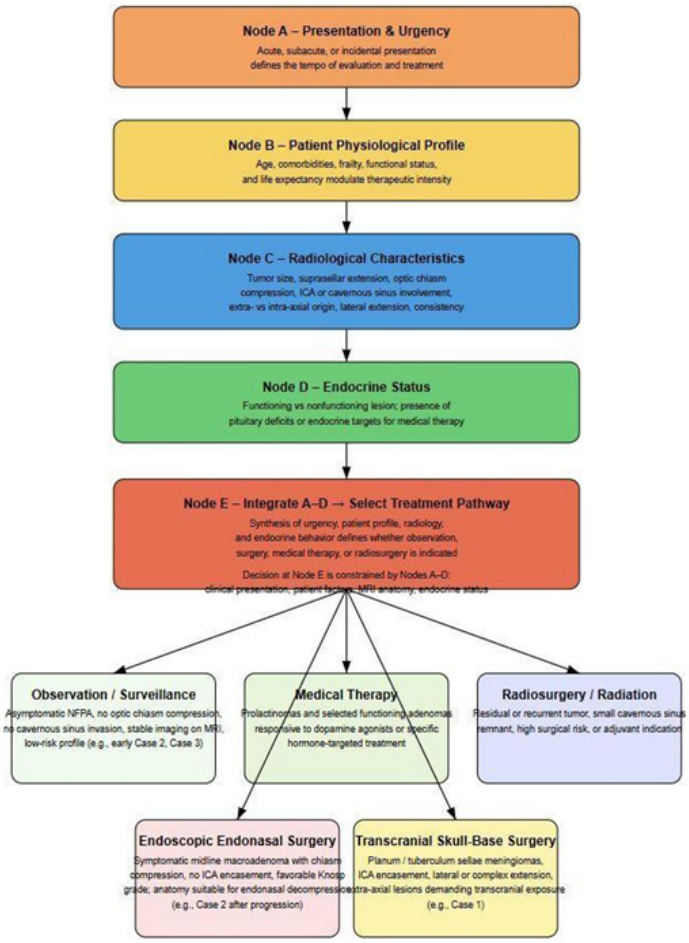


Figure 4: Proposed Diagnostic and Therapeutic Algorithm for Sellar Region Tumors. The Model Synthesizes Presentation, Radiological Features, Endocrine Assessment, and Patient Factors to Determine the Optimal Management Strategy, Including Observation, Medical Therapy, Endoscopic Surgery, Transcranial Surgery, or Radiosurgery.

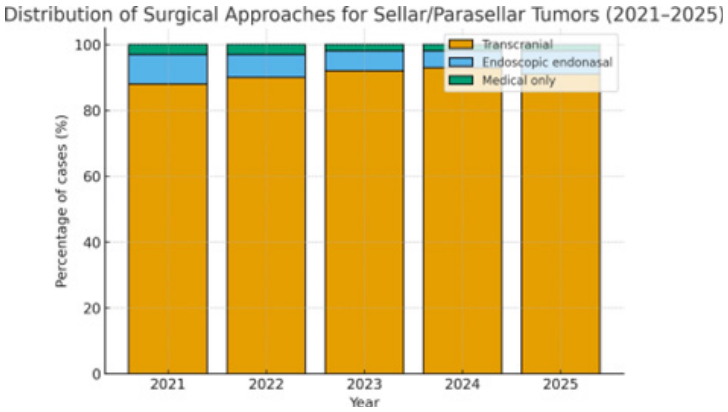


Figure 5: Surgical Approaches Distribution In Our Center (CHIREC DELTA) - (2021–2025)

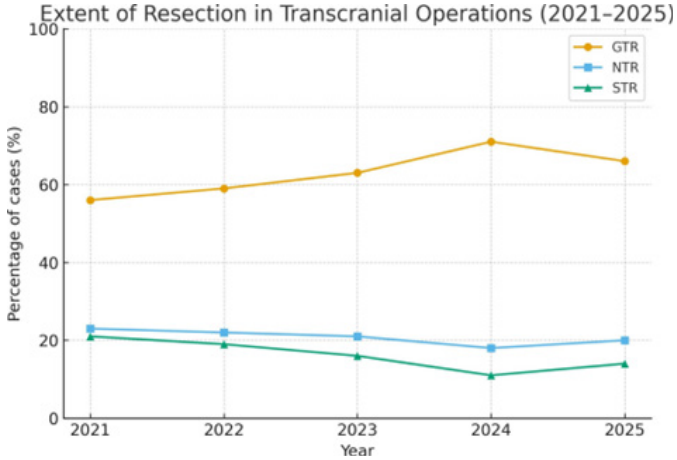


Figure 6: Resection Extent Over Time In Our Center (CHIREC DELTA) - (GTR, NTR, STR) (2021–2025)

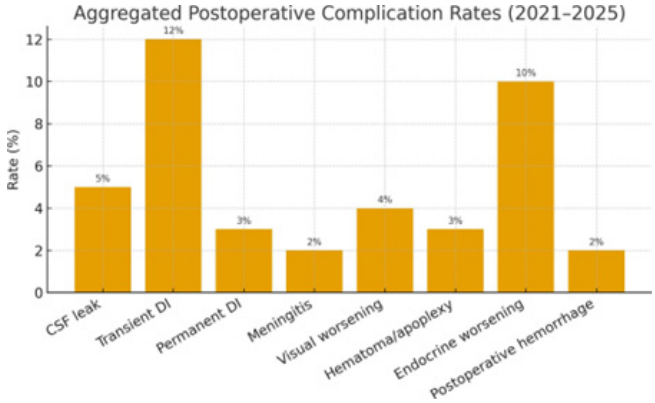


Figure 7: Postoperative Complication Rates for Sellar and Parasellar Tumors in Our Center (CHIREC DELTA) - (2021–2025)

Discussion

The management of sellar and parasellar tumors requires a nuanced integration of anatomical, endocrinological, and clinical parameters. While international guidelines provide essential frameworks for management [1-5], their applicability varies significantly across centers, particularly those with distinct surgical caseload distributions and specialized skull-base expertise. The algorithm presented in this study was developed to align more closely with the complex decision-making processes encountered in our institution, where the diversity and surgical complexity of sellar masses differ considerably from the patterns described in guideline-generating centers.

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Clinical presentation remains the gateway to decision-making in pituitary and parasellar pathology. The tempo of symptoms, particularly the rate of visual decline, severity of headaches, or occurrence of apoplexy, frequently dictates urgency. Numerous longitudinal studies demonstrate that nonfunctioning adenomas are typically slow-growing, with 40–55% remaining stable over 5–10 years [6,7], yet cases of late acceleration or sudden symptom onset are not rare. Our Case 3 exemplifies the typical indolent course of an NFPA managed through extended surveillance, whereas Case 1 underscores the opposite: a suprasellar meningioma where symptom progression necessitated early intervention, consistent with data showing that 60–85% of tuberculum and planum sphenoidale meningiomas eventually produce visual dysfunction [8].

Patient physiology plays a more significant role in our center's decision-making than many guideline frameworks acknowledge. Comorbidities, frailty indices, and neurocognitive profiles influence not only whether surgery is indicated but also the choice of surgical route and postoperative expectations. Our Case 2 illustrates this dynamic, in which observation was initially favored for an elderly patient, despite macroadenoma dimensions that might otherwise have prompted early intervention in a younger or more symptomatic individual. This approach aligns with increasing evidence that advanced age alone should not preclude surgery; instead, physiological resilience and symptom trajectory must guide the therapeutic timeline [9,10].

Radiological analysis remains the most important determinant of surgical approach. Predictors such as suprasellar extension, optic chiasm elevation, cavernous sinus invasion, carotid encasement, lesion consistency, and whether the lesion is intra- or extra-axial directly influence resectability and the feasibility of a specific surgical corridor. Planum sphenoidale and tuberculum sellae meningiomas—particularly when they contact or encase the ICA or extend laterally toward the optic canal—have resection profiles that differ dramatically from midline pituitary adenomas. In such cases, endonasal resection, while increasingly feasible, does not consistently achieve the GTR rates seen with transcranial approaches. Multiple comparative series demonstrate transcranial GTR rates between 50% and 80% for planum/tuberculum lesions [11-13], whereas endonasal GTR rates in similar tumors remain closer to 20–55%. Our Case 1 fits precisely within this pattern and validates the algorithm's emphasis on radiological morphology as the cornerstone of approach selection.

The endocrine profile is essential primarily for differentiating tumors requiring medical therapy from those requiring surgery. Prolactinomas respond to dopamine agonists in 90–95% of cases [14], but these represented only 3–6% of our center's referrals over the last five years (Figure 5), placing greater emphasis on the structural algorithm for nonfunctioning and extra-axial lesions. Both Case 2 and Case 3 aligned with this reality, presenting as hormonally silent macroadenomas requiring management decisions grounded in anatomy and symptom progression rather than endocrine dysfunction.

A distinctive dimension of this analysis is the incorporation of our center's own institutional performance data (2021–2025), which provide a realistic representation of our surgical trends. Unlike pituitary-focused centers where endoscopic endonasal operations represent the overwhelming majority of cases, our department performs a markedly higher proportion of transcranial skull-base surgeries. Over the last five years, 88–93% of all sellar and parasellar tumor operations in our center were performed via transcranial approaches, while endoscopic endonasal surgery represented only 5–9%, and exclusive medical therapy represented 2–3%. This distribution reflects a referral pattern highly enriched with anterior skull-base meningiomas,

ICA-encasing parasellar tumors, complex sphenoid wing/planum lesions, and cases with lateral or superior extension not amenable to endonasal exposure (Figure 5).

Resection outcomes have steadily improved over this period. In 2021, transcranial cases achieved a GTR rate of 56%, with NTR and STR rates of 23% and 21%, respectively. These metrics increased incrementally, reaching 59% in 2022, 63% in 2023, and peaking at 71% in 2024—the highest annual GTR in our series. Complication rates simultaneously declined, with 2024 showing the lowest rate of postoperative morbidity, including a CSF leak rate of 3%, meningitis in 1%, permanent visual decline in 3%, transient DI in 6%, and postoperative hematoma in 2%. In 2025, GTR stabilized at 66%, with NTR at 20% and STR at 14% (Figure 6). Importantly, subtotal resections in our center are often intentional—performed when tumors adhere densely to the optic apparatus, encase the ICA, or involve the hypothalamus. In these cases, functional preservation is prioritized over radicality, reflecting contemporary skull-base surgical philosophy [16-17].

Complication profiles across the five-year interval reflect both the complexity of our cases and consistent refinement in technique. Postoperative CSF leak rates ranged from 3–6%, meningitis from 1–2%, permanent DI from 2–3%, transient DI from 5–9%, endocrine worsening from 7–12%, postoperative hematoma from 2–4%, and postoperative apoplexy from 1–2%. Visual improvement occurred in 55–62% of cases, particularly in planum and tuberculum meningiomas, consistent with evidence that preoperative symptom duration is a major predictor of recovery (Figure 7).

Although endonasal surgery represents a small proportion of our procedures, outcomes paralleled international results. Over the five-year period, endonasal GTR rates for Knosp 0–2 lesions ranged 79–88%, while Knosp 3–4 tumors achieved 34–45%. Endonasal postoperative CSF leak decreased from 7–8% early in the interval to 4–5% in 2024, while transient DI fell from 16% to 11%, and sinonasal morbidity remained low (Figure 6,7).

Compared with major published series, our institutional profile aligns more closely with centers specializing in complex skull-base, meningioma-dominant, or ICA-encasing pathology rather than pituitary adenoma-dominant practices. Centers with high transcranial volumes demonstrate similar GTR ranges and complication profiles, particularly for anterior cranial fossa meningiomas [21-26]. Conversely, centers with primarily endonasal caseloads naturally report higher midline adenoma GTR but lower performance on complex extra-axial lesions. Our algorithm therefore reflects this reality by emphasizing precise corridor selection driven predominantly by radiological morphology.

The improvement in outcomes between 2021 and 2025 coincided with the maturation of our structured algorithm, which increasingly guided patient stratification. By clearly defining the indications for observation, endonasal surgery, transcranial surgery, or deliberate subtotal resection, the algorithm reduced marginal or ambiguous surgical choices. Case 1 exemplifies the importance of correct corridor selection for anterior skull-base meningioma, whereas Case 2 demonstrates the safe timing of surgery after a prolonged observational period in an elderly patient. Case 3 illustrates that algorithm-guided surveillance prevents unnecessary operations while maintaining safety.

In summary, the proposed algorithm synthesizes radiological architecture, clinical trajectory, endocrine status, and patient physiology into a unified, practical decision pathway. Its alignment with guideline principles is complemented by its grounding in real institutional outcomes, particularly within a center that performs a high proportion of transcranial skull-base procedures. The year-to-year improvements observed from 2021 to 2025 support the contention that structured, algorithm-driven surgical decision-making enhances resection quality, reduces morbidity, and aligns operative strategy with tumor biology and anatomy. This model therefore provides a valuable contribution to the neurosurgical management of sellar and parasellar pathology.

Conclusions

The six-node algorithm offers a unified framework for evaluating sellar and parasellar tumors. By integrating urgency, patient biology, radiological determinants, endocrine characterization, therapeutic pathways, and

follow-up, it reflects real-world interdisciplinary practice. The embedded cases illustrate how decisions evolve over time and how guideline principles are applied in complex scenarios. This model may assist institutions in standardizing care while maintaining individualized nuance.

Patents

Author Contributions: Conceptualization, K.H.; methodology, F.C.; investigation, K.H.; resources, K.H.; data curation, K.H.; writing—original draft preparation, F.C and K.H.; writing—review and editing, F.C. H. R, N. OB, and K.H.; visualization, K.H.; supervision, F.C.; project administration, K.H. All authors have read and agreed to the published version of the manuscript.

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