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Preemptive interdural dissection in endoscopic transsphenoidal surgery for cavernous sinus medial wall resection: A technical note with step-by-step illustration

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Abstract

Objective

Microscopic invasion of the cavernous sinus (CS) medial wall is a major cause of surgical failure and persistent hormone hypersecretion in functioning pituitary neuroendocrine tumors (PitNETs). This study provides a step-by-step description of an endoscopic transsphenoidal technique for selective CS medial wall resection, emphasizing preemptive development of the interdural plane before tumor removal to facilitate controlled entry into the CS and subsequent medial wall mobilization.

Methods

We retrospectively reviewed 10 patients with functioning PitNETs who underwent endoscopic transsphenoidal surgery with CS medial wall resection between January 2020 and June 2024 at three institutions. The procedure involved developing an interdural plane at the inferolateral sellar region before tumor removal, followed by stepwise mobilization and detachment of the medial wall. Clinical, radiologic, and endocrinologic outcomes were evaluated.

Results

Gross total resection was achieved in all patients. The mean intraoperative blood loss was 158 mL (range, 70–200 mL). Three patients experienced intraoperative cerebrospinal fluid (CSF) leakage, which was successfully managed with multilayer closure. No postoperative CSF leaks, vascular injuries, or new permanent cranial neuropathies were observed. At a median follow-up of 21 (range, 14–36) months, biochemical remission was achieved in nine patients.

Conclusions

Preemptive interdural dissection during endoscopic transsphenoidal surgery provides an anatomically guided strategy for controlled entry into the CS and subsequent medial wall mobilization. This approach may facilitate CS medial wall resection while minimizing unnecessary manipulation near critical neurovascular structures in selected patients with functioning PitNETs.

Introduction

Functioning pituitary neuroendocrine tumors (PitNETs) account for approximately half of all pituitary tumors and secrete one or more anterior pituitary hormones.[20] Although histologically benign, these tumors cause substantial morbidity and increased mortality due to the pathophysiologic effects of hormone hypersecretion.[4, 7, 11, 20] Achieving timely biochemical control or cure is therefore essential to improve patient outcomes.

These tumors often exhibit invasive behavior, which compromises surgical remission. One of the most significant barriers to achieving complete resection and biochemical cure is microscopic tumor invasion of the medial wall of the cavernous sinus (CS).[5, 6, 17, 23, 24] Despite being relatively thin and well-defined, the medial wall of the CS can harbor hormonally active tumor remnants inaccessible to curettage or blunt removal, resulting in persistent hypersecretion and treatment failure.[8] Resection of the CS medial wall may therefore improve the likelihood of both biochemical cure and long-term oncologic control in selected cases.

Recent advances in endoscopic skull base surgery have enabled selective resection of the CS medial wall through a transsphenoidal approach.[1] Several groups have reported effective techniques, typically involving an anterior-to-posterior approach that begins with opening the anterior-most portion of the medial CS wall.[5, 23, 28] However, the initial step of entering the CS remains technically demanding due to the proximity of critical structures, particularly the internal carotid artery (ICA), and the potential for venous bleeding. These challenges can make the procedure especially difficult for less experienced surgeons.

Accordingly, this study describes a stepwise endoscopic technique for CS medial wall resection in functioning PitNETs, with particular emphasis on the preemptive development of the interdural plane prior to tumor removal as a strategy for safer and more controlled entry into the CS. By establishing this plane early, the technique facilitates subsequent mobilization of the medial wall while minimizing unnecessary manipulation near critical neurovascular structures. The primary aim of this study is to provide a step-by-step description of the procedure, highlight key technical nuances, and discuss practical considerations for safe application of this approach. Our early clinical experience in a small series is additionally presented to illustrate the feasibility of the technique in selected cases.

Materials and Methods

Patient Selection

We retrospectively reviewed the data of patients who underwent endoscopic transsphenoidal surgery for functioning PitNETs with CS medial wall resection between January 2020 and June 2024 at three participating institutions. A clinical diagnosis of functioning PitNET was established in all patients based on endocrinologic evaluation and magnetic resonance imaging (MRI). CS medial wall resection, in addition to tumor excision, was performed in all patients where medial wall invasion could not be completely excluded on preoperative MRI or intraoperative inspection. The decision to proceed with medial wall resection was made intraoperatively by the operating surgeons at each institution. Patients with small tumors that did not directly contact the medial wall were not considered for medial wall resection.

Inclusion criteria for the study were as follows: (1) biochemical evidence of hormone excess (growth hormone [GH] or adrenocorticotropic hormone [ACTH]) with histopathologic confirmation of functioning PitNET; (2) a tumor in direct contact with, and showing suspicious invasion of medial wall of the CS; (3) intraoperative identification and resection of the medial CS wall; and (4) a minimum of 12 months of postoperative follow-up, and availability of brain imaging and endocrinologic assessment results.

Patients with a history of prior surgery or medical therapy were excluded from the analysis. In addition, patients with a clear CS invasion beyond the medial wall on preoperative MRI (e.g., Knosp grade 4) or confirmed intraoperatively were also excluded.[15]

This study was approved by the institutional review boards of all participating centers. (IRB No. 2026-02-069)

Data Extraction

All patients underwent preoperative and postoperative MRI, including contrast-enhanced sequences for radiological assessment. Preoperative MRI was reviewed to evaluate the degree of parasellar extension, graded using the Knosp classification.[15] Endocrinologic investigations were performed in all patients before and after surgery to assess biochemical remission. Intraoperative and postoperative complications were systematically recorded, and estimated intraoperative blood loss volume was extracted from the anesthetic and operative records.

Surgical Technique

The overall concept and schematic outline of the CS medial wall resection, as applied in our operative technique, are illustrated in **Figure 1**, and the corresponding step-by-step intraoperative endoscopic views are presented in **Figure 2**. All procedures were performed using a binostril endoscopic endonasal transsphenoidal approach under general anesthesia. A wide sphenoidotomy was performed, and the sellar floor was broadly removed to provide complete exposure of the CS on the target side. The key surgical steps and their potential pitfalls are described below.

Step 1. Exposure and dural incision

After the wide exposure of the sellar dura, the outer (periosteal) dural layer was incised along the inferolateral aspect of the sella, beginning near the midline and extending laterally toward the target CS, while carefully preserving the inner (meningeal) layer. At this stage, precise control of force is essential to incise only the outer dura. Particular care has to be taken to avoid incising too close to the ICA, which may result in premature entry into the CS (Figure 1A; Figure 2A, B).

Step 2. Interdural dissection

After the initial dural incision, the interdural space was gently developed using a blunt dissector to create a clear plane between the outer and inner dural layers. Establishing this plane before tumor removal preserves a distinct interdural corridor for subsequent dissection. Care should be taken to maintain dissection within the correct plane, as undue force could lead to inadvertent violation of the inner dura. Venous bleeding from the intercavernous sinus may occur as the interdural space is widened; however, it typically ceases once the dissector is withdrawn and the space collapses (*Figure 2C*).

Step 3. Tumor removal and interdural space extension

Both the outer and inner dural layers were subsequently incised circumferentially, resulting in exposure of the pituitary tumor (Figure 1B; Figure 2D), which was then removed using a standard intradural procedure. After tumor removal, the medial wall was inspected to determine the need for resection. When considered necessary, the previously developed interdural plane was further extended using a blunt dissector to widen the working corridor, thereby facilitating subsequent mobilization of the medial wall. Venous bleeding is commonly encountered during this extension but can be effectively controlled with the application of an injectable hemostatic matrix (Figure 1C; Figure 2E).

Step 4. Medial wall mobilization

The medial wall was mobilized in a stepwise manner, as previously described in the literature.[28] After division of the inferior parasellar ligament (IPL), the inferior hypophyseal artery (IHA) was coagulated and transected. Subsequent dissection involved sequential division of the parasellar ligaments tethering the medial wall, allowing gradual release and mobilization. Particular care is required to ensure complete hemostasis of the IHA to maintain a clear operative field (Figure 1D; Figure 2F, G).

Step 5. Final detachment

Further upward dissection exposed the carotico-clinoid ligament (CCL), which was carefully divided to release the superior attachment of the medial wall. The remaining dural connections along the posterior clinoid process and dorsum sellae were then incised, completing the removal of the medial wall. Care must be taken not to extend the incision too superiorly, as this could tear the sellar diaphragm, resulting in cerebrospinal fluid (CSF) leakage (Figure 1E; Figure 2H–J).

Results

Patient and Tumor Characteristics

Ten patients with functioning PitNETs who underwent CS medial wall resection were included (Table 1). The cohort consisted of three females and seven males, with a mean age of 45.1±13.8 years (range, 26–64 years). The mean maximum tumor diameter was 16.8 mm (range, 10–26 mm), and Knosp grades were as follows: grade 1 (n=7) and grade 2 (n=3). The most common hormonal subtype was acromegaly (n=7), followed by Cushing's disease (n=3).

Surgical Morbidity and Biochemical Outcomes

Gross total resection was achieved in all patients. The mean intraoperative blood loss was **158 mL** (range, **70–200 mL**). Intraoperative CSF leakage occurred in **three** patients and was successfully managed with multilayer closure.[9] **No postoperative CSF leaks were observed.** Transient diabetes insipidus developed in **three** patients but resolved spontaneously during the early postoperative period. Transient diplopia occurred in one patient but was also resolved without additional intervention. There were no cases of major vascular injury or new permanent cranial neuropathy. At the last follow-up (median, 21 [range, 14–36] months), biochemical remission was achieved in nine patients based on postoperative endocrinologic evaluation.

Discussion

Invasion of the CS medial wall represents a clinically significant yet often underrecognized aspect of PitNETs. Even in cases without radiographic evidence of invasion, microscopic infiltration of the wall has been demonstrated in several pathological studies.[8, 19, 21–23] Although the clinical implications of such microscopic remnants in nonfunctioning PitNETs remain unclear, in functioning tumors, these residual cells are closely associated with persistent hormone hypersecretion and biochemical recurrence.[10, 13, 17, 24, 30] Therefore, in functioning PitNETs, selective resection of the CS medial wall during surgery is essential to achieve durable endocrine remission in selected cases.

The medial wall of the CS is a dural structure that is firmly adherent to the venous sinusoid channels. Its resection is frequently accompanied by considerable venous bleeding, which can obscure visualization and increase operative difficulty. Therefore, successful dissection requires a precise understanding of regional anatomy. The medial wall is anchored by dense fibrous structures, such as the IPL and CCL, and is traversed by small arterial branches, including the IHA, all of which pose potential risks of neurovascular injury during resection.[27, 28] These anatomical details are schematically summarized in Fig. 1 and demonstrated intraoperatively in Fig. 2.

Adequate exposure is essential to ensure surgical freedom and safety. The anterior wall of the sphenoid sinus should be widely opened, and sufficient bone removal along the anterior sellar floor adjacent to the ICA is required to fully expose the medial wall. At this stage, meticulous care must be taken to avoid ICA injury. The key principle of medial wall resection in our technique lies in identifying and developing the plane between the outer and inner dural layers of the sellar floor. This concept is based on the understanding that the dura covering the pituitary gland comprises two distinct dural layers separated by a potential space.[18] Creating this plane provides a protective barrier from the ICA and venous channels while establishing a safe corridor for subsequent mobilization of the medial wall. Dissection initiated too close to the ICA carries significant risk, whereas attempting to separate the two dural layers after tumor removal can be technically challenging due to tissue collapse and loss of the natural plane.

The initial step of entering the CS remains one of the most technically challenging and potentially hazardous parts of medial wall resection. The most important technical aspect of our method is in establishing the interdural plane before tumor resection. This preemptive interdural dissection is initiated in the midline–inferior sellar region, away from the ICA. After tumor removal and inspection of the medial wall, the previously established interdural plane can be further extended when medial wall resection is considered necessary, facilitating subsequent mobilization and detachment of the medial wall.

Interdural dissection itself is an established component of CS medial wall resection. Our approach shares similarities with previously described techniques; however, the key distinction lies in the timing of interdural dissection. In conventional approaches, interdural dissection is typically initiated after tumor removal, near the anteroinferior portion of the medial wall.[22, 23, 25] However, once the tumor is removed and the sellar dura decompresses, distinguishing the two dural layers becomes more difficult, as the collapsed dura is technically challenging to manipulate. Moreover, bleeding from the intercavernous and cavernous sinuses tends to be more pronounced after decompression of the sellar cavity. Accordingly, performing interdural dissection preemptively provides a clearer anatomical plane and a drier operative field with less venous pooling.

Furthermore, this strategy may reduce the need for blind or forceful dissection near the ICA during the initial entry into the CS and facilitate a more controlled surgical workflow, which may be particularly helpful for surgeons with limited experience in CS surgery. Injury to the ICA represents one of the most catastrophic intraoperative accidents, carrying potentially fatal outcomes.[3, 14, 29] Although several reports have described the successful management of ICA injury during transsphenoidal surgery, such events remain the most feared and can result in devastating neurological sequelae or death.[2, 12, 16]

Potential complications of medial wall resection include vascular injury, CSF leakage, and cranial nerve palsy.[22, 25] The ICA and its branches, including the inferior hypophyseal and capsular arteries, must be meticulously preserved. Blunt or excessive traction should be avoided; sharp dissection with definitive coagulation and controlled division of small vessels is recommended. CSF leakage during surgery may not be directly related to the CS medial wall resection itself but rather to excessive tumor manipulation or excessive dissection of the superior or posterior portion of the medial wall.[26] When intraoperative CSF leakage occurs, multilayered reconstruction with sealant, fat graft, and nasoseptal flap coverage is considered to prevent postoperative leakage. Cranial nerve palsy may result from vigorous packing of the CS cavity or excessive use of flowable hemostatic agents to control CS bleeding.[5, 25] Overpacking can cause direct pressure on the cranial nerves, whereas hemostatic agents may induce inflammation or fibrosis, further contributing to neural injury. Gentle compression and judicious use of flowable hemostatic materials are therefore recommended.

Despite the favorable surgical results, this study has several limitations. As this study primarily focused on providing a step-by-step description of the surgical technique for CS medial wall resection, the number of patients was small, the follow-up period was relatively short, and the resected medial wall was not separately evaluated histopathologically. Consequently, microscopic invasion of the medial wall could not be confirmed in this series. In addition, this technique is applicable only to selected cases with suspected medial wall involvement without extensive cavernous sinus invasion and is not suitable for tumors with full-thickness CS invasion or high Knosp grades requiring aggressive transcavernous approaches. Accordingly, the findings may not be generalizable to more invasive tumors. Future studies with larger patient cohorts, detailed histopathologic analysis, and long-term endocrine outcomes are warranted to further evaluate the clinical applicability of this approach.

Conclusion

Selective resection of the CS medial wall can play an important role in achieving durable biochemical remission in functioning PitNETs. Our stepwise endoscopic transsphenoidal technique, beginning with preemptive interdural dissection near the midline sellar region, facilitates controlled mobilization and removal of the medial wall while minimizing unnecessary manipulation near critical neurovascular structures. This anatomically guided approach may provide a practical and reproducible option for CS medial wall resection in selected cases.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions: All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Sae Min Kwon, Min Kyun Na and Joonho Byun. The first draft of the manuscript was written by Sae Min Kwon and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability: The datasets generated or analyzed during the study are available from the corresponding author on reasonable request

Ethics approval

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the institutional review boards of the participating institutions (IRB No. 2026-02-069).

Consent to participate

The requirement for informed consent was waived by the institutional review board because of the retrospective nature of the study.

Consent to publish

Not applicable.

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Table

Table 1. Summary of patients with functioning pituitary neuroendocrine tumors undergoing cavernous sinus medial wall resection

No.	Sex/Age	Diagnosis	Max. tumor size (mm)	Knosp grade	EOR	Intraoperative blood loss (mL)	Intraoperative complication	Postoperative complication	Endocrinologic outcome	Follow-up (months)
1	F/43	Acromegaly	26	2	GTR	100	CSF leak grade 1	None	Remission	21
2	M/62	Acromegaly	16	1	GTR	130	None	None	Remission	20
3	M/64	Acromegaly	17	2	GTR	180	CSF leak grade 2	Transient diplopia	Remission	16
4	M/53	Cushing's disease	21	1	GTR	70	None	Transient DI	Non-remission	14
5	F/58	Acromegaly	17	1	GTR	200	None	None	Remission	19
6	M/37	Acromegaly	14	1	GTR	150	None	None	Remission	18
7	M/32	Acromegaly	15	1	GTR	200	None	None	Remission	24
8	F/46	Cushing's disease	10	2	GTR	200	CSF leak grade 1	Transient DI	Remission	36
9	M/26	Acromegaly	17	1	GTR	150	None	None	Remission	24
10	M/30	Cushing's disease	15	1	GTR	200	None	Transient DI	Remission	27

* CSF leakage grading was defined according to the classification described by Esposito et al.[14]

DI, diabetes insipidus; EOR, extent of resection; GTR, gross total resection

Figures

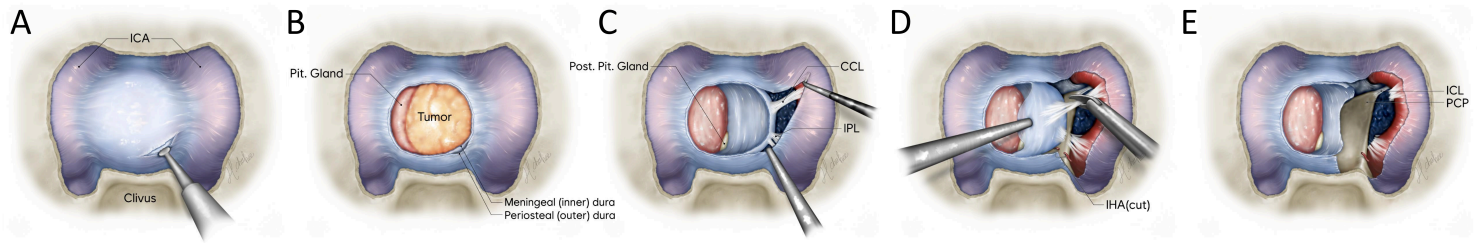


Figure 1

Schematic illustration demonstrating the concept and key steps of cavernous sinus (CS) medial wall resection.

The procedure involves incision of the periosteal (outer) dural layer at the inferolateral aspect of the sella while preserving the meningeal (inner) layer, followed by gentle development of the interdural space (A). A full-thickness circumferential dural incision is then made for tumor removal (B). The previously developed interdural plane is subsequently expanded using a blunt dissector to enter the CS (C), after which the parasellar ligaments are divided and the IHA is coagulated and transected (D), resulting in the complete removal of the medial wall (E). CCL, carotico-clinoid ligament; CS, cavernous sinus; ICA, interal carotid artery; ICL, interclinoidal ligament; IHA, inferior hypophyseal artery; IPL, inferior parasellar ligament; PCP, posterior clinoid process; Post. Pit. Gland, posterior pituitary gland.

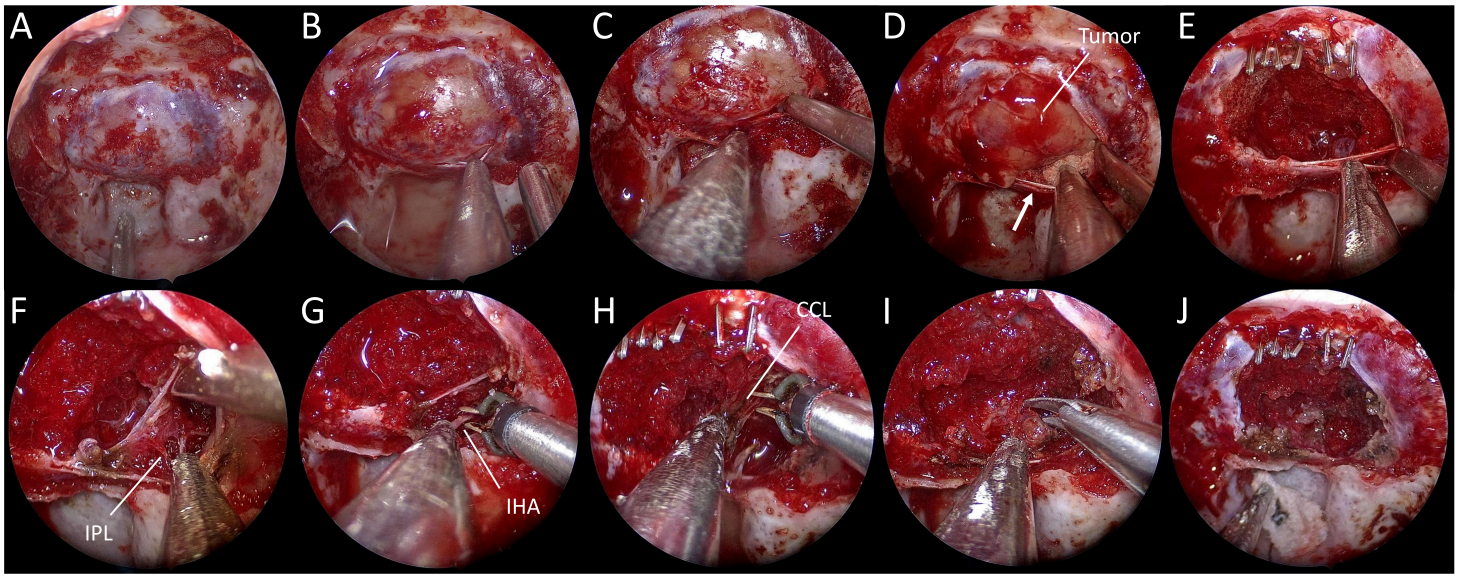


Figure 2

Step-by-step technique for the medial wall resection of the CS, showing the intraoperative endoscopic views

(A) The sellar floor is widely removed, and exposure is extended toward the target CS to ensure adequate visualization and access for the medial wall resection.

(B) The outer (periosteal) dural layer is incised at the inferolateral aspect of the sellar region adjacent to the target CS, with care to preserve the inner (meningeal) dural layer.

(C) The interdural space is carefully developed using a blunt dissector, creating a clear plane between dural layers to facilitate subsequent dissection.

(D) After initial separation of the dural layers, both the outer and inner layers are circumferentially incised to allow tumor removal. The preserved interdural space (arrow) remains clearly visible below the resection plane.

(E) Following tumor removal, the previously developed interdural space is further expanded to enter the CS, facilitating safe resection of the medial wall.

(F) Within the CS, the IPL is exposed and divided to allow further mobilization of the medial wall.

(G) The IHA is coagulated, and transected.

(H) The CCL is identified and divided during further dissection.

(I) The remaining dural attachment over the posterior clinoid process and dorsum sella is incised to complete the medial wall removal.

(J) Final endoscopic view showing the complete removal of the medial wall with clear exposure of the CS.

CCL, carotid-clinoid ligament; CS, cavernous sinus; IHA, inferior hypophyseal artery; IPS, inferior parasellar ligament