

RESEARCH

Recommendation to improve the WHO classification of posterior pituitary tumors as a unique entity: evidence from a large case series

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Abstract

Introduction: Most studies reporting posterior pituitary tumors (PPTs) are small case series or single cases.

Methods: Patients with a histological diagnosis of PPT from January 2010 to December 2021 in a tertiary center were identified. We reported clinical symptoms, endocrine assessments, radiological and pathological features, and surgical outcomes of PPTs.

Results: A total of 51 patients (23 males, 51.3 ± 10.3 years old) with PPT were included in this study. Major symptoms were visual defects, headache, and hypopituitarism, while diabetes insipidus was uncommon (9.8%). The typical radiological feature was homogeneous enhancement (84.3%) of a regular-shaped mass on T1 contrast imaging without cystic change, calcification, or cavernous sinus invasion. We achieved gross total resection in 38/51 patients (74.5%). Pathologically, all tumors showed thyroid transcription factor 1 immunoreactivity. Among 29 patients with suprasellar PPTs, postoperative hemorrhage due to tumor residue was encountered in 2/15 cases in the transcranial group and 0/14 in the endoscopy group. Patients with spindle cell oncocytoma (SCO) were more likely to be surgically treated (25% vs 0%, $P = 0.018$), harbor a higher Ki-67 index (16.7% vs 0% > 5% $P = 0.050$), and present a lower 2-year recurrence-free survival rate (67.5% vs 90.9%) compared with patients with pituicytoma or granular cell tumor.

Conclusion: PPTs should be considered in the differential diagnosis of patients with sellar and suprasellar masses with a regular lesion with homogeneous enhancement. SCOs had high proliferation activity and risk of recurrence.

Key Words

- ▶ pituicytomas
- ▶ granular cell tumors
- ▶ spindle cell oncocytomas
- ▶ pathology surgery

Endocrine Connections
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Introduction

Posterior pituitary tumors (PPTs) are rare neoplasms that include pituicytomas (PCs), granular cell tumors (GCTs), and spindle cell oncocytomas (SCOs) (1). According to new histological and immunohistochemical studies, the 2021 World Health Organization (WHO) classification categorizes PPTs as a morphological spectrum of a single entity with thyroid transcription factor 1 (TTF1) immunopositivity (2).

In clinical practice, PPTs are uncommon and are often misdiagnosed as pituitary adenomas or craniopharyngiomas before operation. Previous studies have suggested that PPTs are hypervascularized (3, 4); thus, clinical suspicion of PPTs before surgery is a real challenge. Recent advances in endoscopic surgery have provided better illumination and close-up observation during transsphenoidal surgery (5, 6). However, surgical results and complications using the endoscopic transsphenoidal approach have been seldom discussed in previous studies.

Although the 2021 WHO classification suggests a good prognosis for all three tumors, recent studies have suggested that the characteristics and prognosis of SCOs are different from those of PCs or GCTs (7, 8). Moreover, most tumors that have been reported were small case series or single cases. Thus, analysis of more cases and further discussion are required to determine whether SCO is an independent entity from other PPTs, to clearly define the proper management. The current study reported clinical symptoms, endocrine assessments, and surgical outcomes of a large cohort of patients with PPTs. We further highlighted tumor characteristics distinguishing a PPT from pituitary adenoma or craniopharyngioma before surgery.

Methods

Patients with histological diagnosis of PPTs (PCs, GCTs, and SCOs) were identified from the Gold Pituitary Database, which recorded all the patients with sellar region tumors from January 2010 to December 2021 in a tertiary center. All of the patients underwent surgical resection of the tumor. The Huashan Hospital institutional review board approved the study, and all of the patients gave their informed consent when their data were logged into the database.

We recorded gender, age at diagnosis, symptoms (headache, visual defects, polydipsia and polyuria, hypopituitarism, or incidental), comorbidities, radiological

findings (tumor volume and location), pituitary function, surgical approaches, histopathology, and post-treatment complications.

All patients underwent standardized endocrine evaluation in our center before and after surgery. Patients with a morning cortisol level <3 mg/dL were deemed to have central adrenal insufficiency, and a morning cortisol level >15 mg/dL were regarded as normal. Patients whose morning cortisol levels were between 3 and 15 mg/dL underwent adrenocorticotrophic hormone stimulation test or insulin tolerance test, and a peak cortisol value <18 mg/dL was defined as central adrenal insufficiency. Central hypothyroidism was diagnosed by serum free thyroxine level below the reference range with insufficiently elevated thyroid-stimulating hormone. In men, central hypogonadism was diagnosed if testosterone was low in conjunction with normal or low luteinizing hormone (LH) and follicle-stimulating hormone (FSH). In premenopausal women, central hypogonadism was diagnosed if low or normal gonadotropins coincided with estradiol levels <100 pmol/L, oligomenorrhea, amenorrhea, or infertility. In postmenopausal women, central hypogonadism was diagnosed by low serum LH and/or FSH. Clinical presentation, urine specific gravity, urine and serum osmolality, serum sodium level, and need for desmopressin treatment were comprehensively evaluated for the diagnosis of central diabetes insipidus.

MR images were acquired on a 3.0 Tesla scanner (Discovery MR 750W; GE Medical Systems, Milwaukee, WI, USA) with an eight-channel head coil. Each patient underwent preoperative MR scanning in the following order: pre-contrast sagittal, coronal T1-weighted imaging (T1WI); contrast-enhanced (CE) coronal, sagittal T1WI. The parameters of MR sequences were as follows: repetition time/echo time 400/13 ms, the field of view 20 cm, matrix size (coronal: 288 × 192; sagittal: 288 × 224), bandwidth 62.5 kHz, echo train length 12, and slice thickness 2 mm. Enhanced imaging was performed immediately after administering a standard dose (0.1 mmol/kg) of gadopentetate dimeglumine (Beilu, Beijing, China) at approximately 3–4 mL/s via the dorsal hand or elbow vein. Preoperative definition of cavernous sinus involvement was made using CE coronal MR images (tumor extends to the lateral tangent into the superior and inferior cavernous sinus compartment or complete encasement of an intracavernous intracarotid artery).

Paraffin-embedded tissue blocks were sectioned at 4- μ m thickness for immunohistochemistry. Subsequently, TTF1 (Leica), S100 protein (Dako), GFAP (Dako),

EMA (Dako), synaptophysin (Dako), and Ki67 (Dako) monoclonal antibodies (1:50) were added, incubated, and washed with phosphate buffer. Next, a secondary antibody was applied, and the color was revealed by DAB substrate solution and counterstained with hematoxylin. Ki-67 index was measured by calculating Ki-67-positive cells in every 100 cells in hot spots at the 200× magnification. The hot spots were defined as areas in which Ki-67 staining was particularly higher relative to the adjacent areas. When a tumor had several hotspots, the ‘hottest’ spot was selected for scoring. When a tumor had no hotspots, the average percentage of positive tumor cells was used.

Patients with PPTs were further categorized as sellar, intra-suprasellar, and suprasellar types. We included patients with suprasellar-type craniopharyngiomas as a comparator to differentiate them from patients with suprasellar PPTs.

Statistical analysis

We compared population characteristics, radiological features, pathological features, and surgical outcomes in patients with different pathological diagnoses. We compared the surgical outcomes using the endoscopic transsphenoidal approach with other approaches in patients with suprasellar-type PPTs. We further compared the symptoms and imaging characteristics between suprasellar-type craniopharyngiomas and PPTs. Continuous data with normal distribution were displayed as mean ± s.d.; otherwise, median values with interquartile range were displayed. We used the chi-square tests and Student's *t*-test for the comparison. All statistical analyses were completed by R software version 3.4.2.

Results

Among the 9956 cases enrolled in the Gold Pituitary Database, we identified 51 patients (23 males and 28 females; 51.3 ± 10.3 years old) with PPT, indicating that the incidence rate was 0.5% of all of the sellar region tumors.

Symptoms

Age and gender were similar among patients with different pathological types. Major symptoms were visual defects, headache, and symptoms related to hypopituitarism (fatigue, menstrual disorder, or libido decrease, [Table 1](#)). Patients with GCTs seemed to have a higher BMI ($P=0.029$) than patients with PCs and SCOs. Three patients were

previously surgically treated and suffered a recurrent tumor, and all these three patients were diagnosed with SCO.

Imaging

The median tumor volume was 2.1 (interquartile range: 1.0–5.6) cm³. Homogeneous enhancement was observed in the majority of the patients (43 cases, 84.3%). None of the cases showed cystic change or cavernous sinus invasion. We observed striated or dotted high signals in T1 contrast imaging in eight patients. There were 29 (56.9%) suprasellar PPTs, and in these cases, the enhanced pituitary gland was located at the sellar inferiorly to the tumor. Only 2 of 12 (16.7%) SCOs presented with the suprasellar type, compared with 63.6 and 71.4% of PCs and GCTs ($P=0.005$). In other cases, the tumors were mainly located in the sella, and the enhanced pituitary gland was located anteriorly to the tumor.

Endocrine assessments

Prevalence of preoperative endocrine deficiencies was similar between the three groups. The overall prevalence of corticotrophic deficiency, thyrotrophic deficiency, and hypogonadotropic deficiency was 32.4, 29.4, and 27.4%, respectively. Only 9.8% of the presented cases had diabetes insipidus.

Pathology

PCs comprised bipolar spindled cells arranged in a fascicular or storiform pattern ([Fig. 1](#)). The tumor cells showed TTF1 and diffuse S-100 immunoreactivity. GCTs contained densely packed polygonal cells with abundant granular eosinophilic cytoplasm ([Fig. 2](#)). Previous studies have suggested that such a cytoplasm is caused by the high concentration of lysosomes, which are stained periodic-acid-Schiff-positive (9). Similarly, they showed TTF1 and diffuse S-100 immunoreactivity. SCOs were composed of spindle-to-epithelioid cells with variable eosinophilic and oncocytic cytoplasm ([Fig. 3](#)). Tumor cells showed TTF1 and GFAP immunoreactivity.

Overall, TTF1 was 100% positive in our cohort, and the majority of cases were positive for GFAP and S100, with a relatively low Ki67 index. However, GFAP positivity was only observed in 25.0% of patients with SCOs ($P < 0.001$). EMA positivity was higher in SCOs (66.7%) than in the other two types (57.1 and 54.5%), although not statistically significant. The Ki-67 index was higher than 5% in only

Table 1 Characteristics of posterior pituitary tumors with different pathology.

	Overall (n = 51)	PCs (n = 28)	GCTs (n = 11)	SCOs (n = 12)	P
Gender (male)	23 (45.1%)	13 (46.4%)	5 (45.5%)	5 (41.7%)	1.000
Age (years)	51.3 (10.3)	51.5 (9.2)	51.3 (12.3)	51.0 (11.7)	0.992
Body mass index (kg/m ²)	25.1 (5.2)	24.3 (3.6)	28.6 (6.6)	23.6 (5.8)	0.029
Symptoms					
Visual defect	19 (37.3%)	10 (35.7%)	4 (36.4%)	5 (41.7%)	0.928
Headache	17 (33.3%)	8 (28.6%)	4 (36.4%)	5 (41.7%)	0.725
Symptoms related to hypopituitarism ^a	11 (21.6%)	6 (21.4%)	4 (36.4%)	1 (8.3%)	0.274
Polydipsia and polyuria	5 (9.8%)	4 (14.3%)	1 (9.1%)	0 (0.0%)	0.488
Incidental	8 (15.7%)	6 (21.4%)	1 (9.1%)	1 (8.3%)	0.669
Surgical history	3 (5.9%)	0 (0.0%)	0 (0.0%)	3 (25.0%)	0.018
Comorbidities					
Hypertension	5 (9.8%)	3 (10.7%)	1 (9.1%)	1 (8.3%)	1.000
Diabetes mellitus	2 (3.9%)	1 (3.6%)	0 (0.0%)	1 (8.3%)	0.704
Imaging features					
Tumor volume (cm ³)	2.1 (1.0, 5.6)	1.7 (1.0, 4.2)	1.7 (0.8, 9.8)	2.6 (2.0, 4.1)	0.560
Homogenous signals	43 (84.3%)	24 (85.7%)	10 (90.9%)	9 (75.0%)	0.591
Suprasellar type	29 (56.9%)	20 (71.4%)	7 (63.6%)	2 (16.7%)	0.005
Pre-operative endocrine assessment					
Hypothyroidism	16 (32.4%)	9 (32.1%)	3 (26.3%)	4 (33.3%)	1.000
Hypoadrenalism	15 (29.4%)	6 (21.4%)	4 (36.4%)	5 (41.7%)	0.381
Hypogonadism	14 (27.4%)	10 (35.7%)	2 (18.2%)	2 (16.6%)	0.708
Diabetes insipidus	5 (9.8%)	4 (14.3%)	1 (9.1%)	0 (0.0%)	0.488
Surgical approach					0.338
Endoscopic transsphenoidal	21 (41.2%)	15 (53.6%)	3 (27.3%)	3 (25.0%)	
Microscopic transsphenoidal	14 (27.5%)	6 (21.4%)	3 (27.3%)	5 (41.7%)	
Transcranial	16 (31.4%)	7 (25.0%)	5 (45.5%)	4 (33.3%)	
Gross total resection	38 (74.5%)	21 (75.0%)	9 (81.8%)	8 (66.7%)	0.760
Pathological features					
TTF1 positive	51 (100.0%)	28 (100.0%)	11 (100.0%)	12 (100.0%)	NA
GFAP positive	35 (68.6%)	24 (85.7%)	8 (72.7%)	3 (25.0%)	< 0.001
EMA positive	30 (58.8%)	16 (57.1%)	6 (54.5%)	8 (66.7%)	0.862
Synaptophysin positive	16 (31.4%)	9 (32.1%)	4 (36.4%)	3 (25.0%)	0.851
S100 positive	43 (84.3%)	24 (85.7%)	10 (90.9%)	9 (75.0%)	0.591
Ki-67 >5%	2 (3.9%)	0 (0.0%)	0 (0.0%)	2 (16.7%)	0.050
Post-operative endocrine assessment					
New diabetes insipidus	18 (35.3%)	9 (32.1%)	5 (45.5%)	4 (33.3%)	0.784
New hypopituitarism	18 (35.3%)	11 (39.3%)	3 (27.3%)	4 (33.3%)	0.710

^aLethargy, fatigue, decrease of libido, or menstrual disorder.

GCTs, granular cell tumors; PCs, pituicytomas; SCOs, spindle cell oncocytomas.

two patients (8 and 6%), and both of them were from the SCO group.

Surgery

We achieved gross total resection in 38 patients (74.5%). Postoperatively, 18 patients (35.3%) developed new hypopituitarism or diabetes insipidus. During the short follow-up (24 months (IQR: 12–48 months)), three patients (two in the SCO group and one in the PC group) relapsed after the initial surgery, suggesting the 2-year recurrence-free survival rate of 90.9% in patients with PCs and GCTs compared with 67.5% in patients with SCOs.

Comparison of different surgical strategies

Among 29 patients with suprasellar-type tumors, 14 cases were treated using the endoscopic transsphenoidal approach, while others were treated with a transcranial approach (Table 2). In the endoscopic group, tumors seem to be larger (higher tumor volume, a higher proportion of preoperative visual defects, hypothyroidism, hypogonadism, and diabetes insipidus, though not statistically significant). The rate of gross total resection was similar ($P=0.682$) between the endoscopic group (78.6%) and the transcranial group (66.7%). However, a disastrous surgical complication, postoperative hemorrhage, was

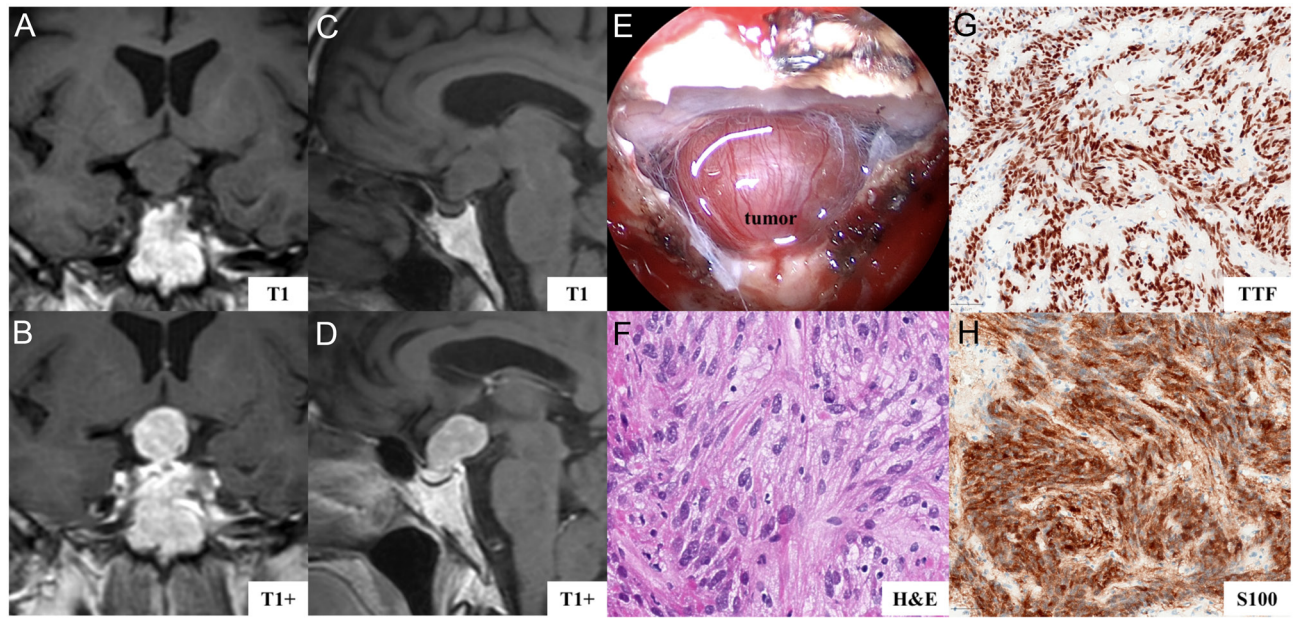


Figure 1

A 67-year-old male patient was diagnosed with pituicytoma. A suprasellar mass with low signal on T1 imaging (A and C) and homogeneous enhancement on T1 contrast imaging (B and D) was observed. A tumor was observed above the pituitary gland during the endoscopic trans-tuberculum surgery (E). Hematoxylin and eosin staining shows bipolar spindled cells arranged in a fascicular or storiform pattern (F). The tumor cells show TTF1 and diffuse S-100 immunoreactivity (G and H).

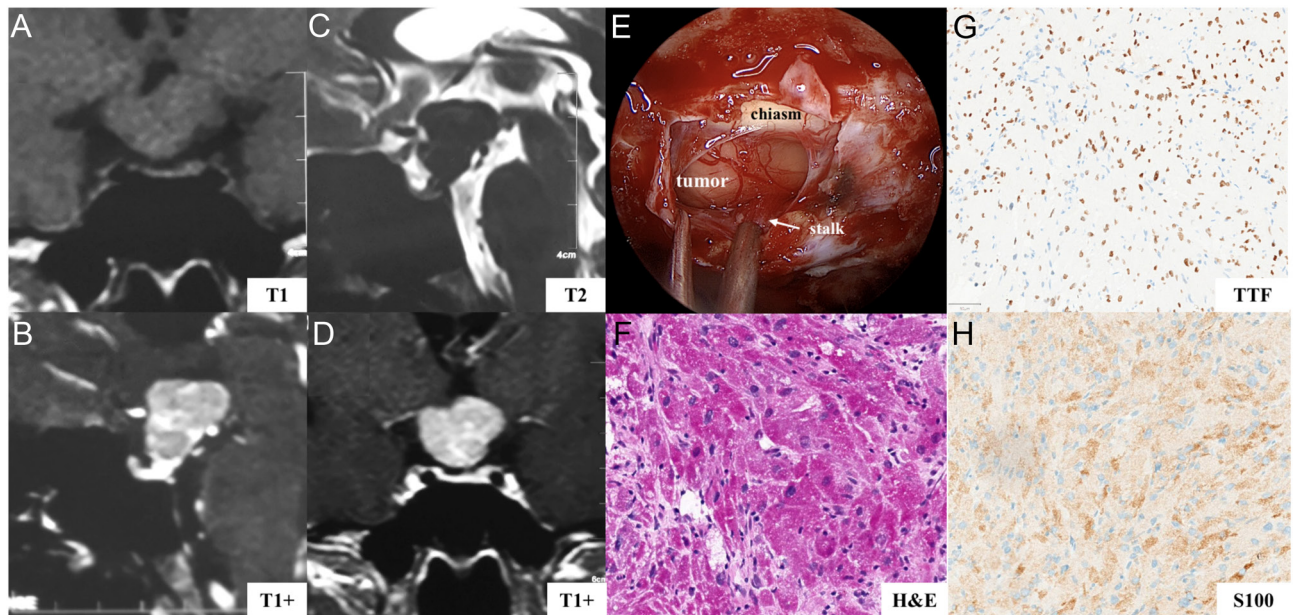
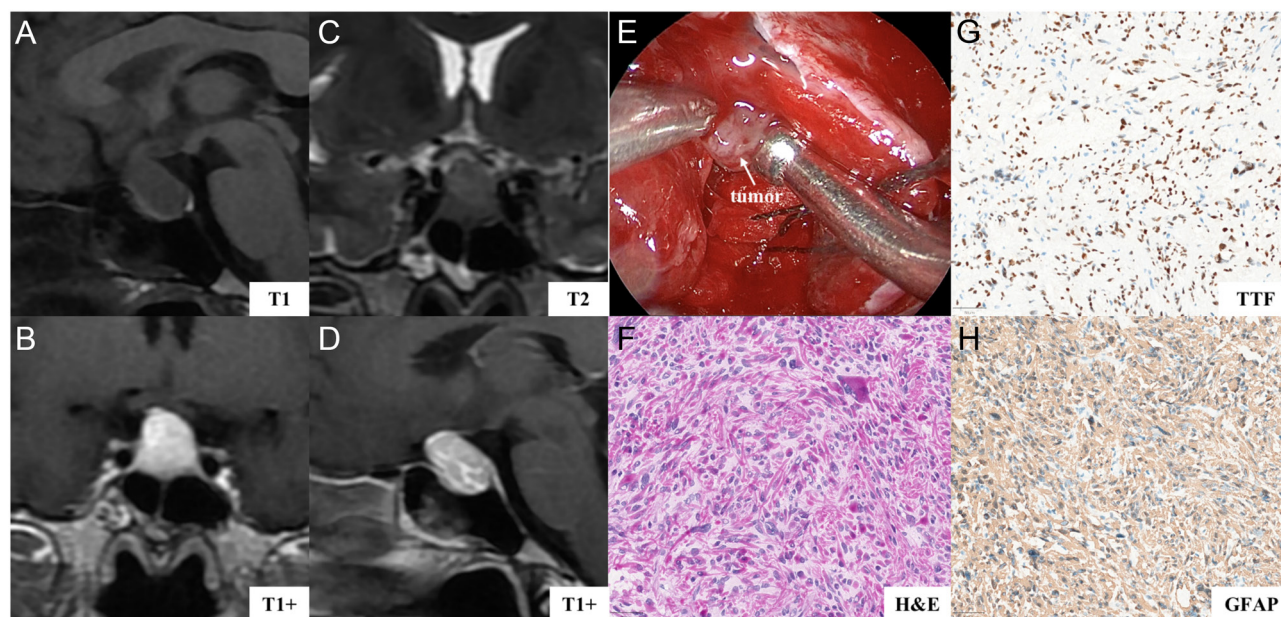


Figure 2

A 36-year-old female patient was diagnosed with a granular cell tumor. The tumor is located in the suprasellar region with iso-signal in both T1 and T2 imaging (A and C). On T1 contrast imaging, the tumor was homogeneously enhanced with striated high signals (B and D). Tumor is located between the optic chiasm and the pituitary gland (E). Densely packed polygonal cells with abundant granular eosinophilic cytoplasm are shown on hematoxylin and eosin staining (F). Similarly, they showed TTF1 and diffuse S-100 immunoreactivity (G and H).

**Figure 3**

A 49-year-old female was diagnosed with spindle cell oncocytoma. The tumor was primarily located within the sellar region with suprasellar invasion (A and C). On T1 contrast imaging, the tumor was homogeneously enhanced with striated high signals (B and D). Tumor was quite vascular during endoscopic resection (E). The tumor was composed of spindle-to-epithelioid cells with variable eosinophilic and oncocytic cytoplasm (F). Tumor cells showing TTF1 and GFAP immunoreactivity (G and H).

encountered in two cases (one SCO and one GCT) in the transcranial group due to tumor residue.

Comparison with craniopharyngiomas

To gain a presumptive diagnosis of PPTs among common suprasellar-type tumors, we compared their clinical symptoms and imaging characteristics with those of suprasellar-type craniopharyngiomas (Table 3). Patients with craniopharyngiomas were younger ($P=0.002$), with a higher proportion of visual defects ($P=0.017$) and surgical history ($P=0.002$). Compared with tumors in the PPT group, in the craniopharyngioma group, tumors were larger, with cystic change and irregular configuration ($P < 0.001$). The preoperative endocrine assessment showed that the two groups had a similar proportion of hypopituitarism.

Discussion

We reported clinical presentation, imaging characteristics, endocrine assessments, and surgical outcomes of the largest cohort of PPTs from a single tertiary center. PPTs were diagnosed in the fourth to the sixth decade, with visual disturbance, headache, or hypopituitarism as the chief complaints. They usually presented with a regular sellar

or suprasellar lesion with homogeneous enhancement on contrast T1 imaging. Though massive hemorrhage was usually encountered during surgical resection, gross total resection was achieved in most of the patients. PCs and GCTs seem to present benign behavior; however, some tumors with SCOs had a high proliferation activity and recurrence probability.

Regarding natural history, our cohort was similar to previously published articles. Roncaroli *et al.* (10) found that the incidence of PPT was 0.4% in another single institution for 9 years. Headache, vision disturbance from the optic pathway compression, and hypopituitarism were the most commonly observed symptoms. However, we did not observe patients with hormone hypersecretion, for example, hypercortisolism, reported in previous studies (11, 12).

PPTs usually appeared as solid and regular-shaped sellar or suprasellar masses. When the tumor was located in the sella, it was similar in appearance to a pituitary adenoma. However, the hyper-enhanced pituitary gland was located anteriorly or inferiorly to the tumor, while in most cases of pituitary adenoma, the gland was usually situated superiorly to the tumor. We observed an anteriorly or inferiorly located pituitary gland in all cases of the intrasellar type, though obscure in six cases. Suprasellar PPTs frequently presented hypo- or iso-signal (multiple hypointense foci

Table 2 Surgical approaches for suprasellar PPTs.

	Endoscopic transsphenoid (n = 14)	Craniotomy (n = 15)	P
Gender (male)	4 (28.6%)	9 (60.0%)	0.139
Age (years)	47.7 (10.4)	52.3 (5.9)	0.149
Visual defect	6 (42.9%)	4 (26.7%)	0.450
Tumor volume (cm ³)	4.0 (1.5, 8.5)	1.7 (0.8, 3.2)	0.149
Homogenous signals	13 (92.9%)	13 (86.7%)	1.000
Pathology			0.132
PCs	12 (85.7%)	8 (53.3%)	
SCOs	0 (0.0%)	2 (13.3%)	
GCTs	2 (14.3%)	5 (33.3%)	
Pre-surgical endocrine assessment			
Hypothyroidism	6 (42.9%)	2 (13.3%)	0.109
Hypocortisolemia	3 (21.4%)	4 (26.7%)	1.000
Hypogonadism	4 (28.5%)	5 (33.3%)	0.228
Diabetes insipidus	4 (28.6%)	1 (6.7%)	0.169
Surgical results			
Gross total resection	11 (78.6%)	10 (66.7%)	0.682
New diabetes insipidus	6 (42.9%)	6 (40.0%)	1.000
New hypopituitarism	7 (50.0%)	5 (33.3%)	0.279
Disastrous residue tumor hemorrhage	0 (0.0%)	2 (13.3%)	0.495

GCTs, granular cell tumors; PCs, pituicytomas; SCOs, spindle cell oncocytomas.

and linear signal void) on T1-weighted imaging and had homogenous enhancement after contrast administration. Previous studies suggested dotted or striated signals among enhancement as indicators of abundant blood supply (13). A hemorrhagic mass has also been reported in patients with SCO; however, in our cohort, none of the SCOs showed hemorrhagic changes (14).

Intraoperative management was more challenging in PPTs, possibly due to abundant vascularity, compared with craniopharyngiomas. Intraoperative hemorrhage usually ranged from 400 to 800 mL, compared with only 200–400 mL in patients with craniopharyngiomas. Preoperative identification might warn surgeons to prepare blood storage. We listed the major points for differentiation from a craniopharyngioma: a small-to-median tumor, regular shape, and no cystic change or calcification.

However, craniopharyngioma is not the only differential diagnosis. Tuberculum sellae meningioma is characterized by a female predominance and a dura tail sign on MRI. Sellar germinoma and sellar glioma are two tumor entities that predominate in young patients. In our database, sellar germinoma was only identified in patients younger than 30 years. Sellar glioma presented with a significantly lower ratio of visual disturbances (14.8%) and a lower ratio of enhancement on contrast-enhanced MRI (10.7%). The most confusing pathology is suprasellar Langerhans cell histiocytosis, which presents with similar

Table 3 Difference between suprasellar-type craniopharyngiomas and posterior pituitary tumors.

	Craniopharyngiomas (n = 29)	Posterior pituitary tumors (n = 29)	P
Gender (male)	19 (65.5%)	13 (44.8%)	0.186
Age (years)	38.8 (16.6)	50.1 (8.6)	0.002
BMI (kg/m ²)	24.7 (4.7)	25.1 (3.6)	0.777
Symptoms			
Headache	9 (31.0%)	11 (37.9%)	0.783
Visual defect	20 (69.0%)	10 (34.5%)	0.017
Symptoms related to hypopituitarism	10 (34.5%)	8 (27.6%)	0.777
Polydipsia and polyuria	4 (13.8%)	5 (17.2%)	1.000
Incidental	1 (3.4%)	4 (13.8%)	0.352
Surgical history	9 (31.0%)	0 (0.0%)	0.002
Hypertension	6 (20.7%)	4 (13.8%)	0.730
Diabetes mellitus	3 (10.3%)	1 (3.4%)	0.611
Imaging features			
Tumor volume (cm ³)	7.8 (5.1, 11.9)	2.3 (1.0, 5.6)	<0.001
Low-iso signal in T1	26 (89.7%)	29 (100.0%)	0.236
Homogenous in T1C	6 (20.7%)	26 (89.7%)	<0.001
Cystic change	22 (75.9%)	0 (0.0%)	<0.001
Regular shape	13 (44.8%)	29 (100.0%)	<0.001
Endocrine features			
Hypothyroidism	6 (20.7%)	8 (27.6%)	0.760
Hypoadrenalism	12 (41.4%)	7 (24.1%)	0.263
Hypogonadism	8 (27.5%)	10 (34.5%)	0.777
Diabetes insipidus	4 (13.8%)	5 (17.2%)	1.000

symptoms; however, we only identified five cases and were not able to perform a valid comparison.

According to the 2021 CNS WHO grading system (2), these lesions were categorized as a single entity. However, our study suggested that SCOs were a different entity compared with other PPTs. These tumors were more likely confined in the sellar region. An increased Ki-67 index and higher probability of recurrence led us to place SCOs in a more aggressive category than other PPTs. Many investigators have supported this notion, given that follow-up reports in the literature showed a higher recurrence rate and re-surgery than expected for SCOs (7, 8, 15, 16). Similarly, in a recently published study, SCOs or PCs with copy number imbalances have been found to have a less favorable outcome (17).

Surgery remains the primary treatment choice for these patients. For tumors located in the suprasellar region, endoscopic transsphenoidal surgery is an alternative surgical approach for these tumors besides the transcranial approach. Endoscopic visualization provides a more panoramic view of the operative field than the microscope, allowing for better viewing of the suprasellar region. Moreover, the transsphenoidal approach offers a direct surgical corridor to suprasellar tumors, better protecting adjacent vesicles or optic chiasm. Unlike endoscopic visualization, the transcranial approach offers a continuous view with a stereotactic display, which is familiar to most surgeons and may allow for better bleeding control in an open field. However, tumors that extend into the third ventricle might not be observed. Because of the high vascularity, gross total resection should be made to a great extent to avoid disastrous postoperative complications. In our experience, the endoscopic approach was superior to the transcranial approach in terms of decreasing postoperative complications.

The indications for postoperative radiation have not been established. In a systematic review of PPTs, patients with persistent or residual PPTs were submitted to postoperative radiation (8). Some patients showed a stable response, whereas others had progression of tumor size after radiotherapy. In our series, only one patient was exposed to radiotherapy due to an enlarged tumor during follow-up. For SCOs, the effectiveness of routine postoperative radiation for residue tumors should be studied, due to their relatively 'aggressive' nature (18, 19, 20).

Our study had several limitations. Multiple surgeons performed surgeries, and surgical results were biased by preference and experience. However, endoscopic surgeries were only adopted in the recent 5 years in our center and are still on the rising learning curve. Furthermore, due

to a relatively slow-growing tumor, long-term follow-up is warranted to decide on clinical management. We did not stain neurofilament protein or vasopressin, which is the ideal marker to avoid confusion between normal neurohypophysis and pituitary tumor. However, though the pathological appearance might be similar, evidence of a tumor on MRI supports the diagnosis of a PC. Finally, we did not quantify or document lymphocytic and macrophagic infiltrates in patients with SCOs, which are common and can affect Ki-67 quantification.

Conclusion

In this study, we found that PPTs should be considered in the differential diagnosis of patients with sellar and suprasellar masses with a regular lesion with homogeneous enhancement. Endoscopic transsphenoidal surgery served as a treatment choice for these tumors, and the surgical results were good. A portion of the SCO tumors in this study had a high proliferation activity and risk of recurrence.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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Ethics approval

This study was approved by the Institutional Review Board.

Consent to participate

Patients were consented before their clinical data were logged into the database.

Consent for publication

All the authors agreed this publication.

Availability of data and material

De-identified data would be available upon request.

Code availability

All statistical analyses were completed by R software version 3.4.2, and code would be available upon request.

Author contribution statement

N Q and H C did the analysis and wrote the first draft of the manuscript. H C and X Z collected the data. Z Z and H Y provided endocrinological consultation of the study. M S, X S, and X C provided neurosurgical consultation of the study. Y Z and Y W revised the draft, and the final version was approved by all listed authors.

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