Endoscopic endonasal transsphenoidal approach for craniopharyngioma: Case series

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Abstract. Thanks to the rapid development and progress of endoscopic technology, the endoscopic endonasal transsphenoidal approach has become one of the best surgical methods for resection of sellar and suprasellar tumors. The craniopharyngioma is usually located in the sellar region or suprasellar region, which is suitable for resection through the endoscopic endonasal transsphenoidal approach. The present report describes 21 cases of craniopharyngioma treated by endoscopic endonasal transsphenoidal approach in the Department of Neurosurgery at the Chongqing General Hospital from February 2014 to September 2019. The characteristics of patients and tumors, including clinical symptoms, preoperative magnetic resonance imaging, intraoperative conditions, as well as postoperative and follow-up outcomes were evaluated. The main clinical symptoms were headache in 15 cases, visual deficiency in 13 cases and growth retardation in two cases. All 21 patients with craniopharyngioma underwent endoscopic endonasal transsphenoidal surgery. Of these, 20 patients achieved gross total resection and one case achieved subtotal resection. After surgery, headache symptoms improved in 11 patients without deterioration and the vision of 11 patients improved without deterioration. The primary postoperative complications were pituitary deficiency in eight cases and permanent diabetes insipidus in five cases. The patients were followed up from one to 52 months post-operation. There was no recurrence in all patients during the follow-up period. The endoscopic endonasal transsphenoidal approach is a safe and effective resection for craniopharyngioma. Moreover, the endoscopic endonasal trans-sphenoidal approach is one of the preferred surgical methods for treatment of sellar or suprasellar tumor.

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Abbreviations: ACTH, adrenergic assay; COR, plasma cortisol; DI, diabetes insipidus; E2, blood estradiol; EETA, endoscopic endonasal transsphenoidal approach; FT3, free triiodothyronine; FSH, follicle-stimulating hormone; GH, growth hormone; GTR, gross total resection; LH, luteinizing hormone; NEU, neutrophil; PRL, prolactin; STR, subtotal resection; T, testosterone; TA, transcranial approach; TSH, thyroid-stimulating hormone; WBC, white blood cell

Key words: craniopharyngioma, surgery, endoscopic endonasal transsphenoidal approach, clinical outcomes, case report

Introduction

Due to the rapid development and progress of endoscopic technology, the endoscopic endonasal transsphenoidal approach (EETA) is widely used for the resection of sellar and suprasellar tumors, such as pituitary adenoma, hypothalamic glioma and meningioma (1-3). Of these, craniopharyngioma is a rare benign tumor, which originates from the sellar or suprasellar region and grows from Rathke's pouch remnants of the craniopharyngeal duct (4). Craniopharyngioma occurs at a rate of ~1.3 per million person-years and is similar in males and females (5). In addition, craniopharyngioma shows a bimodal age distribution, in which the onset peak age is 5-14 years in children and 50-74 years in older adults (5). Due to the space-occupying effect, common clinical symptoms include headaches, visual and pituitary deficiency and growth retardation (6). Craniopharyngioma is classified according to histopathology, tumor location or the association between the tumor and the infundibulum (7). Based on histopathology, craniopharyngioma is divided into adamantinomatous and the papillary subtype (8). The papillary subtype is primarily found only in adults, while the adamantinomatous subtype is mainly found in children (8). According to tumor location, craniopharyngioma is divided into intrasellar, suprasellar and intra- and supra-sellar type, with distribution probability of ~5, 20 and 75%, respectively (9). Furthermore, according to the association between tumor and infundibulum, Kassam *et al* (10) proposed the following anatomical classification system for craniopharyngiomas: Type I, preinfundibular; II, transinfundibular; III, retroinfundibular; IIIa, retroinfundibular/third ventricular; IIIb, retroinfundibular/interpeduncular cistern and IV, purely third ventricular. Generally, EETA is not recommended for type IV patients because the bottom of the third ventricle between the tumor and sellar region is intact. Except for type IV, other types of craniopharyngiomas can be resected by EETA. In addition, craniopharyngioma with transverse extension cannot be seen under a nasal endoscope or directly so is also not suitable for EETA. Since craniopharyngiomas

are usually close to key neurovascular structures, such as the hypothalamus, pituitary gland, optic nerve or chiasma and circle of Willis, EETA surgery for craniopharyngiomas represents a challenge. Moreover, postoperative complications, including pituitary and visual deficiency, cerebrospinal fluid (CSF) leakage, electrolyte disorder and diabetes insipidus, increase the requirements for surgical experience and skills. The present case report describes 21 patients with craniopharyngioma treated by EETA, including preoperative patient and tumor characteristics, classification, postoperative outcomes and complications and follow-up.

Patients and methods

Patients and evaluation. This study was approved by the Ethics Committee of Chongqing General Hospital (Chongqing, China) (approval No. KY S2022-058-01), and all patients signed a written informed consent form. The present study reports 21 cases of patients with craniopharyngioma treated by EETA in the Department of Neurosurgery at the Chongqing General Hospital from February 2014 to September 2019. There were 14 male and 7 female patients, aged 7 to 61 years old. The specific conditions for exclusion were as follows: Coagulation dysfunction; the patient was in poor physical condition; the patient was unwilling to receive operation. All patients received preoperative and postoperative comprehensive examination, including endocrine examination, vision and brain magnetic resonance imaging (MRI). The endocrine examination included thyroid, gonadal, growth and adrenocorticotropic hormone. The visual acuity (VA) and visual field (VF) of each eye were measured by a neuro-ophthalmologist. Based on preoperative and postoperative status, VA and VF were divided into improvement, maintenance or deterioration. According to preoperative MRI, tumors were classified as cystic, solid or mixed and intrasellar, suprasellar or intra- and supra-sellar. Moreover, the level of the tumor was determined according to Kassam's classification (10). Based on intraoperative findings and postoperative MRI, the extent of resection for the tumor was determined. Postoperative histopathology of all patients was performed. At 4˚C, the tumor was fixed by 4% paraformaldehyde for 24 h and the section thickness was 4 μm. Then, at 26˚C, the sample sections were stained with hematoxylin for ~15 min) and eosin (for 1-3 min). Finally, these samples were observed under the light microscope. Postoperative histopathology identified craniopharyngioma as adamantinoma or papilloma. The preoperative clinical symptoms, postoperative outcomes and complications and follow-up were also recorded.

Surgical procedure. All operations were performed through EETA. Following successful general anesthesia, the patient was placed supine and the head was tilted slightly to the right. Subsequently, an endoscope was placed along the right nasal canal and the sphenoid was cut to expose the anterior wall and floor of the sellar. The dura was widely cut to expose the pituitary gland and allow transposition as needed for access to the tumor. Depending on the texture and location of the tumor, the specific surgical strategy was different. For cystic craniopharyngioma, intracapsular decompression and deflation were performed, then the capsule wall was separated from the neurovascular structure by blunt/sharp dissection and aspiration. For solid craniopharyngioma, the solid tumor was resected and aspirated in blocks, then the capsule wall was resected. For mixed craniopharyngioma, a combination of cystic and solid craniopharyngioma techniques was used. Intracapsular decompression and deflation were performed first, then the solid tumor was resected and aspirated in blocks, and finally the capsule wall was resected. For intrasellar craniopharyngioma, the surgical strategy was to locate the boundary between the tumor and the pituitary gland, then separate the tumor. For suprasellar and intra- and supra-sellar craniopharyngioma, the surgical strategy was to locate the boundary between the tumor and the optic chiasma, pituitary stalk or internal carotid artery and its branches, then separate the tumor. In conclusion, the principle of surgical resection was to decompress the capsule, then remove the solid tumor in blocks, find the boundary between the tumor and normal structure to separate the tumor sharply along the boundary, remove the tumor capsule and complete the craniopharyngioma resection. During the operation, key landmarks to expose were the lateral opticocarotid recess laterally, the planum sphenoidale superiorly and the floor of the sphenoid and the clival recess inferiorly. Closure was achieved by a vascularized nasal septal mucosal flap, gelatin sponge and artificial dura mater (Video S1).

Statistical analysis. Microsoft Excel (Microsoft Corporation, version 2019) was used for data collection and sorting. The details of the patients were summarized, including sex, age, clinical symptoms, radiological and endocrine examination, location of craniopharyngioma, cystic or solid craniopharyngioma, improvement of postoperative clinical symptoms, postoperative complications, follow-up and recurrence rate. SPSS version 25.0 software (IBM Corp.) was used for statistical analysis. When comparing ≥3 independent groups of samples conforming to the normal distribution, one-way analysis of variance test was used. The categorical variables were assessed for statistical significance by Fisher's exact test. $P<0.05$ was considered to indicate a statistically significant difference.

Results

Preoperative characteristics. The preoperative characteristics of 21 patients are shown in Table I. According to the location of craniopharyngioma, there were nine cases in the intrasellar region, nine in the suprasellar region and three in the intra- and supra-sellar region. According to Kassam's classification, there were four cases of type I, 10 cases of type II and seven cases of type III. For intrasellar, there were four cases of type I, four cases of type II and one case of type III. For suprasellar, there were five cases of type II and four cases of type III. For intra- and supra-sellar, there were one case of type II and two cases of type III. The patient age ranged from 7-61 years, with a mean age of 31 years. For the intrasellar, suprasellar as well as intra- and supra-sellar region, the patient age range and mean age were 7-59 and 29, 9-61 and 36 and 16-29 and 21 years, respectively. There were 14 males and seven females, including seven males and two females in the intrasellar group, five males and four females in the suprasellar group and two males

Table I. Preoperative characteristics of 21 patients.

Characteristic	Intrasellar	Suprasellar	Intra- and supra-sellar	P-value
Cases	9	9	3	
Mean age, years	28.56±15.84	36.22±16.28	20.67±7.23	0.29
Sex, n (%)				0.82
Male	7 (77.78)	5 (55.56)	2 (66.67)	
Female	2 (22.22)	4 (44.44%)	1 (33.33)	
Tumor classification, n (%)				0.56
Cystic	1 (11.11)	3 (33.33)	1 (33.33)	
Solid	4 (44.44)	1 (11.11)	1 (33.33)	
Mix	4 (44.44)	5 (55.56)	1 (33.33)	
Kassam type, n (%)				0.07
I	4 (44.44)	0 (0.00)	0 (0.00)	
II	4 (44.44)	5 (55.56)	1 (33.33)	
III	1 (11.11)	4 (44.44)	2 (66.67)	
Clinical symptoms, n (%)				
Headache				1.00
No	2 (22.22)	3 (33.33)	1 (33.33)	
Yes	7 (77.78)	6 (66.67)	2 (66.67)	
Visual acuity				0.60
No	5 (55.56)	3 (33.33)	2 (66.67)	
Yes	4 (44.44)	6 (66.67)	1 (33.33)	
Visual field				0.17
No	9 (100.00)	6 (66.67)	3 (100.00)	
Yes	0 (0.00)	3 (33.33)	0 (0.00)	
Growth retardation				0.27
No	8 (88.89)	9 (100.00)	2 (66.67)	
Yes	1 (11.11)	0 (0.00)	1 (33.33)	
Preoperative pituitary deficiency, n (%)				
Thyroid hormone				0.24
No	3 (33.33)	5 (55.56)	0 (0.00)	
Yes	6 (66.67)	4 (44.44)	3 (100.00)	
Gonadal hormone				0.04
No	1 (11.11)	6 (66.67)	0 (0.00)	
Yes	8 (88.89)	3 (33.33)	3 (100.00)	
Growth hormone				1.00
No	7 (77.78)	7 (77.78)	2 (66.67)	
Yes	2 (22.22)	2 (22.22)	1 (33.33)	
Adrenocorticotropic hormone				1.00
No	7 (77.78)	8 (88.89)	3 (100.00)	
Yes	2 (22.22)	1 (11.11)	0 (0.00)	

and one female in the intra- and supra-sellar group. Moreover, 18 patients were adults while three were children. The primary clinical symptoms were headache and visual deficiency. There were 15 patients with headaches, including seven cases in the sellar region, six in the suprasellar region, and two in the intra- and supra-sellar region. The proportion of headache was 71.4%. Meanwhile, 13 patients had a visual deficiency, including four cases in the intrasellar region, eight in the suprasellar region and one in the intra- and supra-sellar region. The proportion of visual deficiency was 61.9%. Specifically, 10 cases exhibited poor VA, two cases suffered from poor VF and one case suffered both. In addition, two patients (one case in the intrasellar region, one case in the intra- and supra-sellar region) had growth retardation. The preoperative hormone examination indicated that 17 patients showed a pituitary deficiency, including 13 cases (61.9%) with abnormal thyroid, 14 cases (66.7%) with abnormal gonadal, five cases (23.8%) with abnormal growth and three cases (14.2%) with abnormal

adrenocorticotropic hormone. Of these, three patients (14.2%) had hypopituitarism in thyroid hormone, gonadal hormone, growth hormone and adrenocorticotropic hormone, which was considered as panhypopituiarism. Preoperative MRI images showed cystic, solid and mixed craniopharyngioma in five, six and 10 cases, respectively. According to preoperative MRI, the maximum diameter of craniopharyngioma was 2.0-5.0 cm, with a mean diameter of ~3.2 cm. The mean body mass index (BMI) of 18 adults was ~22.66 kg/m^2 with a range of 16.65-28.81 kg/m^2 (data not shown). In some cases of intra- and supra-sellar type, the tumor extended to the hypothalamus and third ventricle, anteriorly to the anterior skull base and protruded into the interpedullary cistern posteriorly. For example, in case no. 3, the upper part of the tumor compressed the third ventricle and hypothalamus and the posterior part of the tumor protruded into the interpedullary cistern. Except for gonadal hormone deficiency, there was no significant statistical differences between intrasellar, suprasellar, intra- and supra-sellar region (Table I).

Surgical outcomes and complications. Surgical outcomes and postoperative complications are shown in Table II. At three days after the operation, MRI reexamination was performed on all the patients. By comparing the preoperative and postoperative MRI combined with the intraoperative situation, the extent of tumor resection was determined, including 20 cases of gross total resection (GTR) and one case of subtotal resection (STR). The GTR rate of the tumor was 95.2%, which is one of the important factors to reduce the recurrence rate of craniopharyngioma.. Following surgery, the headache was improved in nine (42.9%) and maintained in four patients (19.0%), while the visual symptoms improved in eight (38.1%) and maintained in two patients (9.5%; Table II). VA was improved in eight and maintained in two patients, while VF was improved in three patients. In addition, growth retardation symptoms were maintained in two patients. Postoperative clinical symptoms of all patients did not deteriorate. After the operation, all patients underwent a comprehensive endocrine examination, including thyroid, gonadal, growth and adrenocorticotropic hormone. The short-term postoperative pituitary function evaluation showed 19 cases of abnormal thyroid, 14 cases of abnormal gonadal, five cases of abnormal growth and 13 cases of abnormal adrenocorticotropic hormone. After 3-6 months, thyroid hormone in 11 cases, gonadal hormone in eight cases, growth hormone (GH) in four cases and adrenocorticotropic hormone in eight cases reached normal values (6). Considering all the hormone gland axes, the number of cases with normal pituitary function, partial pituitary hypofunction and panhypopituitarism was 13, seven and one, respectively, of which eight patients with pituitary hypofunction needed hormone supplements. Some patients experienced postoperative complications, such as transient diabetes insipidus (DI) in 12 cases, CSF leakage in one case, infection in two cases and seizures in two cases. Specifically, CSF leakage was low-flow leakage (11) and infection was caused by bacteria). For postoperative complications, such as DI, CSF leakage, infection and seizures, desmopressin, surgical repair, antibiotics and phenobarbital were used as treatment methods, respectively. Following treatment, all the patients with CSF leakage, infection, or seizures were cured, while seven of the 12 cases with transient DI were cured and five patients developed permanent DI. Among these patients with permanent DI, four cases were type II and one case was type III. In addition, two patients had postoperative hypothalamic obesity. One patient's BMI increased from 25.1 (preoperative) to 37.4 kg/m^2 (~4 years after surgery) and the other patient's BMI increased from 27.4 (preoperative) to 36.6 kg/m^2 (~3 years after surgery). Moreover, there was no perforation of the nasal septum, epistaxis, hyposmia or anosmia. The patients were followed up for 1-52 months, with a mean follow-up of eight months. Tumor recurrence was defined as the appearance of new pathological tissue or growth of tumor residue on MRI and there was no recurrence in all patients during follow-up. Except for transient gonadal hormone deficiency and DI, there was no significant difference between intrasellar, suprasellar and intra-and supra-sellar regions (Table II). Postoperative pathological examination was performed for all cases, which showed that four cases were adamantinomaous and 17 cases were papillary subtype (Table III).

Case illustrations. A total of three representative cases are presented, of which the tumor of case no. 1 was located in the sellar region, the tumor of case no. 2 was located in the suprasellar region, and the tumor of case no. 3 invaded the third ventricle.

Case no. 1. In March 2018, a 39-year-old man presented as Chongqing General Hospital due to recurrent headaches and visual deficiency. Preoperative endocrine examination showed that the levels of GH, blood estradiol (E2), Blood progesterone (P) and testosterone (T) were decreased [0.08 ng/ml (range, 0.55-4.74 ng/ml), 10.00 pg/ml (range, 20.00-75.00 pg/ml), 0.04 ng/ml (range, 0.10-0.84 ng/ml) and 0.48 ng/ml (range, 1.75-7.81 ng/ml), respectively] (6). Preoperative cranial MRI showed cystic-solid mixture space-occupying lesions in the sellar region and compression and displacement of the optic chiasm (Fig. 1A and B). The patient underwent EETA resection for the tumor; intraoperative endoscopic images are shown in Fig. 1E-H. The tumor was exposed after opening the sellar base and anterior skull base (Fig. 1E). Fig. 1F shows the separation of tumor from the surrounding tissue. Fig. 1G shows the nipple after removing the capsule wall. Fig. 1H shows that the tumor had been removed. Postoperative pathological results confirmed the tumor as craniopharyngioma (Table III). On the second day after the operation, comprehensive endocrine examination was performed; levels of GH, plasma cortisol (COR), triiodothyronine (T3), free (F)T3, thyroid-stimulating hormone (TSH), adrenergic assay (ACTH), E2, blood follicle-stimulating hormone (FSH), luteinizing hormone (LH) and prolactin (PRL) and T decreased [0.26 ng/ml (range, 0.55-4.74 ng/ml), 74.37 nmol/l (range, 181.83-716.30 nmol/l), 1.14 nmol/l (range, 1.30-3.10 nmol/l), 2.93 pmol/l (range, 3.10-6.80 pmol/l), 0.04 μIU/ml (range, 0.27-4.20 μIU/ml), 2.01 pg/ml (range, 5.00-60.00 pg/ml), 2.00 pg/ml (range, 20.00-75.00 pg/ml), 0.68 mIU/ml (range, 1.27-19.26 mIU/ml), 0.08 mIU/ml (range, 1.24-8.62 mIU/ml), 1.15 ng/ml (2.64-13.13 ng/ml) and 0.02 ng/ml (range, 1.75-7.81 ng/ml), respectively] (6). Therefore, hydrocortisone (20 mg, bid) and levothyroxine (50 mg, qd) were supplemented for symptomatic treatment. Postoperative MRI showed that the tumor was grossly resected

Table II. Surgical outcome and complications of 21 patients.

Characteristic	Intrasellar	Suprasellar	Intra- and supra-sellar	P-value
Extent of resection, n (%)				1.00
Gross total	9 (100.00)	8 (88.89)	3 (100.00)	
Subtotal	0 (0.00)	1 (11.11)	0 (0.00)	
Clinical symptom outcome, n (%)				
Headache (improved)				1.00
No	5 (55.56)	5 (55.56)	2 (66.67)	
Yes	4 (44.44)	4 (44.44)	1 (33.33)	
Headache (maintained)				0.78
No	8 (88.89)	7 (77.78)	2 (66.67)	
Yes	1 (11.11)	2 (22.22)	1 (33.33)	
Visual acuity (improved)				0.51
No	7 (77.78)	4 (44.44)	2 (66.67)	
Yes	2 (22.22)	5 (55.56)	1 (33.33)	
Visual acuity (maintained)				1.00
No	8 (88.89)	9 (100.00)	3 (100.00)	
Yes	1 (11.11)	0 (0.00)	0 (0.00)	
Visual field (improved)				0.17
No	9 (100.00)	6 (66.67)	3 (100.00)	
Yes	0 (0.00)	3 (33.33)	0 (0.00)	
Visual field (maintained)				0.14
No	9 (100.00)	9 (100.00)	2 (66.67)	
Yes	0 (0.00)	0 (0.00)	1 (33.33)	
Growth retardation (improved)				-
No	9 (100.00)	9 (100.00)	3 (100.00)	
Growth retardation (maintained)				0.27
No	8 (88.89)	9 (100.00)	2 (66.67)	
Yes	1 (11.11)	0 (0.00)	1 (33.33)	
Postoperative complication, n (%)				
Cerebrospinal fluid leak (short-term)				1.00
No	8 (88.89)	9 (100.00)	3 (100.00)	
Yes	1 (11.11)	0 (0.00)	0 (0.00)	
Cerebrospinal fluid leak (long-term)				-
No	9 (100.00)	9 (100.00)	3 (100.00)	
Seizure (short-term)				0.27
No	9 (100.00)	8 (88.89)	2 (66.67)	
Yes	0 (0.00)	1 (11.11)	1 (33.33)	
Seizure (long-term)				-
No	9 (100.00)	9 (100.00)	3 (100.00)	
Infection (short-term)				1.00
No	8 (88.89)	8 (88.89)	3 (100.00)	
Yes	1 (11.11)	1 (11.11)	0 (0.00)	
Infection (long-term)				-
No	9 (100.00)	9 (100.00)	3 (100.00)	
Diabetes insipidus (short-term)				<0.001
No	8 (88.89)	1 (11.11)	0 (0.00)	
Yes	1 (11.11)	8 (88.89)	3 (100.00)	
Diabetes insipidus (long-term)				0.08
No	9 (100.00)	5 (55.56)	2 (66.67)	
Yes	0 (0.00)	4 (44.44)	1 (33.33)	
Preoperative pituitary deficiency, n (%)				
Thyroid hormone (short-term)				1.00
No	1 (11.11)	1 (11.11)	0 (0.00)	
Yes	8 (88.89)	8 (88.89)	3 (100.00)	

Table II. Continued.

Characteristic	Intrasellar	Suprasellar	Intra- and supra-sellar	P-value
Gonadal hormone (short-term)				0.04
No	1 (11.11)	6 (66.67)	0 (0.00)	
Yes	8 (88.89)	3 (33.33)	3 (100.00)	
Growth hormone (short-term)				0.18
No	7 (77.78)	8 (88.89)	1 (33.33)	
Yes	2 (22.22)	1 (11.11)	2 (66.67)	
Adrenocorticotropic hormone (short-term)				0.51
No	2 (22.22)	5 (55.56)	1 (33.33)	
Yes	7 (77.78)	4 (44.44)	2 (66.67)	
Thyroid hormone (long-term)				1.00
No	6 (66.67)	5 (55.56)	2 (66.67)	
Yes	3 (33.33)	4 (44.44)	1 (33.33)	
Gonadal hormone (long-term)				0.17
No	6 (66.67)	8 (88.89)	1 (33.33)	
Yes	3 (33.33)	1 (11.11)	2 (66.67)	
Growth hormone (long-term)				1.00
No	8 (88.89)	9 (100.00)	3 (100.00)	
Yes	1 (11.11)	0 (0.00)	0 (0.00)	
Adrenocorticotropic hormone (long-term), n (%)				0.51
No	6 (66.67)	8 (88.89)	2 (66.67)	
Yes	3 (33.33)	1 (11.11)	1 (33.33)	

Short-term, within three days of the operation; long-term, at time of final examination.

Table III. Postoperative histopathology of 21 patients.

Case no.	Age, years	Sex	Tumor location	Classification	Pathological type
1	25	Male	Intrasellar	Solid	Papillary
2	10	Female	Intrasellar	Cystic	Adamantinomatous
3	7	Male	Intrasellar	Solid	Adamantinomatous
4	21	Female	Suprasellar	Solid	Papillary
5	41	Male	Suprasellar	Cystic	Papillary
6	59	Male	Intrasellar	Mix	Papillary
7	29	Female	Suprasellar	Cystic	Papillary
8	29	Male	Intra- and supra-sellar	Mix	Papillary
9	61	Male	Suprasellar	Mix	Papillary
10	17	Male	Intra- and supra-sellar	Cystic	Adamantinomatous
11	30	Male	Intrasellar	Mix	Papillary
12	25	Female	Suprasellar	Mix	Papillary
13	9	Male	Suprasellar	Mix	Adamantinomatous
14	16	Female	Intra- and supra-sellar	Solid	Papillary
15	20	Male	Intrasellar	Mix	Papillary
16	48	Male	Suprasellar	Mix	Papillary
17	39	Male	Intrasellar	Solid	Papillary
18	47	Female	Suprasellar	Cystic	Papillary
19	37	Female	Intrasellar	Mix	Papillary
20	30	Male	Intrasellar	Solid	Papillary
21	45	Male	Suprasellar	Mix	Papillary

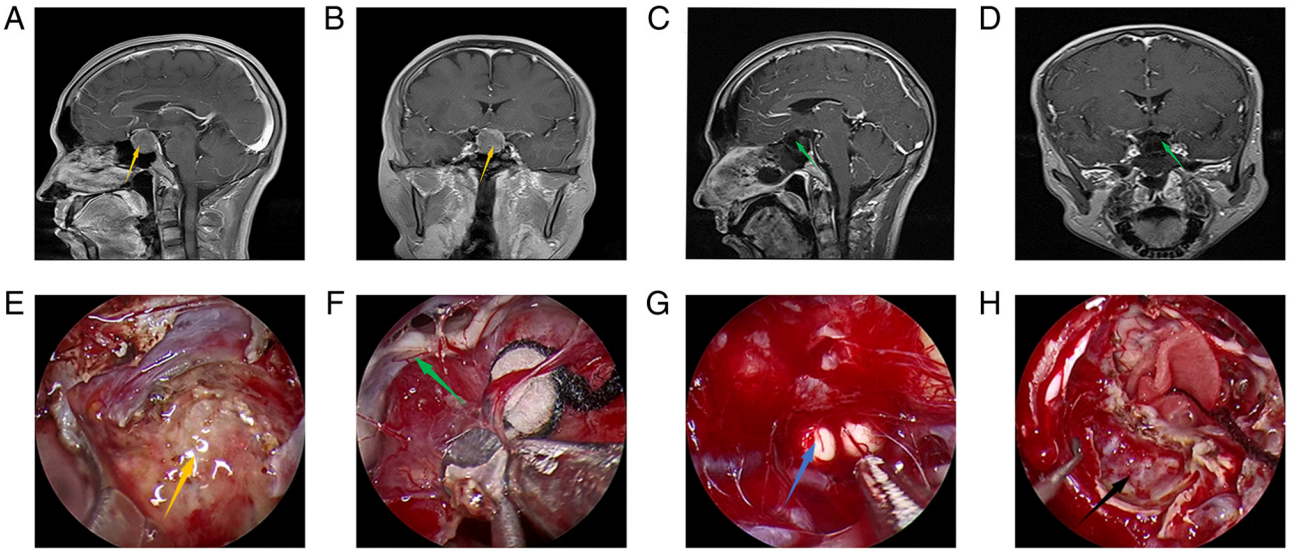

Figure 1. Case illustration of patient 1. Preoperative (A) sagittal and (B) coronal MRI. Yellow arrow indicates preoperative tumor. Postoperative (C) sagittal and (D) coronal MRI. Green arrow vacancy after tumor resection. Intraoperative images. (E) Exposure and (F) separate the tumor from the surrounding tissue. Removal of (G) capsule wall and (H) tumor. Yellow, green, blue and black arrows indicate tumor, optic chiasma, nipple and tumor resection, respectively. MRI, magnetic resonance imaging.

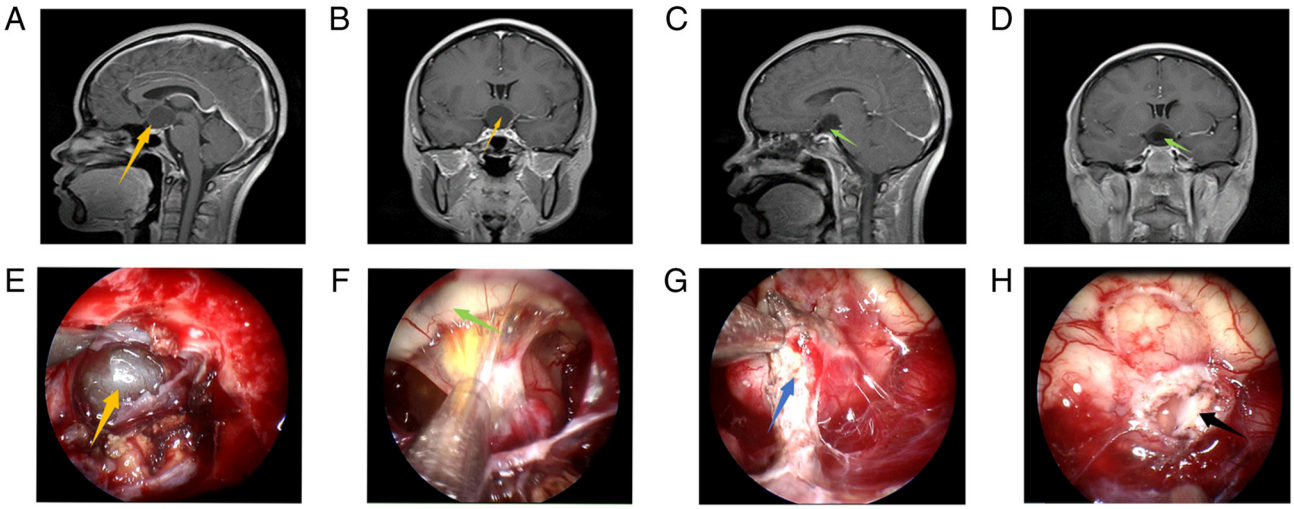

Figure 2. Case illustration of patient 2. Preoperative (A) sagittal and (B) coronal MRI. Yellow arrow indicates preoperative tumor. Postoperative (C) sagittal and (D) coronal MRI. Green arrow vacancy after tumor resection. Intraoperative images. (E) Exposure and (F) separate the tumor from the surrounding tissue. (G) Tumor originated from the pituitary stalk. (H) Removal ofr the tumor. Yellow, green, blue and black arrows indicate tumor, optic chiasma, nipple and tumor resection, respectively. MRI, magnetic resonance imaging.

(Fig. 1C and D). On the eighth day after surgery, the patient had a fever. A blood examination showed that the white blood cell count (WBC) was $11.21x10^9$/l and neutrophil (NEU)% was 60.1%, which indicated that there was an ongoing infection. Serum electrolyte assessment showed that the potassium ion (K^+) concentration was 3.02 mmol/l (range, 3.50-5.50 mmol/l) and sodium ion (Na^+) concentration was 134.30 mmol/l (range, 135.00-155.00 mmol/l) (10). Therefore, vancomycin (2 g, bid), potassium chloride (10 ml, qd) and sodium chloride (500 ml, qd) were used for symptomatic treatment. At 20 days after surgery, the patient suffered CSF leakage, which was repaired surgically and supplemented by continuous drainage of the lumbar cistern. At three months after surgery, cranial MRI was reexamined, showing that most of tumor was resected and had no recurrence. In addition, endocrine examination showed COR 62.19 nmol/l, ACTH 1.00 pg/ml and TSH 0.005 μIU/ml. At 18 months after the operation, a cranial MRI showed no recurrence of the tumor and an endocrine examination showed there was still pituitary deficiency.

Case no. 2. In December 2015, a 29-year-old female patient presented with a recurrent headache. Preoperative cranial MRI showed a cystic space-occupying lesion in the supra-sellar region (Fig. 2A and B). However, no evident endocrine disorder was found in the preoperative endocrine examination. The patient underwent EETA resection (Fig. 2E-H). Firstly, the suprasellar tumor was exposed (Fig. 2E). The tumor was separated from the optic chiasma (Fig. 2F) and it

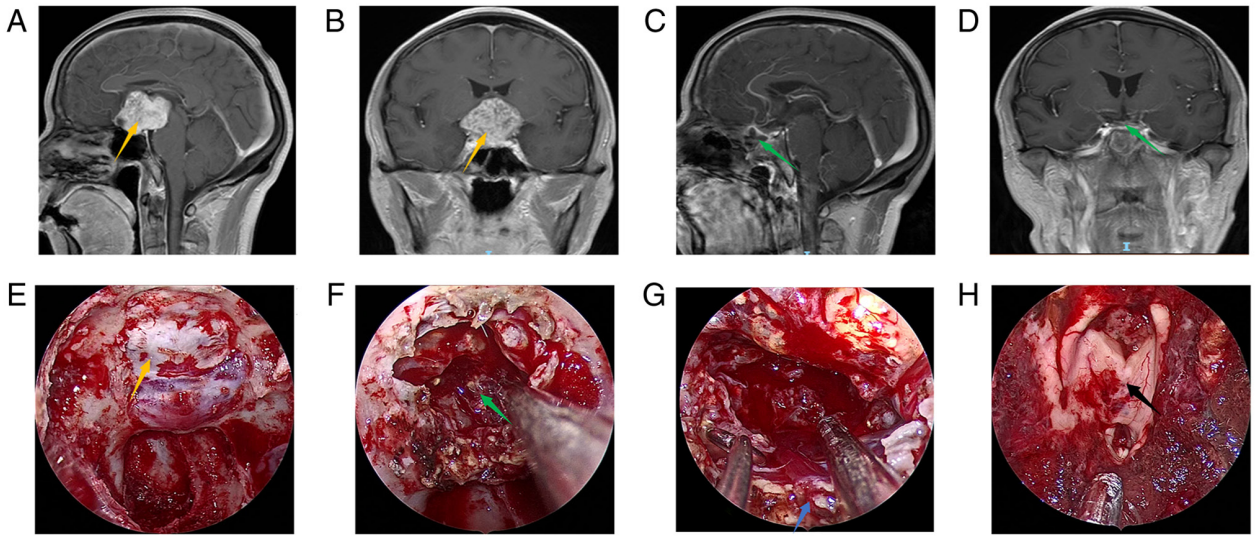

Figure 3. Case illustration of patient 3. Preoperative (A) sagittal and (B) coronal MRI. Yellow arrow indicates preoperative tumor. Postoperative (C) sagittal and (D) coronal MRI. Green arrow vacancy after tumor resection. Intraoperative images. Exposure of (E) dura mater, (F) tumor and (G) pituitary stalk. (H) Removal of the tumor. Yellow, green, blue and black arrows indicate dura mater, tumor, pituitary stalk and bottom of the third ventricle respectively. MRI, magnetic resonance imaging.

was established that the tumor originated from the pituitary stalk (Fig. 2G). Finally, the tumor was removed (Fig. 2H) and the postoperative pathological characteristics suggested craniopharyngioma. On the first day after surgery, the patient had a fever and was treated with antibiotics [meropenem (2 g, tid), vancomycin (2 g, bid)] and cooling. However, on the second day after the operation, the patient still had a fever and transient DI. Blood examination showed a WBC of $10.13x10^9$/l, NEU of $9.42x10^9$/l and NEU% of 93.0%, which indicated ongoing infection. Endocrine examination showed that T was 0.05 ng/ml, T3 was 1.00 nmol/l, FT3 was 2.92 pmol/l and ACTH was 1.00 pg/ml, which suggested pituitary function deficiency. Subsequently, meropenem (2 g, tid) and vancomycin (2 g, bid), cooling, desmopressin acetate (0.2 mg, tid), hydrocortisone (20 mg, bid) and levothyroxine (50 mg, qd) were used for symptomatic treatment. The postoperative cranial MRI indicated no secondary intracranial hemorrhage and the tumor was grossly resected (Fig. 2C and D). However, 12 days after operation, the patient refused treatment and condition deteriorated. At 16 days after operation, the patient fell into a coma. Finally, the patient's family gave up treatment of the patient and the patient was discharged.

Case no. 3. In July 2016, a 58-year-old man presented at Chongqing General Hospital due to recurrent headaches and visual deficiency. Preoperative endocrine examination showed that the levels of ACTH, LH and FT3 were low (3.70 pg/ml, 0.27 mIu/ml and 3.25 pmol/l, respectively). The levels of T, FSH, and T3 were 2.02 ng/ml ,3.04 mIu/ml, and 0.97 nmol/l, respectively, which were in the normal range. Preoperative cranial MRI showed cystic space-occupying lesions in the sellar region with surrounding structure compression (Fig. 3A and B). The patient underwent EETA resection for the tumor (Fig. 3E-H). Fig. 3E shows the dura mater of the exposed sellar floor. Fig. 3F shows decompression in the tumor capsule. Fig. 3G shows that the pituitary stalk was located at the posterior edge of the tumor. Fig. 3H shows that the tumor had been removed. The postoperative pathological results confirmed that the tumor was craniopharyngioma. On the third day after the operation, comprehensive endocrine examination was performed; levels of ACTH, LH, FSH, T, FT3 and T3 decreased (1.00 pg/ml, 0.08 mIu/ml, 0.21 mIu/ml, 0.01 ng/ml, 2.39 pmol/l and 0.36 nmol/l, respectively). Therefore, hydrocortisone (20 mg, bid)and levothyroxine (50 mg, qd) were supplemented for symptomatic treatment. On the fifth day after surgery, the patient exhibited transient electrolyte disorder; serum electrolyte analysis showed K^+ was 3.28 mmol/l and Na^+ concentration was 134.10 mmol/l. Therefore, correcting electrolyte disorder therapy [potassium chloride (12 ml, qd) and sodium chloride (500 ml, qd)] was used for symptomatic treatment. At the time of discharge from the Chongqing General Hospital, the patient's headache was relieved and visual symptoms improved. At 6 months after surgery, cranial MRI (Fig. 3C and D) showed that the tumor had been grossly resected and there was no recurrence. In addition, endocrine examination showed that ACTH was 1.00 pg/ml, FSH was 0.55 μIU/ml and LH was 0.20 mIu/ml and there was still pituitary deficiency.

Discussion

Craniopharyngioma is a rare histologically benign tumor and is usually located in the sellar or suprasellar region, which makes both the transcranial approach (TA) and EETA feasible surgical methods (12). Hence, comparing the outcomes of these two surgical approaches, including GTR rate, improvement of clinical symptoms, postoperative pituitary function and complications and recurrence, is a meaningful topic. Table IV shows the comparison of surgical outcomes between TA and EETA for craniopharyngioma. In 2012, Komotar *et al* (13) reported that GTR, visual improvement and recurrence rate in patients receiving EETA were

Table IV. Surgical outcomes of TA and EETA.

	TA			EETA		
Variable	Komotar *et al*, 2012 (10)	Moussazadeh *et al*, 2016 (11)	Marx *et al*, 2021 (12)	Komotar *et al*, 2012 (10)	Moussazadeh *et al*, 2016 (11)	Marx *et al*, 2021 (12)
Cases	-	5.0	13.0	-	21	17
Extent of resection, %						
Gross total	48.3	40.0	54.0	66.9	90.0	59.0
Subtotal	45.5	60.0	38.0	33.1	10.0	18.0
Visual outcome, %						
Improved	33.0	0.0	64.0	56.0	63.0	91.0
Stable	-	100.0	18.0	-	27.0	0.0
Worse	-	0.0	18.0	-	10.0	9.0
Post-operative complication, %						
Cerebrospinal fluid leakage	2.6	0.0	15.0	18.4	5.0	29.0
Meningitis	2.3	20.0	0.0	5.1	0.0	12.0
Infection	-	-	-	-	-	-
Stroke	-	0.0	-	-	10.0	-
Diabetes insipidus	-	-	62.0	-	-	41.0
Recurrence, %	28.2	60.0	15.0	18.4	0.0	12.0
Follow-up, months	-	30.1	56.0	-	56.8	136.0

TA, transcranial approach; EETA, endonasal transsphenoidal approach.

significantly improved compared with those receiving TA (66.9 vs. 48.3, 56.0 vs. 33.0 and 18.4 vs. 28.2%, respectively. However, the postoperative CSF leakage and meningitis rate in patients receiving EETA were worse than those receiving TA (18.4 vs. 2.6 and 5.1 vs. 2.3%, respectively) (13). In 2016, Moussazadeh *et al* (14) compared outcomes of TA and EETA for the treatment of craniopharyngioma; GTR, visual improvement and recurrence rate of patients receiving EETA were improved compared with those receiving TA (90.0 vs. 40.0, 63.0 vs. 0.0 and 0.0 vs. 60.0%, respectively). However, postoperative pituitary deficiency and CSF leakage rate of EETA was worse than TA (73.3 vs. 50.0 and 5.0 vs. 0.0%, respectively) (14). In 2021, Marx *et al* (15) reported that the GTR, VA improvement and recurrence rate of patients receiving EETA were improved compared with those receiving TA (59.0 vs. 54.0, 91.0 vs. 6.0% and 12.0 vs. 15.0%, respectively). However, postoperative complications such as CFS leakage and meningitis rate in patients receiving EETA group were worse than those receiving TA (29 vs. 15 and 12 vs. 0%, respectively) (15). GTR rate of TA is 40.0-89.6% (14,16,17), while GTR rate of EETA is up to 95% (18). In the present study, following EETA, GTR, visual improvement and recurrence rate were 95.2, 38.1 and 0% respectively, which were improved compared with those of previous studies following TA (13-15). Incidence of postoperative complications, such as permanent DI, CSF leakage and meningitis, was 23.8, 4.8 and 9.5%, respectively, which was worse than that reported in the previous studies following TA (13-15). In addition, compared with previous studies following EETA, the GTR rate and postoperative DI rate of the present study were improved and postoperative CSF leakage rate was similar, while visual improvement rate was slightly worse (13-18). According to the outcomes of previous studies and the present study, for the treatment of craniopharyngioma, EETA gave improved results than TA in improving clinical symptoms and GTR and recurrence rate, while EETA was worse than TA in terms of postoperative complications (13-18). Several factors may lead to these outcomes. Firstly, craniopharyngiomas are close to important neurovascular structures, such as the thalamus, pituitary and optic nerve or optic chiasm (19). Secondly, it is difficult for TA to directly observe and dissect the tumor, while EETA directly enters the sub-infrachiasmatic area, third ventricle and hypothalamus, olfactory and subfrontal areas, to directly look at the tumor and important neurovascular structure; protection of optic nerves under EETA leads to greater visual compared with that in TA. Moreover, to a certain extent, the recurrence of craniopharyngioma is associated with tumor resection rate (20,21). Therefore, GTR rate of EETA is higher than that of TA, resulting in the recurrence rate of EETA being lower than that of TA (13-16). However, EETA also has limitations, such as a wider bone opening and arachnoid disruption, which increase the risk of postoperative CSF leakage and meningitis. The level of experience with EETA surgeons is particularly important to reduce postoperative complications. Therefore, EETA is an effective surgical method to improve clinical symptoms and tumor GTR rate, as well as reduce recurrence; however, postoperative complications are a challenge for patients and surgeons.

With rapid development of endoscopic technology and improvement of the surgeon's level of experience with

EETA, EETA has been widely used in craniopharyngioma resection. In 2010, Jane *et al* (22) reported that GTR and visual improvement rate of EETA are up to 83% in 12 and 78% in nine patients, respectively. However, up to one-third of patients suffered postoperative complications, such as meningitis in one patient <48 h after surgery, sinusitis in one patient, memory difficulties in two patients and novel DI in four patients (22). In 2014, Cavallo *et al* (23) reported GTR and visual improvement rate of EETA in 103 patients were 68.9 and 74.7%, respectively, while the number of cases of CSF leakage requiring surgical treatment, novel onset of DI, subdural hematoma, hydrocephalus and vascular injury was 15 (14.6%), 38 (48.1%), two (1.9%), two (1.9%) and two (1.9%), respectively. In addition, during the follow-up time, 23 (22.3%) patients experienced recurrence and/or tumor regrowth (23). In 2018, Tang *et al* (24) reported that 12 cases (80%) achieved GTR and 10 cases (66.7%) improved vision following EETA. However, 14 cases suffered postoperative DI (eight cases with transient postoperative and six with permanent DI) and one patient experienced meningitis (24). Recently, in 125 patients treated with EETA, GTR and VA improvement rate were 92 and 70%, respectively (25). The new onset of DI occurred in 29 patients and CSF leak requiring surgery occurred in three patients (25). Thus, EETA improves total resection rate and decreases recurrence, but postoperative complications cannot be avoided.

Pituitary function after EETA resection is an important postoperative index. The origin of craniopharyngioma is associated with the pituitary stalk, which is easy to identify under normal conditions. However, due to the distortion, displacement or merging of the tumor, it is difficult to identify in a pathological state (26). When the pituitary stalk cannot be identified, there are conflicting views on the treatment of the pituitary stalk. One view is that the pituitary stalk should be removed to achieve GTR and reduce recurrence and another view is that the pituitary stalk should be preserved to ensure pituitary function and decrease the risk of DI (27). By removing the pituitary stalk during EETA for craniopharyngioma, GTR rate was 91.1 and 89.0%, recurrence rate was 2.9 and 0.0% and postoperative pituitary defect rate was 80.9% vs. 78.0%, respectively (28,29). By preserving the pituitary stalk in EETA for craniopharyngioma, GTR rate decreased to 45.5 and 70.0%, the recurrence rate was relatively increased to 9.0 and 15.0% and the postoperative pituitary defect rate decreased to 54.5 and 55.0% (30,31). The aforementioned methods of dealing with pituitary stalk have advantages of relatively high GTR rate and low recurrence rate. In the present study, the pituitary stalk was removed if the tumor invaded the pituitary stalk to obtain a higher GTR rate and avoid tumor recurrence.

In the present study, there were 21 cases of craniopharyngioma, which were classified as nine cases of pure intrasellar type, three of intra- and the supra-sellar type and nine of pure suprasellar type. The majority of craniopharyngiomas involving intrasellar (pure intrasellar and intra- and supra-sellar type) had hypopituitarism. The normal structures adjacent to these types of craniopharyngioma primarily include normal arachnoid, carotid artery, optic nerve and chiasma, pituitary stalk and the bottom of the third ventricle. The surgical strategy is to separate the tumor along the interface between the tumor and pituitary gland (25). For the tumor extending to the suprasellar part, the surgical procedure is to decompress the tumor, separate the tumor from the internal carotid artery along the arachnoid interface and separate the tumor along the interface between the tumor and normal arachnoid. Moreover, sharp separation is often used for adhesion between the tumor and optic nerve and chiasm and pituitary stalk and the bottom of the third ventricle (25). For pure suprasellar craniopharyngioma, most of them have no hypopituitarism. The normal structures adjacent to suprasellar craniopharyngioma are the pituitary stalk, optic chiasma, the third ventricle, hypothalamic nuclei, and intracranial vessels. The surgical strategy is to distinguish the tumor and the pituitary stalk and retain the pituitary stalk as much as possible. After the decompression of the tumor, the tumor was sharply separated along the optic chiasma and the third ventricle (25).

Here, 21 patients with craniopharyngioma treated with EETA are reported. A total of 20 cases (95.2%) achieved GTR; the GTR rate was relatively high, which may be related to the surgical strategy of removing the pituitary stalk (27). Following surgery, the visual improvement rate was as high as 84.6%, which is a good outcome among the existing reports (22-25). Hypopituitarism occurred in eight patients and rate of hypopituitarism was ~38.1%, which was, to the best of our knowledge, not only lower than levels reported by the existing literature (13-18) using the same surgical strategy but also at a low level in all the literature of EETA in the treatment of craniopharyngioma (22-25). In addition, there were five cases of postoperative permanent DI, accounting for 23.8%, which was also within the normal range (32). CSF leakage occurs frequently following EETA (up to 58.8%) (22-25,32). Among the present patients, only one suffered CSF and the incidence of CSF leakage was 4.8%, which was relatively low (22-25). The low CSF leak may be related to multilayer repair technology surgery (33). In addition, two patients exhibited transient seizures and two patients suffered transient infection, all treated with drugs and cured when discharged from the hospital. During the follow-up, there was no recurrence, which may be associated with the surgical strategy of GTR or insufficient follow-up time. The total resection, VA improvement and recurrence rate and postoperative complications were satisfactory; however, this study also has limitations. Firstly, since the number of cases in the sellar, suprasellar, intrasellar and suprasellar region was relatively small, there was no statistical significance. Secondly, the surgical strategy of removing the pituitary stalk is controversial (28-31). Finally, mastering EETA technology requires long-term training, which is also a challenge for surgeons.

The present report describes 21 cases of craniopharyngioma treated via EETA. During the operation, the surgical strategy of near-total tumor resection to decrease recurrence rate was used. The results showed that 20 cases achieved GTR (95.2%). The postoperative visual improvement rate was 84.6%. There were eight cases of hypopituitarism, accounting for 38.1% and one case of CSF leakage, accounting for 4.8%. During the follow-up period of 1-52 months, there was no recurrence. EETA is an effective and safe method for treatment of craniopharyngioma. Sample and data collection will be continued in a follow-up study.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

JL, PW, CT, HTJ, GZ and NW participated in conception and design of the study and data acquisition. JL wrote the manuscript. PW critically revised the paper. JL, PW, CT, HTJ, GZ and NW confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

Ethical approval and consent to participate

The present study was approved by the committee ethics of Chongqing General Hospital (approval no. KY S2022-058-01). All patients signed written informed consent.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. Chowdhury FH, Haque MR, Goel AH and Kawsar KA: Endoscopic endonasal extended transsphenoidal removal of tuberculum sellae meningioma (TSM): An experience of six cases. Br J Neurosurg 26: 692-699, 2012.
2. Regmi D, Thapa A, Kc B and Shakya B: Endoscopic endonasal transsphenoidal approach to pituitary adenoma: A multi-disciplinary approach. J Nepal Health Res Counc 15: 174-177, 2017.
3. Zoli M, Mazzatenta D, Valluzzi A, Marucci G, Acciarri N, Pasquini E and Frank G: Expanding indications for the extended endoscopic endonasal approach to hypothalamic gliomas: Preliminary report. Neurosurg Focus 37: E11, 2014.
4. Benitez WI, Sartor KJ and Angtuaco EJ: Craniopharyngioma presenting as a nasopharyngeal mass: CT and MR findings. J Comput Assist Tomogr 12: 1068-1072, 1988.
5. Bunin GR, Surawicz TS, Witman PA, Preston-Martin S, Davis F and Bruner JM: The descriptive epidemiology of craniopharyngioma. J Neurosurg 89: 547-551, 1998.
6. Muller HL, Merchant TE, Warmuth-Metz M, Martinez-Barbera JP and Puget S: Craniopharyngioma. Nat Rev Dis Primers 5: 75, 2019.
7. Pascual JM, Carrasco R, Prieto R, Gonzalez-Llanos F, Alvarez F and Roda JM: Craniopharyngioma classification. J Neurosurg 109: 1180-1182; author reply 1182-1183, 2008.
8. Crotty TB, Scheithauer BW, Young WF Jr, Davis DH, Shaw EG, Miller GM and Burger PC: Papillary craniopharyngioma: A clinicopathological study of 48 cases. J Neurosurg 83: 206-214, 1995.
9. Harwood-Nash DC: Neuroimaging of childhood craniopharyngioma. Pediatr Neurosurg 21 Suppl 1: S2-S10, 1994.
10. Kassam AB, Gardner PA, Snyderman CH, Carrau RL, Mintz AH and Prevedello DM: Expanded endonasal approach, a fully endoscopic transnasal approach for the resection of midline suprasellar craniopharyngiomas: A new classification based on the infundibulum. J Neurosurg 108: 715-728, 2008.
11. Patel MR, Stadler ME, Snyderman CH, Carrau RL, Kassam AB, Germanwala AV, Gardner P and Zanation AM: How to choose? Endoscopic skull base reconstructive options and limitations. Skull Base 20: 397-404, 2010.
12. Fernandez-Miranda JC, Gardner PA, Snyderman CH, Devaney KO, Strojan P, Suárez C, Genden EM, Rinaldo A and Ferlito A: Craniopharyngioma: A pathologic, clinical, and surgical review. Head Neck 34: 1036-1044, 2012.
13. Komotar RJ, Starke RM, Raper DM, Anand VK and Schwartz TH: Endoscopic skull base surgery: A comprehensive comparison with open transcranial approaches. Br J Neurosurg 26: 637-648, 2012.
14. Moussazadeh N, Prabhu V, Bander ED, Cusic RC, Tsiouris AJ, Anand VK and Schwartz TH: Endoscopic endonasal versus open transcranial resection of craniopharyngiomas: A case-matched single-institution analysis. Neurosurg Focus 41: E7, 2016.
15. Marx S, Tsavdaridou I, Paul S, Steveling A, Schirmer C, Eördögh M, Nowak S, Matthes M, El Refaee E, Fleck SK, *et al*: Quality of life and olfactory function after suprasellar craniopharyngioma surgery-a single-center experience comparing transcranial and endoscopic endonasal approaches. Neurosurg Rev 44: 1569-1582, 2021.
16. Yu T, Sun X, Ren X, Cui X, Wang J and Lin S: Intraventricular craniopharyngiomas: Surgical management and outcome analyses in 24 cases. World Neurosurg 82: 1209-1215, 2014.
17. Shi X, Zhou Z, Wu B, Zhang Y, Qian H, Sun Y, Yang Y, Yu Z, Tang Z, Lu S: Outcome of radical surgical resection for craniopharyngioma with hypothalamic preservation: A single-center retrospective study of 1054 patients. World Neurosurg 102: 167-180, 2017.
18. Leng LZ, Greenfield JP, Souweidane MM, Anand VK and Schwartz TH: Endoscopic, endonasal resection of craniopharyngiomas: Analysis of outcome including extent of resection, cerebrospinal fluid leak, return to preoperative productivity, and body mass index. Neurosurgery 70: 110-123; discussion 123-4, 2012.
19. Jane JA Jr and Laws ER: Craniopharyngioma. Pituitary 9: 323-326, 2006.
20. Duff J, Meyer FB, Ilstrup DM, Laws ER Jr, Schleck CD and Scheithauer BW: Long-term outcomes for surgically resected craniopharyngiomas. Neurosurgery 46: 291-302; discussion 302-5, 2000.
21. Chakrabarti I, Amar AP, Couldwell W and Weiss MH: Long-term neurological, visual, and endocrine outcomes following transnasal resection of craniopharyngioma. J Neurosurg 102: 650-657, 2005.
22. Jane JA Jr, Kiehna E, Payne SC, Early SV and Laws ER Jr: Early outcomes of endoscopic transsphenoidal surgery for adult craniopharyngiomas. Neurosurg Focus 28: E9, 2010.
23. Cavallo LM, Frank G, Cappabianca P, Solari D, Mazzatenta D, Villa A, Zoli M, D'Enza AI, Esposito F and Pasquini E: The endoscopic endonasal approach for the management of craniopharyngiomas: A series of 103 patients. J Neurosurg 121: 100-113, 2014.
24. Tang B, Xiao L, Xie S, Huang G, Wang Z, Zhou D, Zeng E and Hong T: Extended endoscopic endonasal approach for recurrent or residual symptomatic craniopharyngiomas. Clin Neurol Neurosurg 168: 38-45, 2018.
25. Lei C, Chuzhong L, Chunhui L, Peng Z, Jiwei B, Xinsheng W, Yazhuo Z and Songbai G: Approach selection and outcomes of craniopharyngioma resection: A single-institute study. Neurosurg Rev 44: 1737-1746, 2021.
26. Figueiredo EG, Welling LC, de Faria JW and Teixeira MJ: Pituitary stalk craniopharyngioma. BMJ Case Rep 2011: bcr0620103097, 2011.
27. Xiao G, Yuan X, Yuan J, Krumtally NA, Li Y, Feng C, Liu Q, Peng Z, Li X and Ding X: Pituitary stalk management during the microsurgery of craniopharyngiomas. Exp Ther Med 7: 1055-1064, 2014.
28. Dho YS, Kim YH, Se YB, Han DH, Kim JH, Park CK, Wang KC and Kim DG: Endoscopic endonasal approach for craniopharyngioma: The importance of the relationship between pituitary stalk and tumor. J Neurosurg 129: 611-619, 2018.
29. Gauden AJ, Harley B, Pears C, Wickremesekera A, Parker A, Robinson S, Baguley C and Wormald PJ: A regional Australasian experience of extended endoscopic transsphenoidal surgery for craniopharyngioma: Progression of the mentoring model. J Clin Neurosci 68: 188-193, 2019.

30. Alalade AF, Ogando-Rivas E, Boatey J, Souweidane MM, Anand VK, Greenfield JP and Schwartz TH: Suprasellar and recurrent pediatric craniopharyngiomas: Expanding indications for the extended endoscopic transsphenoidal approach. J Neurosurg Pediatr 21: 72-80, 2018.
31. Schelini JC, Cavalheiro S, Dastoli PA, Hirai ÉR, Atallah C, Costa M, Nicacio J, Capellano AM, Silva N, Zymberg S and de Paula Santos R: Endoscopic endonasal transsphenoidal approach for pediatric craniopharyngiomas: A case series. Int J Pediatr Otorhinolaryngol 130: 109786, 2020.
32. Koutourousiou M, Gardner PA, Fernandez-Miranda JC, Tyler-Kabara EC, Wang EW and Snyderman CH: Endoscopic endonasal surgery for craniopharyngiomas: Surgical outcome in 64 patients. J Neurosurg 119: 1194-1207, 2013.
33. Learned KO, Adappa ND, Loevner LA, Palmer JN, Newman JG and Lee JY: MR imaging evaluation of endoscopic cranial base reconstruction with pedicled nasoseptal flap following endoscopic endonasal skull base surgery. Eur J Radiol 82: 544-551, 2013.