Clinical parameters and postoperative outcomes of pituitary adenomas in children: Analysis according to size of adenomas and adopted surgical procedures

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Abstract. Pathologies of pediatric pituitary adenomas are uncommon and challenging to diagnose. Pituitary adenomas cause mass effects and neurological disruption in children. Postoperative evaluations of endocrine functions are challenging. The present study categorized adenomas by size and type, and evaluated outcomes based on the surgical procedures adopted. In addition, the present study analyzed the demographic parameters of children as well as the factors supposed to be influencing remission. Clinical characteristics, treatment parameters and postoperative outcomes of curative surgeries in 135 children [80 (59%) females and 55 (41%) males; age 12 (11-13) years at the time of first diagnosis] with pituitary adenomas who underwent curative surgeries operated between 1998 and 2023 in the Yichang Central People's Hospital, (Yichang, China) were included in the present retrospective study. A total of 112 (83%) children had microadenomas (<10 mm adenomas), 6 (4%) had macroadenomas (≥10 mm adenomas) and 17 (13%) had invisible adenomas. Pathological examination revealed that 59 (44%) children had functional adenomas and 10 (7%) had non-functional adenomas. Among functional adenomas, acromegaly (excess secretion of insulin-like growth factor 1) was reported to be the most common [30 (22%)] pediatric adenomas, followed by prolactinomas [prolactin secretion ≥1,000 mIU/l; 20 (15%) and Cushing syndrome (9 (7%)]. A total of 23 (17%), 3 (2%), 4 (3%), 3 (2%) and 3 (2%) children were reported to have remission and underwent re-surgery. These patients (remission) underwent microscopic trans-sphenoidal resection, endoscopic endonasal trans-sphenoidal resection, trans-sphenoidal resection alone, bilateral adrenalectomy and gross total resection adopted curative surgeries initially, respectively. Postoperative diabetes insipidus, adrenal insufficiency and cerebrospinal fluid leaks have been reported in children who have undergone curative surgeries for macroadenomas or Cushing syndrome. Female pediatric patients with clinical manifestations were more likely to have pituitary adenomas. Pediatric patients generally have functional pituitary adenomas, particularly adreno-corticotropin-secreting adenomas. Microscopic trans-sphenoidal resection is associated with a lower risk of under-treatment. Postoperative outcomes and clinical benefits of curative surgeries are based on the complete type of surgical removal and size of the pituitary adenomas mass (Level of Evidence: 3; Technical Efficacy Stage: 4).

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Introduction

Pediatric pituitary adenomas are rarely reported in children (1). Among pediatric patients with brain adenomas, a maximum of 10% may have pituitary adenomas (2,3). Most pediatric pituitary adenomas are predominantly benign (4). However, these adenomas are mostly associated with hormone hypersecretion, which leads to mass effects and neurological disruptions in children (2). Trans-sphenoidal surgery overcomes mass effects and normalizes the endocrine functions of children (1,2). However, complication rates are higher in children than in adults with pituitary adenomas before and after resection treatment (5). The incidence of pituitary adenomas increases annually in pediatric patients (6). Almost 50% of children are cured after curative surgeries (7) and are more difficult to cure than adult patients (5). Pathologies of pediatric pituitary adenomas are uncommon. However, considering endocrine and neurological characteristics is challenging (2). Postoperative evaluations of endocrine functions are challenging (8).

The objectives of the present retrospective analysis were to compare the clinical characteristics, treatment parameters and postoperative outcomes of curative surgeries in children under the age of 16 years who reported pituitary adenomas in the last 25 years at the Yichang Central People's Hospital (Yichang, China). The present study categorized adenomas

by size (microadenomas and macroadenomas) and type (functional and non-functional) and evaluated outcomes based on the surgical procedures adopted. In addition, the present study analyzed the demographic parameters of children as well as the factors they supposed to be influencing remission.

Materials and methods

Inclusion criteria. Children (<16 years) with pituitary adenoma (confirmed through pathological and imaging examinations, as per data reported for remission same for the first diagnosis) who underwent curative surgeries and were available for follow-up in the outpatient department (neuroendocrine and neurosurgery) were included in the present study.

Exclusion criteria. Children with missing information (>3 vital parameters) were excluded from the present study. Children with any diseases in sphenoid sinus and sellar area were excluded. The ectopic endocrine adenomas were diagnosed firmly and excluded from the present study. Children with pituitary tumors (other than adenomas) are excluded.

Clinical characteristics. Medical records of children were evaluated and analyzed for demographical and clinical characteristics.

Treatment parameters. Besides image analyses, the type of hormones that the adenomas secrete was the basis for the surgical plan in Yichang Central People's Hospital (Yichang, China). Therefore, microadenomas and even invisible (pathological examinations were performed to diagnose invisible adenomas) pituitary adenomas were treated with surgery. In general, decision was based on all parameters including clinical manifestations and surgeons' decision for surgeries (not based on single parameter for decision of surgeries). The curative surgical notes of surgeons were evaluated from the medical records of the hospitals and analyzed for treatment parameters.

Postoperative outcomes. Outcomes, including adverse effects of follow-up in the outpatient department, were evaluated and analyzed for postoperative outcomes.

Clinical benefits for curative surgeries. The clinical benefits of curative surgery for pituitary adenomas in children were evaluated as a function of the beneficial scores. Beneficial scores for curative surgeries were calculated from the risk of undertreatment, as expressed in Equation 1. The risk of undertreatment was defined with a calculation that involved diagnostic confidence above which curative method was performed for pituitary adenomas (Equation 2). The diagnostic confidence (pathological and imaging examinations) was considered to be a numerical value ranging from 0 to 1. The beneficial score of the treatment is the area above the curve of the method adopted, and the working area is the area under the curve of the adopted curative method. For all curative methods, pathological and imaging examinations were used as the reference standards (9,10).

$$\text{Beneficial score} = \frac{\text{Number of children with lack of residual adenomas}}{\text{Total number of children evaluated}} - \left(\frac{\text{Number of children with residual adenomas}}{\text{Total number of children evaluated}} \times \text{Risk of undertreatment}\right)$$

(Equation 1)

$$\text{Risk of undertreatment} = \frac{\text{Diagnosis confidence above which curative method was performed for pituitary adenomas}}{1-\text{Diagnosis confidence above which curative method was performed for pituitary adenomas}}$$

(Equation 2)

Remission. Prolactin levels <20 ng/ml in females and <15 ng/ml in males on the first postoperative day for children with prolactinoma were considered to be in remission. For children with acromegaly, remission was determined as a normal insulin-like growth factor 1 (IGF-1) level combined with a basal growth hormone level of <1 μg/l or combined with a growth hormone level of <0.4 μg/l after oral glucose tolerance test suppression. For children with Cushing syndrome [Cushing syndrome was diagnosed according to symptoms, magnetic resonance imaging, histopathology of sinus and pathological examinations (11)], remission was considered when there was clinical adrenal insufficiency and serum cortisol levels were <2.5 μg/dl at postoperative 2 days or <1.8 μg/dl with low-dose dexamethasone suppression test in the postoperative third month (2). In addition, every 3 months, magnetic resonance imaging was performed for children during follow-up after curative surgeries.

Cure. The absence of adenomas on magnetic resonance imaging and the absence of any hypersecretion of hormones 3 months after surgery was considered a cure for pituitary adenomas in children (6).

Microadenoma. Adenomas size <10 mm (11).

Macroadenoma. Adenomas size ≥10 mm (11).

Acromegaly. Excess secretion of IGF-1 (12).

Prolactinoma. Prolactin secretion of ≥1,000 mIU/l is considered prolactinoma (13).

Invisible tumors and microglia are sister groups, not a subset and its collection. The histopathological examinations were performed for the tissue examination and dissection and were not pathological examinations.

Statistical analysis. InStat 3.01 GraphPad Software (Dotmatics) was used for statistical analysis. Soup Calculator® software (https://www.calculatorsoup.com/calculators/statistics/quartile-calculator.php) was used to calculate the interquartile range. Categorical, non-normal continuous, and normal continuous parameters are expressed as frequencies with percentages in parentheses, medians with first quartile value-third quartile value in parentheses, and mean ± standard deviation, respectively. Column failure in the normality test ($P<0.05$) was considered a non-normal parameter otherwise non-normal variable. Univariate analyses following logistic regression analysis were performed to develop correlation of clinical characteristics at the time of diagnosis, treatment parameters of the adopted curative surgeries, and postoperative outcomes for the cure of pituitary adenomas in children [normality tests and box-and-whisker plots; the assumptions (results) are not

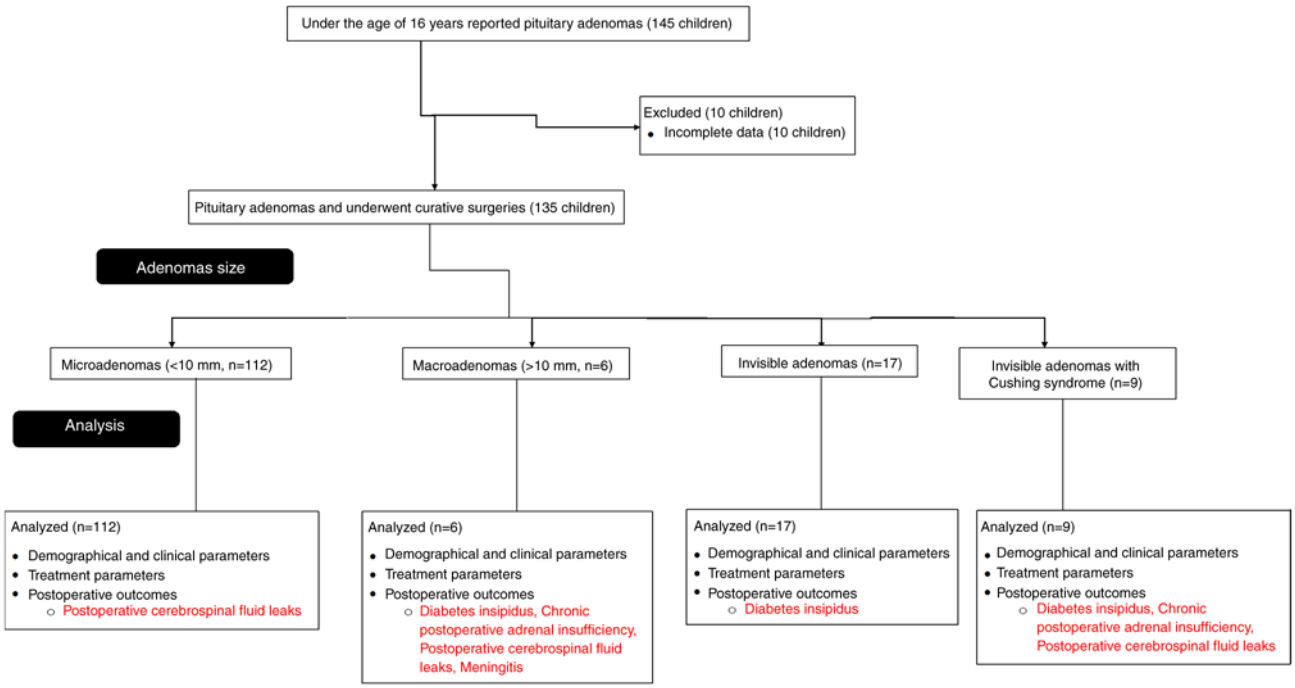

Figure 1. Flow diagram of the present study (according to pituitary adenomas size of adenomas).

reported)] (6). All results were considered significant at a 95% confidence interval (CI) and P<0.05.

Results

Study population. From June 15, 1998, to July 1, 2023, a total of 145 children with pituitary adenomas underwent curative surgeries and were available for follow-up in the outpatient department (neuroendocrine and neurosurgery) at Yichang Central People's Hospital (Yichang, China). Among them, the complete data of 10 children were not available in hospital records. Therefore, these patients were excluded from the present study. The clinical characteristics, treatment parameters and postoperative outcomes of curative surgeries in 135 children with pituitary adenomas who underwent curative surgery were included in the present study. A flow diagram of the retrospective study according to pituitary adenomas size is demonstrated in Fig. 1.

Clinical characteristics. There were 59% females and 41% males. The children were aged 12 (11-13) years at the time of the first diagnosis. A total of 83% of patients had microadenomas, 4% had macroadenomas and 13% had invisible adenomas. Pathological examination revealed that 44% of the children had functional adenomas, and 7% of the children had non-functional adenomas. Giant macroadenomas were absent. (However, data for 49% of the children were inconclusive or unavailable in hospital records regarding functional adenomas). Among functional adenomas, acromegaly was reported highest in pediatric adenomas following prolactinoma and Cushing syndrome. Children reported headaches, visual impairments, gynecomastia, amenorrhea and galactorrhea. The demographic, clinical and pathological characteristics of the children are presented in Table I.

Treatment parameters. Only 15% of the children received preoperative pharmacotherapy. Children mostly underwent microscopic trans-sphenoidal resection (80%) or trans-sphenoidal resection (7%; often). However, in rare cases, endoscopic endonasal trans-sphenoidal resection, bilateral adrenalectomy, or gross total resection was preferred for the treatment of pituitary adenomas in children (preference for surgery was the decision of endocrinologists and neurosurgeons). The details of the treatment parameters are reported in Table II. The present study's diagram of the retrospectively collected data according to the adopted curative surgeries is demonstrated in Fig. 2.

Postoperative outcomes of curative surgeries. None of the children succumbed during follow-up after curative surgery. A total of 36 (27%) children reported remission and underwent re-surgery. A total of 23, three, four, three and three children were reported remission and underwent re-surgery; those underwent microscopic trans-sphenoidal resection, endoscopic endonasal trans-sphenoidal resection, trans-sphenoidal resection alone, bilateral adrenalectomy, and gross total resection adopted curative surgeries initially, respectively. Re-surgeries were performed for recurrence. During remission, the children underwent microscopic trans-sphenoidal resection as a re-surgery. Postoperative diabetes insipidus, adrenal insufficiency and cerebrospinal fluid leaks were reported in children who had undergone curative surgeries for macroadenomas and/or Cushing syndrome. Postoperative cerebrospinal fluid leaks have been reported in children with macroadenomas. Details of the postoperative adverse outcomes of the curative surgeries are reported in Table III.

Clinical benefits for curative surgeries. The beneficial scores for curative surgeries were 0-0.74 diagnostic confidence. Curative surgeries >0.74 diagnostic confidence have the risk of remission and re-surgeries. The beneficial scores for

Table I. Demographical, clinical and pathological characteristics at the time of the first diagnosis.

Characteristics	Population
Numbers of children	135
Sex	
Male	55 (41)
Female	80 (59)
Age (years)	12 (11-13)
Ethnicity	
Han Chinese	123 (91)
Mongolian	10 (7)
Tibetan	1 (1)
Uyghurs Muslim	1 (1)
Adenoma size	
Microadenoma (<10 mm)	112 (83)
Macroadenoma (≥10 mm)	6 (4)
Invisible adenoma	17 (13)
Headache	45 (33)
Visual impairments	27 (20)
Prolactinoma	20 (15)
Acromegaly	30 (22)
Cushing syndrome	9 (7)
Non-functional adenoma	10 (7)
Amenorrhea	4 (3)
Galactorrhea	6 (4)
Gynecomastia	3 (2)

Categorial variables are presented as frequencies (percentages). Non-normal continuous variables are expressed as median with first quartile value-third quartile value in parenthesis. Children may have one or more clinical characteristics.

Table II. Treatment parameters of the adopted curative surgeries at the time of the first diagnosis.

Characteristics	Population
Numbers of children	135
Time between diagnosis and adopted treatment(s) (days)	46.64±4.3
Any preoperative pharmacotherapy	20 (15)
Type of adopted curative surgeries	
Microscopic trans-sphenoidal resection	108 (80)
Endoscopic endonasal trans-sphenoidal resection	7 (5)
Transsphenoidal resection alone	9 (7)
Bilateral adrenalectomy	6 (4)
Gross total resection	5 (4)
Any postoperative pharmacotherapy	25 (19)

Categorial variables are presented as frequencies (percentages). Normal continuous variables are presented as mean ± standard deviation.

Table III. Postoperative adverse outcomes of curative surgeries (detail of surgical or endocrinological complications).

Characteristics	Population (%)
Numbers of children	135
Chronic postoperative pituitary insufficiency	40 (30)
Chronic postoperative adrenal insufficiency	5 (4)
Postoperative cerebrospinal fluid leaks	2 (2)
Permanent postoperative visual dysfunction	3 (2)
Postoperative diabetes insipidus	3 (2)
Radiation necrosis	5 (4)
Optic neuropathy due to radiation	5 (4)
Abducens palsy due to radiation	1 (1)
Meningitis	5 (4)
Death	0 (0)
Reported remission and underwent re-surgery	36 (27)

Categorial variables are presented as frequencies (percentages). Children have one or more adverse events.

microscopic trans-sphenoidal resection, endoscopic endonasal trans-sphenoidal resection, bilateral adrenalectomy, trans-sphenoidal resection alone, and gross total resection were 0-0.79 diagnostic confidence, 0-0.57 diagnostic confidence, 0-0.5 diagnostic confidence, 0-0.44 diagnostic confidence and 0-0.44 diagnostic confidence, respectively. Above 0.79 diagnostic confidence, 0.57 diagnostic confidence, 0.5 diagnostic confidence, 0.44 diagnostic confidence, and 0.44 diagnostic confidence microscopic trans-sphenoidal resection, endoscopic endonasal transsphenoidal resection, bilateral adrenalectomy, trans-sphenoidal resection alone, and gross total resection had a risk of remission and re-surgeries, respectively (Table IV). The details of the graphical presentation of clinical benefits of curative surgeries are presented in Fig. 3.

Independent parameters for cure. A total of 99 children reported a cure. These were considered as reference standards to evaluate the independent parameters for cures from pituitary adenomas in 99 children who reported cures. Sex, ethnicity, adenomas size, hormonal secretion, or any pre-or post-operative pharmacotherapies are not associated with the cure of children. The details of the parameters evaluated for the cure of pituitary adenomas in children are presented in Table V.

Discussion

In addition to demographic characteristics, 20 (15%), 30 (22%), 9 (7%) and 10 (7%) children were diagnosed with prolactinoma, acromegaly, Cushing's syndrome and non-functional adenomas, respectively. The pathological characteristics of the present study were consistent with those of a multicenter retrospective cohort study (2). Unlike adult patients, pituitary

Table IV. Clinical benefits for curative surgeries.

Diagnostic confidence	Curative surgeries	Microscopic trans-sphenoidal resection	Endoscopic endonasal trans-sphenoidal resection	Trans-sphenoidal resection alone	Bilateral adrenalectomy	Gross total resection
Total numbers of children	135	108	7	9	6	5
Numbers of children without remission	95	85	4	5	3	2
Numbers of children with remission	36	23	3	4	3	3
0	0.73	0.79	0.57	0.44	0.5	0.4
0.1	0.70	0.76	0.52	0.38	0.44	0.34
0.2	0.67	0.73	0.46	0.31	0.38	0.28
0.3	0.62	0.7	0.39	0.21	0.29	0.19
0.4	0.56	0.65	0.29	0.07	0.17	0.07
0.5	0.47	0.57	0.14	-0.11	0	-0.1
0.6	0.33	0.47	-0.07	-0.39	-0.25	-0.35
0.7	0.11	0.29	-0.43	-0.85	-0.67	-0.77
0.8	-0.33	-0.06	-1.14	-1.78	-1.5	-1.6
0.9	-1.67	-1.13	-3.29	-4.56	-4	-4.1
0.99	-25.67	-20.3	-41.86	-54.56	-49	-49.1
Beneficial score (diagnostic confidence)	0-0.74	0-0.79	0-0.57	0-0.5	0-0.44	0-0.44

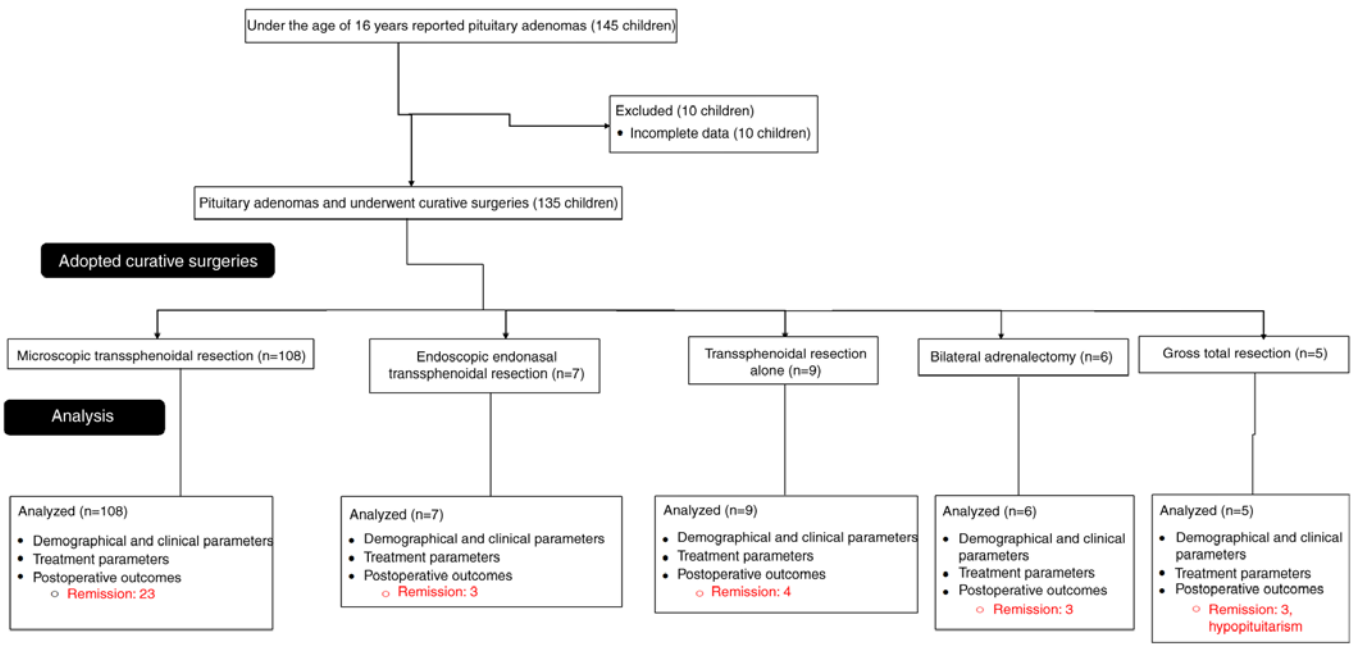

Figure 2. Flow diagram of the present study (according to adopted curative surgeries for pituitary adenomas of adenomas).

adenomas present in pediatric patients are generally functional adenomas and adreno-corticotropin-secreting adenomas, and prolactin-and growth hormone-secreting adenomas are generally reported in pediatric patients (14). Pediatric patients generally have functional adenomas, particularly adreno-corticotropin-secreting adenomas.

Within the study population, 59% were females and 41% were males. The results of the higher proportion of female patients in the study population were consistent with those of retrospective studies (1,2,6,11,14,15). Female pediatric patients with clinical manifestations were more likely to have pituitary adenomas.

Table V. Independent parameters for cure from pituitary adenomas in children.

Parameters	Odds ratio	95% CI	P-value
Sex (male vs. female)	0.7169	0.3681-1.3541	0.4152
Ethnicity (Han Chinese vs. non-Han Chinese)	0.5121	0.3214-0.8541	0.3215
Size of adenoma (microadenoma vs. macroadenoma/invisible adenoma)	1.5421	0.5712-7.2241	0.3512
Hormonal secretion (non-functional adenoma vs. acromegaly/prolactinoma/ cushing syndrome)	0.8951	0.2351-1.6841	0.3921
Surgeries type (microscopic transsphenoidal resection vs. rest of the other surgeries)	0.8156	0.3345-1.214	0.4152
Any preoperative/post-operative pharmacotherapy (yes vs. no)	0.4251	0.2215-0.9851	0.4514

CI, Confidence interval. An odd ratio of 1 or more and a P<0.05 were considered significant. Cure, is considered the absence of tumors in magnetic resonance imaging and the absence of any hypersecretion of hormone after 3 months of surgeries.

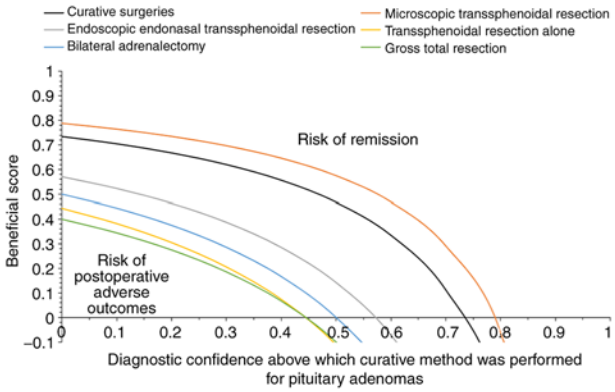

Figure 3. A graphical presentation of clinical benefits of the adopted curative surgeries.

Headache, visual impairment, gynecomastia, amenorrhea and galactorrhea have been reported in pediatric patients with adenomas. These are the effects of high prolactin secretion (2,15,16). Prolactin-secreting functional pituitary adenomas are most frequent among children (2,4,17). Medical treatment with dopamine is necessary for headaches, visual impairments, gynecomastia, amenorrhea and galactorrhea to neutralize hormone secretion, because it may be a pituitary adenoma in children.

A total of 36% of children reported remission and underwent re-surgery after the initial surgery, and during remission, children mainly underwent microscopic trans-sphenoidal resection as re-surgeries. The results of remission and re-surgeries in children are consistent with those of retrospective studies (2,6,14,15), single pituitary center experience (1) and a comparative study (11). The remission adenomas were small. Therefore, microscopic trans-sphenoidal resection was preferred for re-surgery. The children included in the present study were optimally treated in the Yichang Central People's Hospital (Yichang, China).

In the present study microscopic trans-sphenoidal resection had the highest clinical benefit, followed by endoscopic endonasal trans-sphenoidal resection, bilateral adrenalectomy, trans-sphenoidal resection alone and gross total resection. In the center included in the present study (Yichang Central People's Hospital, Yichang, China), microscopic trans-sphenoidal resection was preferred, mostly for children with microadenomas. Except for Cushing syndrome, adenomas size affects surgical outcomes and clinical benefits (11). The children reported in the present study have improved clinical benefits if they had microadenomas. Microscopic trans-sphenoidal resection is superior to achieve endocrine remission than the other surgical modalities (however, it could be highly variable related with patient selection).

Children with Cushing syndrome and macroadenomas had higher remission rates and adverse postoperative outcomes than those with microadenomas. Cushing syndrome and pituitary macroadenomas are more aggressive and refractory to treatment than pituitary microadenomas (11). Higher serum hormone levels are also responsible for remission and adverse postoperative outcomes (11). The postoperative outcomes and clinical benefits of curative surgeries are based on complete surgical removal and the size of the pituitary adenomas mass.

The present study had certain limitations; for example, the sample size was small, limiting the generalizability of the findings. None of the parameters were reported to be independent of cure for pituitary adenomas in children. The results for evaluating cure from pituitary adenomas in children were inconsistent with those of a larger retrospective study (6). A possible justification for such contradictory results is that the sample size was smaller than that in a retrospective study (6). In addition, technical difficulties of curative surgeries and follow-up and surgeon's experience are effective cure for pituitary adenomas in children (2). The details of the comparative studies on pituitary adenomas in children and adults who underwent curative surgeries in different settings are presented in Table VI. The effect of treatment parameters on vision and sexual development after surgical procedures are not reported. The possible justification for the same is that such parameters are not available with institutional records (long-term follow-up data are not available). The effect of treatment parameters on vision and sexual development after curative surgical procedures would be future direction for a long-term prospective follow-up study. In the 2022 fifth edition of the World Health Organization Classification of Endocrine Tumors and of Central Nervous System Tumors (18), the name of pituitary adenomas has been cancelled, collectively referred to as pituitary neuroendocrine adenomas. However, it is not possible to analyze

Table VI. Comparative studies on pituitary adenoma in children or adults underwent curative surgeries in different setting.

First author	Publication year	Study population	Sample size (N; children)	Age (years)	Sex		Pathological characteristics	Type of curative surgeries	Major postoperative outcomes	Remission	(Refs.)
					Male	Female					
Single pituitary center experience, Kilc*i et al*	2024	Turkish	79	15.8	27	52	Non-functioning adenoma-35.5%; prolactinoma-29%; corticotropinoma 22%, and somatotropinoma-14%	Endoscopic endonasal trans-sphenoidal surgery-63%;	Permanent central diabetes insipidus-6%	4	(1)
Multicentric retrospective cohort study, Locatelli *et al*	2019	European	29	15.3±3.3 (4-18)	11	16	Cushing's disease-13; growth hormone-secreting adenoma:5; prolactinoma-5; non-functional adenoma-4	Trans-sphenoidal approach	The technical difficulties	22	(2)
Single-center retrospective, Li *et al*	2023	Chinese	232	15	104	128	ACTH-secreting adenoma-90/232; prolactin-secreting adenoma-63/232); growth hormone-secreting adenoma-41/232.	Curative surgeries	Irreversible postoperative complications	30%	(6)
Comparative study, Hwang *et al*	2009	Korean	30	35.7±3.7 and 39.6±3.3	5	25	Macroadenomas-7; microadenomas-23; ACTH-secreting adenoma	Trans-sphenoidal surgery-15; gamma knife surgery-6	Not reported	17	(11)
Retrospective study, Chen *et al*	2019	North American	42	≤21	15	27	Prolactin-secreting; ACTH-secreting adenoma; Growth hormone-secreting adenoma	Curative surgeries	General postoperative complications	21	(14)
Retrospective study, Castellanos *et al*	2021	North American	7,563	≤21	2,341	5,222	Majority functional adenomas	Total resection	Not reported	32%	(15)

and discuss a study according to the new classification because these are retrospective collection of last 25 years of parameters of pediatric patients. Moreover, when Yichang Central People's Hospital (Yichang, China) adopts these guidelines for classifications, a manuscript can be published after that instruction. At present, old guidelines are being followed.

In the present study, according to the size there were 112 microadenomas and 6 cases of macroadenomas; however, in the clinical manifestation there were 27 cases with visual manifestations, and it is well known that microadenomas do not cause any visual manifestations. Furthermore, the study mentioned that 30 cases were acromegalic and it is well known that in 90% of pituitary secretion are growth hormone in macroadenomas (2). The justification for such contradictory results is the present study is not representative of the whole pediatric Chinese population. The present study is about the pituitary adenomas in pediatric age group who underwent curative surgeries operated between 1998 and 2023 in the Yichang Central People's Hospital, (Yichang, China). Some patients were refereed to Yichang Central People's Hospital, (Yichang, China) and some patients were referred to the other institutes during the study period (because of large study period). Moreover, some geographical parameters also affected these situations. Therefore, there were deviations in expected data from general population in the present study.

In conclusion, the present study discussed the pediatric pituitary adenomas that are rare and pose significant challenges. It highlights the mass effects and neurological disruptions in children with pituitary adenomas. It was stated that evaluating endocrine function after surgery is difficult because recovery varies depending on the adenomas' size and the type of surgery performed. The present study also concluded that pediatric patients generally have functional adenomas, particularly adreno-corticotropin-secreting adenomas. Clinical and pathological examinations may predict pituitary adenomas in children. Children with microadenomas may have improved clinical benefits. The postoperative outcomes and clinical benefits of curative surgeries are based on complete surgical removal and the size of the pituitary adenomas mass. Microscopic trans-sphenoidal resection is superior to achieve endocrine remission than the other surgical modalities. Female pediatric patients with clinical manifestations were more likely to have pituitary adenomas. Further well-designed randomized and rigorous patient data (further data collection and analysis, including a larger sample size, long-term follow-up, rigorous and statistical analysis) is required to establish the authors' conclusions. A long term prospective follow up study should be required to state the results strongly.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

XL was a project administrator and contributed to the formal analysis, supervision, resources, methodology, validation, and literature review. CT contributed to the investigation, resources, conceptualization, visualization, data curation, methodology, and literature review. JY contributed to the resources, conceptualization, formal analysis, methodology and literature review of the present study and drafted and edited the manuscript for intellectual content. All authors agree to be accountable for all aspects of this work, ensuring its integrity and accuracy. XL, CT and JY confirm the authenticity of all the raw data. All authors have read and approved the final version of the manuscript.

Ethics approval and consent to participate

The authors prepared the protocol by themselves (approval no. YCPh15 dated March 5, 2022) and was approved by the Yichang Central People's Hospital review board. The present study adheres to the laws of China and the v2008 Declarations of Helsinki. As this was a retrospective study, informed consent was waived by the Yichang Central People's Hospital review board.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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