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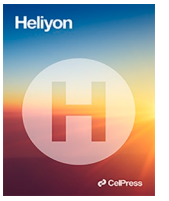

Research article

Analysis of factors influencing the occurrence of diabetes insipidus following neuroendoscopic transsphenoidal resection of pituitary adenomas and risk assessment

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ABSTRACT

Objective: Studies have revealed a higher prevalence of diabetes insipidus in patients following resection of pituitary adenoma surgery. By comprehensively analysing the clinical history of patients undergoing endoscopic transnasal sphenoidal resection for pituitary adenomas, the factors influencing development of postoperative diabetes insipidus were investigated and a predictive model was developed to assess its risk.

Methods: A retrospective analysis was conducted on the medical records of 281 patients with pituitary adenomas who underwent neuroendoscopic transsphenoidal resection at our institution between October 2020 and October 2022. The Mann-Whitney *U* test, chi-square test, and logistic regression analysis were used to identify the independent factors that potentially contribute to the development of postoperative diabetes insipidus. Additionally, a nomogram was constructed to evaluate the predicted risk of postoperative diabetes insipidus in patients with pituitary adenomas.

Results: Diabetes insipidus occurred in 100 (35.59 %) of the 281 enrolled patients. The results of the multifactorial logistic regression analysis revealed that diabetes, hypertension, cardiopathy, preoperative serum cortisol level, cerebrospinal fluid leakage, and tumour texture independently influenced the occurrence of postoperative diabetes insipidus ($P < 0.05$). A nomogram was developed to evaluate the risk of postoperative diabetes insipidus in patients with pituitary adenoma.

Conclusions: Multiple independent risk factors associated with the patient and tumour were identified in predicting diabetes insipidus. Early recognition of these risk factors may contribute to the prevention or reduction of diabetes insipidus incidence following pituitary adenoma surgery.

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1. Introduction

Pituitary adenoma represents the most prevalent neoplasm in the sellar region, frequently resulting in visual field impairment due to compression of the optic nerve by the tumour [1,2]. Currently, surgical resection remains the primary treatment modality. There are two primary surgical techniques available for the treatment: a transsphenoidal approach using a microscope and a transnasal sphenoidal approach employing neuroendoscopic surgery. In recent years, scientific and technological progress has accelerated the development of neuroendoscopy technology. The transnasal neuroendoscopic approach has the advantages of reduced surgical trauma, accelerated postoperative recovery, and favourable prognosis, rendering it the primary surgical technique for resecting pituitary adenomas [3,4]. Serious complications following resection of pituitary adenoma are infrequent but some patients may experience cerebrospinal fluid leakage, epistaxis, intracranial infection, electrolyte imbalances, or diabetes insipidus [5–9]. The most prevalent complication following resection of a pituitary adenoma is diabetes insipidus, as reported in multiple studies [10].

Diabetes insipidus arises from the dysregulation of arginine vasopressin (AVP) secretion, leading to the clinical presentation of excessive urine output (polyuria) and increased thirst (polydipsia). If left untreated in a timely manner, patients may encounter complications such as hyperosmolarity, renal failure, seizures, or coma. In severe cases, there is also an elevated risk of hypovolemic shock or even fatality due to inadequate circulating blood volume [11,12].According to reports, transient diabetes insipidus is typically observed in 1.6 %–34 % of patients following pituitary adenoma surgery, while permanent diabetes insipidus occurs in 0 %–2.7 % of patients under observation [13]. Postoperative diabetes insipidus (DI) in patients with pituitary adenoma is a well-documented phenomenon, and previous research has identified several preoperative risk factors. For instance, literature reports have indicated that the occurrence of postoperative DI is associated with intraoperative cerebrospinal fluid leakage, Cushing's disease, tumour size reduction, and changes in serum sodium levels. However, further investigation is warranted to establish a consensus on these factors [14,15]. In addition, these studies failed to provide a comprehensive multifactorial prediction of the probability of postoperative diabetes insipidus. Timely prediction and management of postoperative diabetes insipidus (DI) patients can significantly enhance patient prognosis, reduce hospitalization duration, and mitigate treatment expenses.

This retrospective study analysed the medical records of 281 patients with pituitary adenoma who underwent surgical resection at our hospital between October 2020 and October 2022, investigating the factors associated with diabetes insipidus in patients following transnasal sphenoidal neuroendoscopic resection. This study aimed to construct a risk prediction model for diabetes insipidus, enabling early identification of high-risk postoperative patients and facilitating the development of scientifically sound intervention measures. The findings serve as a reference for future research endeavors.

2. Material and methods

2.1. Research objects

From October 2020 to October 2022, 281 patients with pituitary adenomas underwent neuroendoscopic transsphenoidal resection in our hospital. For all patients, the pathological diagnosis criteria for pituitary adenomas were fulfilled. There were 152 males with a median (interquartile range) age of 54 (43.25–64) years and 129 females with a median age of 53 (40.5–59.5) years.

2.2. Inclusion criteria

(1) Patients diagnosed with pituitary adenoma underwent endoscopic transsphenoidal resection at the Department of Neurosurgery in our hospital between October 2020 and October 2022.
(2) The postoperative histopathological findings revealed the presence of a pituitary adenoma.
(3) There was comprehensive patient clinical and imaging data pre- and post-surgery.

2.3. Exclusion criteria

(1) Patients who underwent prior treatment before undergoing transsphenoidal resection of a pituitary adenoma via neuroendoscopy.
(2) Patients diagnosed with diabetes insipidus prior to transnasal sphenoidal resection of pituitary adenoma using neuroendoscopy.
(3) Patients with incomplete preservation of case data.

2.4. Diagnosis of diabetes insipidus

(1) The urinary volume exceeds 4000 mL within a 24-h period.
(2) Plasma osmotic pressure exceeding 300 mmol/L, or urine osmotic pressure below 300 mmol/L.
(3) The urinary specific gravity is less than 1.005.
(4) Insufficient water intake is frequently associated with hypernatremia and hyperuricemia.
(5) The administration of stimuli to induce vasopressin release does not lead to a reduction in urine output.
(6) The administration of arginine vasopressin has demonstrated significant effects, characterized by a reduction in urine volume and an elevation in both urine specific gravity and osmolality.

2.5. Nomogram construction

The clinical data of the patients were analysed using R software (version 4.1.0) and the R language package "rms" (version 4.1.0). The following formula was used to construct a risk profile for breakdown and to test the profile: "fit1<-lrm(ins ~ dia + hyp + car + cor + sod + pot + cfl + tex, data = mydata,x = T,y = T),nom1 <- nomogram(fit1, fun = plogis,fun.at = c(0.001, 0.01, 0.05, seq(0.1,0.9, by = 0.1), 0.95, 0.99, 0.999), l*P*=F, funlabel = "Diabetes insipidus rate")".

2.6. Statistical analysis

Calculations and analysis were performed using SPSS27.0 statistical software. The Shapiro-Wilk test was employed to assess the normality of the distribution of the measurement data. Mean ± standard deviation was used to represent measurement data that followed a normal distribution and an independent sample *t*-test was utilized for between-group comparisons. The measurement data that deviated from the orthometric distribution were represented by the median (inter-quartile range) and the inter-group comparison was conducted using the non-parametric Mann-Whitney *U* test. The statistical data was analysed using the chi-square test, followed by logistic analysis to identify independent influencing factors of diabetes insipidus after resecting pituitary adenoma with a neuro-endoscope, for factors showing statistical significance ($P < 0.05$). The statistical significance of differences are indicated by a *P*-value less than 0.05.

3. Results

3.1. Fundamental characteristics of the research patients

Among the 281 patients with pituitary adenoma who underwent endoscopic transnasal sphenectomy, there were 152 males (56 with diabetes insipidus, accounting for 36.84 %) and 129 females (44 with diabetes insipidus, accounting for 34.11 %). The sex distribution did not show any significant disparity between the two groups. The median age of the patients was 53 (42,60) years, those with diabetes insipidus had a median age of 53 (41.25,63.75) years, and those without diabetes insipidus had a median age of 53 (42,60) years. The age distribution did not exhibit any statistically significant disparity between the two groups. The variables including body mass index, first onset, duration of disease, hyperlipidaemia, renal insufficiency, hyperuricaemia, serum sodium level, serum potassium level, serum chlorine level, serum urea nitrogen level, serum cortisol level, free triiodothyronine level and serum free thyroxine level were not statistically significantly different between the diabetes insipidus group and the non-diabetes insipidus group in terms of their association with pituitary adenoma size during surgery, total resection of tumour or occurrence of pituitary stroke.

Table 1
Basic characteristics of patients with pituitary tumor.

Variable	Diabetes insipidus group n = 100	No diabetes insipidus group n = 181	*P* value
Gender			
Male	56(56 %)	96(53.04 %)	0.633
Female	44(44 %)	85(46.96 %)	
Age(years)	53(41.25,63.75)	53(42,60)	0.835
Body mass index	24.49(22.60,27.44)	24.34(22.49,26.66)	0.433
First onset			
YES	9(9 %)	13(7.18 %)	0.587
NO	91(91 %)	168(92.82 %)	
Duration of disease (years)	0.55(0.10,2)	0.6(0.10,2)	0.554
Diabetes			
YES	36(36 %)	27(14.92 %)	<0.001
NO	64(64 %)	154(85.08)	
Hypertension			
YES	44(44 %)	49(27.07)	0.004
NO	56(56 %)	132(72.93 %)	
Hyperlipemia			
YES	53(53 %)	84(46.41 %)	0.290
NO	47(47 %)	97(53.59 %)	
Cardiopathy			
YES	15(15 %)	13(7.18 %)	0.040
NO	85(85 %)	168(92.82 %)	
Hypohepatia			
YES	20(20 %)	17(3.87 %)	0.014
NO	80(80 %)	164(94.13 %)	
Renal insufficiency			
YES	9(9 %)	16(8.84 %)	0.964
NO	91(91 %)	165(91.16 %)	
Hyperuricemia			
YES	14(14 %)	34(18.78 %)	0.308
NO	86(86 %)	147(81.22 %)	

Statistically significant differences were observed for diabetes, hypertension, cardiopathy, hypohepatia, postoperative variation of serum urea nitrogen, preoperative adrenocorticotropin and thyrotropin levels and their respective variations after surgery, duration of surgery, cerebrospinal fluid leakage, and tumour texture between the diabetes insipidus group and the non-diabetes insipidus group ($P < 0.05$). (Tables 1–3).The screening process for clinical data is shown in Fig. 1.

3.2. Univariate logistic regression analysis on the factors associated with postoperative diabetes insipidus

The occurrence of diabetes insipidus following neuroendoscopic resection of pituitary adenoma was not associated with sex, age, body mass index, initial onset, disease duration, hyperlipidaemia, renal insufficiency, hyperuricaemia, serum sodium level, serum potassium level, serum chloride level, serum urea nitrogen level, serum thyrotropin level, free triiodothyronine level, serum free thyroxine level, pituitary tumour volume, total tumour resection, or the presence of pituitary stroke ($P > 0.05$). An association was observed between diabetes, hypertension, cardiopathy, hypohepatia, preoperative adrenocorticotropin and cortisol levels, duration of surgery, postoperative cerebrospinal fluid leakage, and tumour texture ($P < 0.05$) (Tables 4–6).

3.3. Multivariate logistic regression analysis was conducted to identify the independent factors associated with postoperative diabetes insipidus

Results of the multivariate logistic regression analysis: The presence of diabetes (B = 0.845, odds ratio [OR] 2.329, 95 % confidence interval [CI]: 161,4.673, $P = 0.017$), hypertension (B = 0.672, OR 1.958, 95 % CI: 1.035,3.705, $P = 0.039$, cardiopathy (B = 1.039, OR 2.826, 95 % CI: 1.142,6.991, $P = 0.02$), preoperative cortisol (B = 0.001, OR 1.001, 95 % CI: 1,1.002, $P = 0.038$), postoperative cerebrospinal fluid leakage (B = 1.121, OR 3.067, 95 % CI: 1.53,6.149, $P = 0.002$), and tumour texture characteristics (B = 0.776, OR 2.174, 95 % CI: 1.129,4.186, $P = 0.02$) were identified as independent factors associated with the development of diabetes insipidus following neuroendoscopic transsphenoidal pituitary adenoma resection(Table 7).

Table 2
Preoperative and postoperative laboratory examinations of patients with pituitary tumor.

Variable	Diabetes insipidus group n = 100	No diabetes insipidus group n = 181	*P* value
Serum sodium(mmol/L)			
pre-operation	140.5(138.75,142)	140.7(139.25,141.90)	0.792
Postoperative day	136.8(134.93,138.68)	136.5(134.35,138.35)	0.256
variation	−3.4(-5.80,-1.23)	−4.6(-6,-2.15)	0.109
Serum potassium(mmol/L)			
pre-operation	3.96(3.75,4.23)	4.04(3.85,4.23)	0.112
Postoperative day	3.79(3.55,4.08)	3.76(3.53,4.05)	0.673
variation	−0.19(-0.48,0.11)	−0.3(-0.55,0)	0.096
Serum chlorine(mmol/L)			
pre-operation	104.85(103.50,106.75)	105.2(103.60,106.90)	0.597
Postoperative day	102.3(99.90,104.90)	102.7(100.45,104.65)	0.981
variation	−2.5(-4.40,0.40)	−2.6(-4.40,-0.50)	0.544
Serum urea nitrogen(mmol/L)			
pre-operation	4.95(3.93,5.70)	5(4,5.85)	0.449
Postoperative day	4.95(4.03,6.15)	4.60(3.70,5.50)	0.095
variation	0(-1,1.48)	−0.4(-1.2,0.30)	0.006
Serum adrenocorticotropin(mmol/L)			
pre-operation	5.29(4.25,10.01)	5.44(3.63,7.62)	0.047
Postoperative day	3.66(1.90,6.60)	3.07(1.88,5.41)	0.207
variation	−2.48(-5.03,0.01)	−1.62(-4.11,0.06)	0.296
Serum cortisol(mmol/L)			
pre-operation	343.53(209.94,575.03)	310.41(192.13,440.56)	0.095
Postoperative day	850.20(437.87,1231.36)	665.32(423.25,1058.70)	0.341
variation	393.25(50.84,835.69)	394.26(78.68,813.86)	0.936
Serum TSH(mmol/L)			
pre-operation	1.33(0.77,2.19)	1.7(1.07,2.53)	0.024
Postoperative day	0.58(0.38,1.30)	0.67(0.45,1.07)	0.370
variation	−0.57(-1.17,-0.14)	−0.93(-1.51,-0.41)	0.002
Serum FT3(mmol/L)			
pre-operation	4.17(3.22,4.84)	4.18(3.68,4.84)	0.187
Postoperative day	2.59(2.19,2.98)	2.60(2.34,3.07)	0.221
variation	−1.55(-2.09,-0.67)	−1.54(-2.01,-1.16)	0.365
Serum FT4(mmol/L)			
pre-operation	14.30(11.85,16.38)	14.20(11.35,16.10)	0.651
Postoperative day	14.50(12.38,16.90)	14.10(11.75,16)	0.165
variation	0.50(-1.40,2.90)	0(-1.40,1.75)	0.168

Table 3
Operation of patients with pituitary tumor.

Variable	Diabetes insipidus group n = 100	No diabetes insipidus group n = 181	*P* value
Pituitary tumor information			
Anteroposterior diameter(cm)	2.1(1.60,2.68)	2.1(1.70,2.60)	0.687
Left-right diameter(cm)	1.7(1.40,2.28)	1.8(1.50,2.10)	0.357
Top and bottom diameter(cm)	1.75(1.20,2.28)	1.8(1.30,2.20)	0.507
Tumor volume(cm^3)	3.54(1.27,6.60)	3.52(1.99,5.19)	0.735
Time of operation(min)	110(95,133.75)	100(85,120)	0.005
Total resection of tumor			
YES	71(71 %)	109(60.22 %)	0.071
NO	29(29 %)	72(39.78 %)	
Pituitary apoplexy			
YES	18(18 %)	40(22.10 %)	0.463
NO	82(82 %)	141(77.90 %)	
Postoperative cerebrospinal fluid leakage			
YES	37(37 %)	23(12.71 %)	<0.001
NO	63(63 %)	158(87.29 %)	
Tumor texture			
tough	39(39 %)	44(24.31 %)	0.010
soft	61(61 %)	137(75.69 %)	

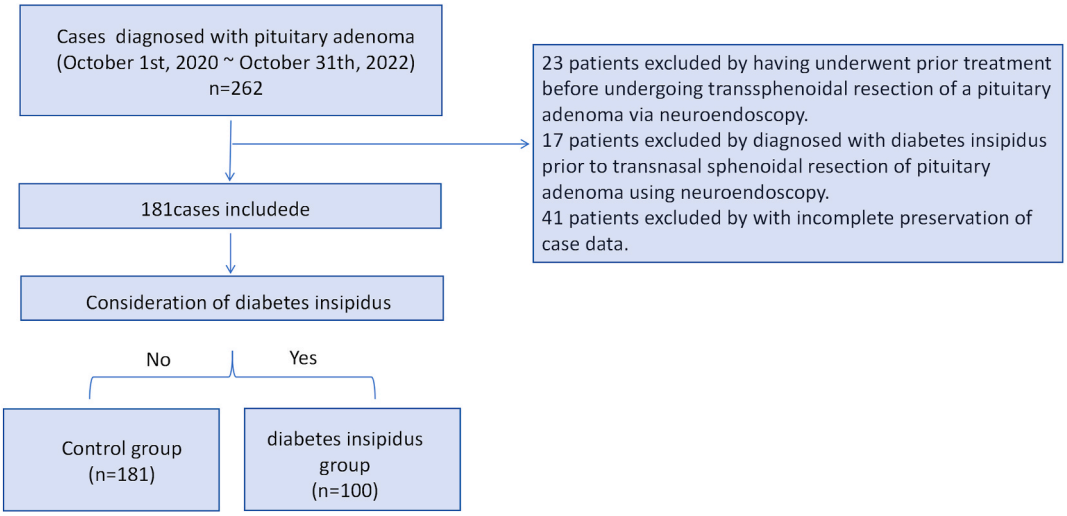


Fig. 1. Screening process of patients' clinical data for this study.

3.4. Development and verification of nomogram

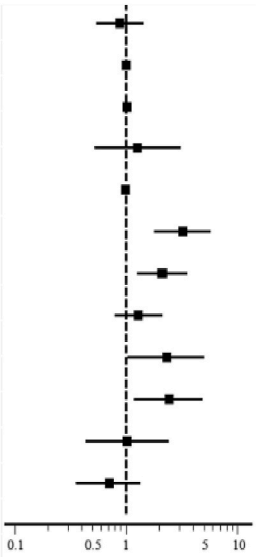
The construction of a nomogram was based on the multivariate logistic analysis (Fig. 2). For each patient undergoing endoscopic transnasal sphenoid surgery for pituitary adenoma removal, vertical lines were every variable, and the score points for each variable were recorded and subsequently summed up. Subsequently, the total score was compared against the probability scale for diabetes insipidus, enabling a final assessment of the probability of postoperative diabetes insipidus in the patients undergoing transnasal sphenoidal surgery for pituitary adenoma. The constructed multivariate logistic analysis lineup yielded an area under the curve (AUC) of 0.753 (95%CI: 0.694, 0.815; $P<0.001$) (Fig. 3A). The nomogram was subjected to calibration, which demonstrated excellent predictive accuracy (Fig. 3B).

4. Discussion

Pituitary adenomas constitute approximately 15 % of primary intracranial central nervous system tumours [16]. The neuroendoscopic transsphenoidal resection of pituitary adenoma represents the optimal therapeutic approach for patients requiring surgical intervention. Among these complications, diabetes insipidus is the most prevalent adverse outcome following transnasal sphenectomy of pituitary adenoma using neuroendoscopy [17]. Preoperative prediction of diabetes insipidus can facilitate the development of personalized surgical and therapeutic strategies by neurosurgeons. However, currently there is a lack of high-level tools to predict the incidence of diabetes insipidus following neuroendoscopic transsphenoidal pituitary adenoma resection. In this study, variables associated with postoperative diabetes insipidus identified through multivariate logistic regression analysis were integrated into a

Table 4
Univariate logistic regression analysis of basic characteristics of patients with pituitary tumor.

Variable	Senlitu	Odds Ratio (95 %)	*P* value
Gender		0.887(0.543,1.450)	0.633
Age(years)		1.002(0.984,1.020)	0.813
Body mass index		1.022(0.955,1.094)	0.522
First onset		1.278(0.526,3.104)	0.588
Duration of disease(years)		0.990(0.928,1.056)	0.757
Diabetes		3.208(1.800,5.718)	<0.001
Hypertension		2.117(1.267,3.536)	0.004
Hyperlipemia		1.302(0.798,2.124)	0.290
Cardiopathy		2.281(1.038,5.011)	0.040
Hypohepatia		2.412(1.198,4.855)	0.014
Renal insufficiency		1.020(0.433,2.400)	0.964
Hyperuricemia		0.704(0.358,1.358)	0.309



nomogram model to estimate the probability of patients developing diabetes insipidus over time after surgery.

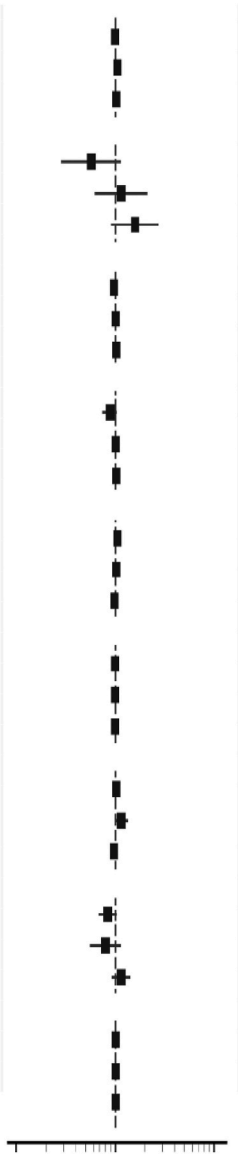
Currently, a plethora of studies have elucidated the risk factors associated with diabetes insipidus following surgical resection of pituitary adenomas. The study conducted by Yasuyuki et al. revealed a positive correlation between the incidence of diabetes insipidus following pituitary adenoma surgery and younger age of patients [10]. Additionally, Ajlan et al. demonstrated that individuals below 50 years old were at an increased risk for permanent diabetes insipidus after undergoing pituitary adenoma resection [18]. However, these findings are inconsistent with the results obtained in this study, which showed that there was no significant association between patients' age and the occurrence of diabetes insipidus following transnasal neuroendoscopic sphenotomy for pituitary adenoma ($P>0.05$). The median age of patients in the diabetes insipidus group was 53 years (range: 41.25–63.75), while in the non-diabetes insipidus group it was also 53 years (range: 42–60) ($P=0.835$). However, a detailed analysis is conducted on specific issues. Given that the patient population in this hospital exclusively comprises adults, it is plausible to consider potential disparities in sella development between children and adults. The surgical exposure range and operating space in pediatric patients are comparatively smaller than in adults, thereby posing an increased level of complexity to the surgical procedure. It is plausible that the inclusion of paediatric patients may yield divergent outcomes.

Schreckinger et al.[17]demonstrated a correlation between the size the of pituitary adenoma and postoperative diabetes insipidus, whereas Yasuyuki et al.[10]reported that larger tumour size was associated with an increased incidence of postoperative diabetes insipidus. However, these findings are inconsistent with the results obtained in our study. The present study demonstrated that the occurrence of diabetes insipidus in pituitary adenoma following transnasal sphenotomy by neuroendoscopy was not significantly associated with pituitary tumour volume. When the pituitary adenoma is very large, it can penetrate the suprasellar region and extend upwards by breaking through the sella septum due to limited volume in the sella. This not only poses challenges for pituitary adenoma surgery but also increases the risk of compression on the posterior pituitary gland and hypothalamus upon sudden decompression, leading to dysfunction of the pituitary portal system and a higher incidence of postoperative diabetes insipidus. The study conducted by Lin et al. demonstrated that alterations in the diameter of tumour cavities in the head and tail following transsphenoidal surgery may serve as a significant predictor for the development of diabetes insipidus among patients with pituitary adenoma [19]. This study demonstrated no significant correlation between pituitary tumour volume and the incidence of postoperative diabetes insipidus, which requires specific analysis. First, there were only seven patients with a giant pituitary adenomas with a diameter greater than 3 cm, including three (3 %) in the diabetes insipidus group and four (2.2 %) in the non-diabetes insipidus group, making it difficult to draw conclusive comparisons. Second, our hospital has a relatively high medical standard in China, and our doctors are proficient in neuroendoscopic transsphenoidal resection techniques for pituitary adenoma. Therefore, surgical difficulty caused by large tumours does not significantly affect patient prognosis. Furthermore, the univariate analysis in this study revealed significant associations between the duration of the surgical procedure、hypohepatia and the pre-operative serum adrenocorticotropin levels with post-operative diabetes insipidus; however, these variables did not emerge as independent influencing factors of postoperative diabetes insipidus according to the multivariate logistic regression analysis.

Carolina et al. demonstrated that the occurrence of diabetes insipidus following pituitary adenoma resection was associated with the skill level of the operator and the presence of cerebrospinal fluid leakage, independent of serum adrenocorticotropin secretion [20], which aligns with our study findings. Hypohepatia can lead to reduced inactivation of angiotensin enzymes, resulting in

Table 5
Univariate logistic regression analysis of preoperative and postoperative laboratory examinations of patients with pituitary tumor.

Variable	Senlitu	Odds Ratio (95 %)	*P* value
Serum sodium(mmol/L)			
pre-operation		1.006(0.933,1.083)	0.883
Postoperative day		1.052(0.978,1.131)	0.175
Variation		1.030(0.977,1.085)	0.273
Serum potassium(mmol/L)			
Pre-operation		0.573(0.286,1.151)	0.118
Postoperative day		1.154(0.622,2.143)	0.650
Variation		1.602(0.916,2.802)	0.098
Serum chlorine(mmol/L)			
Pre-operation		0.978(0.890,1.075)	0.644
Postoperative day		1.016(0.945,1.093)	0.668
Variation		1.03(0.957,1.108)	0.431
Serum urea nitrogen(mmol/L)			
Pre-operation		0.883(0.743,1.051)	0.161
Postoperative day		1.007(0.948,1.068)	0.830
Variation		1.022(0.96,1.088)	0.487
Serum adrenocorticotropin(mmol/L)			
Pre-operation		1.050(1.013,1.088)	0.007
Postoperative day		1.027(0.994,1.06)	0.111
Variation		0.988(0.96,1.016)	0.387
Serum cortisol(mmol/L)			
Pre-operation		1.002(1.001,1.003)	0.003
Postoperative day		1(1,1.001)	0.375
Variation		1(0.999,1)	0.504
Serum TSH(mmol/L)			
Pre-operation		1.024(0.987,1.063)	0.204
Postoperative day		1.153(0.984,1.35)	0.079
Variation		0.977(0.94,1.016)	0.243
Serum FT3(mmol/L)			
Pre-operation		0.846(0.689,1.037)	0.108
Postoperative day		0.798(0.554,1.15)	0.227
Variation		1.152(0.921,1.441)	0.215
Serum FT4(mmol/L)			
Pre-operation		1.010(0.965,1.057)	0.662
Postoperative day		1.018(0.975,1.063)	0.411
Variation		1.011(0.965,1.058)	0.648



decreased levels of these enzymes in the blood, thereby potentially contributing to diabetes insipidus; however, this may not be an independent factor influencing its occurrence after pituitary adenoma surgery [21]. The multivariate logistic regression analysis in this study revealed that diabetes, hypertension, cardiopathy, preoperative serum cortisol level, postoperative cerebrospinal fluid leakage, and tumour texture were independent factors influencing the development of diabetes insipidus following neuroendoscopic transsphenoidal pituitary adenoma resection. The stability of patient fluid balance can be easily compromised by comorbidities such as diabetes, hypertension, and cardiopathy [21–24], which may contribute to the increased incidence of diabetes insipidus. Moreover, during the transnasal sphenoidal resection of pituitary adenoma using a neuroendoscope, it was observed that the pituitary adenoma typically had a soft texture and presented as an erosive paste. Following the opening of the dural membrane at the base of the saddle, gentle scraping with a spoon-like instrument facilitated tumour removal. However, in patients where the pituitary adenoma had a hard texture, its extraction could potentially cause traction on surrounding structures leading to possible damage to the posterior pituitary lobe and pituitary stalk, resulting in diabetes insipidus. These findings align with our findings. In this study, a nomogram model was developed based on the findings of multivariate logistic regression analysis using patient scores to accurately predict the risk of diabetes insipidus following pituitary tumour surgery.

Table 6
Univariate logistic regression analysis of operation of patients with pituitary tumor.

Variable	Senlitu	Odds Ratio (95 %)	*P* value
Pituitary tumor information			
Anteroposterior diameter(cm)		1.114(0.83,1.496)	0.471
Left-right diameter(cm)		0.821(0.578,1.167)	0.273
Top and bottom diameter(cm)		0.985(0.725,1.339)	0.924
Tumor volume(cm^3)		1.020(0.977,1.065)	0.362
Time of operation(min)		1.009(1.002,1.016)	0.012
Total resection of tumor		1.617(0.957,2.733)	0.072
Pituitary apoplexy		0.774(0.417,1.43)	0.417
cerebrospinal fluid leakage		4.035(2.221,7.328)	0.001
Tumor texture		1.991(1.176,3.369)	0.01

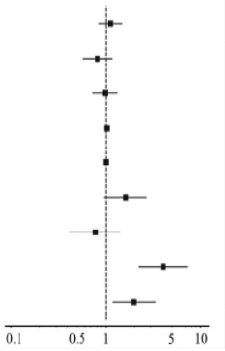
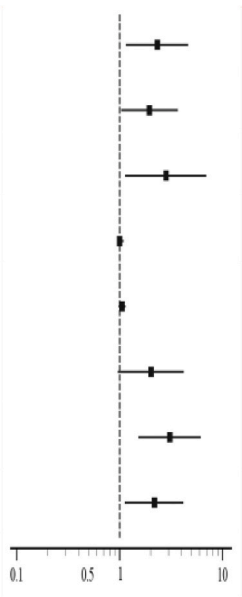


Table 7
Multivariate logistic regression analysis of factors associated with diabetes insipidus after neuroendoscopic transsphenotomy of pituitary adenoma.

Variable	B	Senlitu	Odds Ratio (95 %)	*P* value
Diabetes	0.845		2.329(1.161,4.673)	0.017
Hypertension	0.672		1.958(1.035,3.705)	0.039
Cardiopathy	1.039		2.826(1.142,6.991)	0.025
Preoperative cortisol(mmol/L)	0.001		1.001(1,1.002)	0.038
Postoperative serum sodium(mmol/L)	0.060		1.062(0.98,1.151)	0.142
Postoperative serum potassium(mmol/L)	0.702		2.017(0.963,4.225)	0.063
Cerebrospinal fluid leakage	1.121		3.067(1.53,6.149)	0.002
Tumor texture	0.776		2.174(1.129,4.186)	0.020



However, it is important to acknowledge limitations in this study. First, being a single-center study with a limited sample size, there may be inherent biases in the results. Therefore, caution should be exercised when applying the nomogram for predicting the risk of diabetes insipidus after neuroendoscopic transnasal sphenectomy of a pituitary adenoma, and individualized analysis is recommended. Second, due to inadequate sample size, no separate training set or verification set was established to validate the predictive accuracy of the model. In future studies, efforts will be made to expand the sample size by collecting more data and collaborating with multiple research centres to enhance the reliability of the findings.

5. Conclusions

The findings of this study indicate that diabetes, hypertension, cardiopathy, preoperative cortisol levels, postoperative cerebrospinal fluid leakage, and tumour texture are independent factors influencing the development of diabetes insipidus following transnasal sphenectomy for pituitary adenoma using neuroendoscopy. In this study, we have developed a practical and reliable nomogram to predict the risk of post-surgical diabetes insipidus. The predictive model based on the aforementioned risk factors can be considered for implementation in clinical practice to effectively evaluate the risk of postoperative diabetes insipidus and implement targeted

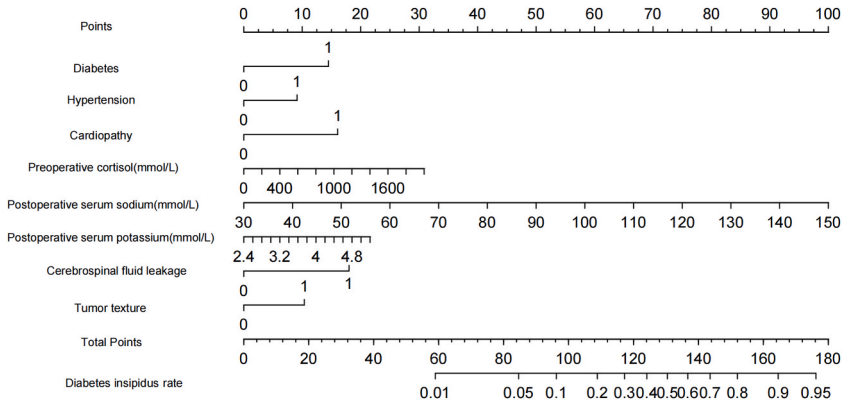


Fig. 2. Nomogram for predicting the proportion of diabetes insipidus after transnasal sphenoidal resection of pituitary adenoma by neuroendoscope.

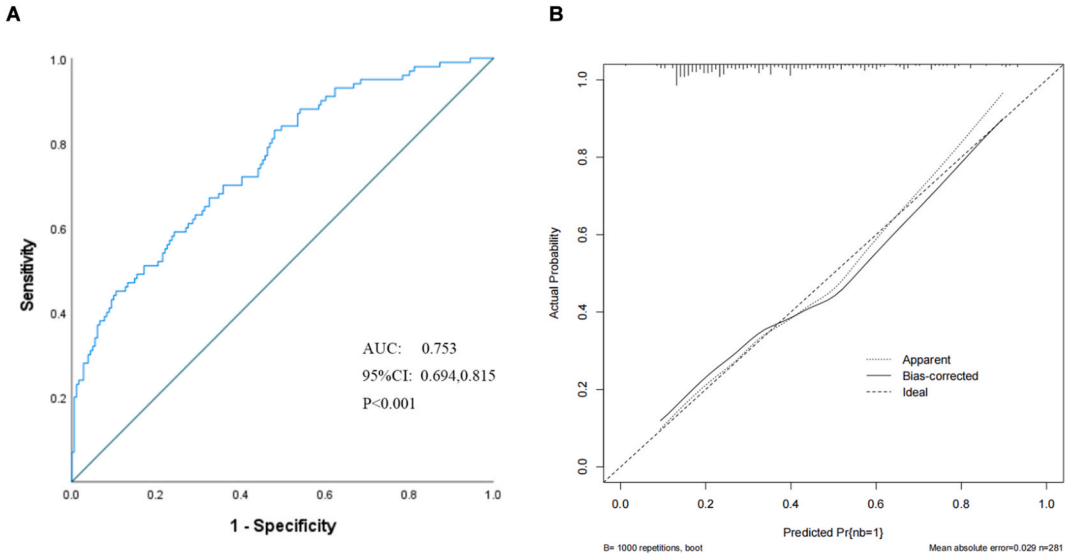


Fig. 3. Predictive performance of the nomogram. A. ROC analysis of the nomogram. B. Calibration of the nomogram.

interventions to mitigate its occurrence. However, it is crucial to emphasize that personalized management remains essential due to the unique characteristics of each patient's condition.

Ethical statement

The research involving human subjects underwent review and approval by hospital research ethics committees of Drum Tower Hospital (No. 20180323). We ensure that the work involving the use of human subjects described herein is conducted in strict adherence to the World Medical Association's Code of Ethics for experiments involving humans (Declaration of Helsinki). This study followed STROBE guidelines. Informed consent from patients was waived due to the retrospective nature of the analysis and use of non-identified data.

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Data availability statement

The original data for this article may be provided upon reasonable request of the corresponding author.

CRediT authorship contribution statement

Xiao-Jian Li: Writing – original draft, Software, Investigation, Data curation. **Zheng Peng:** Writing – original draft, Investigation, Data curation. **Yun-Feng Wang:** Resources, Formal analysis, Data curation, Conceptualization. **Jie Wang:** Visualization, Validation, Software, Formal analysis. **Hui-Ying Yan:** Visualization, Validation, Software, Investigation. **Wei Jin:** Validation, Methodology. **Zong Zhuang:** Validation, Resources, Conceptualization. **Chun-Hua Hang:** Writing – review & editing, Validation, Supervision, Project administration, Methodology. **Wei Li:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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