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Original Article

Analysis of factors influencing cerebral hyperperfusion syndrome after stent thrombectomy in patients with acute ischemic stroke due to large vessel occlusion: a retrospective study

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Abstract: Objective: To analyze the factors influencing symptomatic cerebral hyperperfusion syndrome (CHS) after stent thrombectomy in patients with acute ischemic stroke due to large vessel occlusion (AIS-LVO) and to provide a basis for clinical prevention and treatment. Methods: A retrospective analysis was conducted on the clinical data of 98 patients with AIS-LVO who underwent stent thrombectomy at The First People's Hospital of Yinchuan from January 2020 to January 2025. Patients were divided into a normal group (n = 82) and a CHS group (n = 16) based on the occurrence of symptomatic CHS within 7 days postoperatively. Clinical baseline data were collected, and univariate analysis and multivariate logistic regression analysis were used to identify risk factors for postoperative CHS. Results: Univariate analysis showed that the CHS group had higher proportions of patients with hypertension, diabetes, moderate to severe vascular stenosis, and poor collateral circulation, as well as higher admission blood glucose levels, but a lower Alberta Stroke Program Early CT Score (ASPECTS) compared with the normal group. Multivariate logistic regression analysis revealed that hypertension (odds ratio, OR = 3.876), admission hyperglycemia (OR = 3.645), poor collateral circulation (OR = 2.368), and moderate to severe vascular stenosis (OR = 3.392) were independent risk factors for postoperative CHS, while a higher ASPECTS (OR = 0.617) was a protective factor (all $P < 0.05$). Regarding prognosis, the CHS group had a significantly higher incidence of symptomatic intracranial hemorrhage (31.25% vs. 4.88%, $\chi^2 = 8.647$, $P = 0.003$) and a significantly lower rate of good functional outcome at 90 days (modified Rankin Scale ≤ 2) (37.50% vs. 79.27%, $\chi^2 = 11.034$, $P = 0.001$) compared with the normal group. The hospitalization time was longer in the CHS group than that in the normal group (21.38 ± 5.62 days vs. 14.25 ± 4.17 days, $t = 4.216$, $P < 0.001$). However, no significant difference was observed in in-hospital mortality between the two groups ($P = 0.664$). Conclusion: Hypertension, admission hyperglycemia, poor collateral circulation, and moderate to severe vascular stenosis are independent risk factors for symptomatic CHS after stent thrombectomy in patients with AIS-LVO, whereas a higher ASPECTS score is a protective factor. Clinical monitoring and intervention should be strengthened for patients with these risk factors to reduce the risk of postoperative CHS.

Keywords: Acute large vessel occlusive stroke, stent thrombectomy, cerebral hyperperfusion syndrome, vascular stenosis, poor collateral circulation

Introduction

Acute ischemic stroke due to large vessel occlusion (AIS-LVO) is one of the diseases with the highest mortality and disability rates among severe neurological disorders. It is a series of clinical syndromes resulting from acute ischemia and hypoxia of brain tissues due to sudden embolization or thrombosis of large intracranial arteries, leading to irreversible neurological damage [1, 2]. Studies have shown that there are more than 10 million new ischemic stroke patients worldwide each year, of which about 30-40% are large vessel occlusions. Stent thrombectomy, as the preferred recanalization strategy for AIS-LVO, can significantly improve patient prognosis, but postoperative complications still significantly limit its clinical

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benefits [3, 4]. As one of the most dangerous complications after stent thrombectomy, cerebral hyperperfusion syndrome (CHS) is mainly manifested as a sharp increase in postoperative cerebral blood flow (CBF) that exceeds the capacity of cerebrovascular autoregulation, leading to cerebral edema, increased intracranial pressure, and even intracranial hemorrhage. The incidence of CHS is about 5-15%, and it is closely associated with postoperative death and poor neurological prognosis [5]. Data show that the 90-day mortality rate in AIS-LVO patients with hyperperfusion is nearly three times as high as that in patients without hyperperfusion. Therefore, early identification and intervention for hyperperfusion risk factors are of great clinical significance for optimizing individualized treatment plans and improving the quality of life of patients [6].

At present, the diagnosis of CHS mainly depends on postoperative imaging examination and clinical symptom monitoring [7]. Although digital subtraction angiography and computed tomography (CT) perfusion imaging can accurately evaluate changes in cerebral hemodynamics, the real-time dynamic evaluation at the bedside is limited due to the complicated operation, high cost and intolerance to transport in some critically ill patients [8]. Therefore, early warning models based on clinical baseline data and laboratory indicators are still the main means to identify high-risk groups for hyperperfusion. Previous studies have confirmed that the history of hypertension, admission hyperglycemia, collateral circulation status, and degree of vascular stenosis are associated with postoperative hemodynamic disorders in patients with ischemic stroke. However, most studies have focused on the recovery of neurological function in the acute phase of stroke, and the systematic analysis of the specific complications of CHS after stent thrombectomy is still insufficient [9]. Based on this, this study retrospectively analyzed the clinical data of AIS-LVO patients undergoing stent thrombectomy to explore the independent risk factors for postoperative CHS. It aims to provide evidence-based basis for early identification of high-risk individuals and development of targeted intervention strategies, thereby reducing the incidence of hyperperfusion-related adverse events and improving the long-term neurological prognosis of patients.

Materials and methods

General information

The clinical data of 98 patients with AIS-LVO who underwent stent thrombectomy in our hospital from January 2020 to January 2025 were retrospectively analyzed. According to whether CHS occurred within 7 days after operation, the patients were divided into normal group (82 cases) and CHS group (16 cases). This study was approved by the Ethics Committee of The First People's Hospital of Yinchuan.

Inclusion criteria

(1) Age ≥ 18 years. (2) Patients with AIS-LVO confirmed by imaging examination and treated with stent thrombectomy in our hospital. (3) Onset-to-reperfusion time within 24 hours. (4) Complete clinical data, including imaging, laboratory examination, and follow-up data. (5) No medical disputes during hospitalization.

Exclusion criteria

(1) History of cerebrovascular disease or cerebrovascular surgery (note: these patients were excluded to minimize confounding factors in this exploratory study, which may limit the generalizability of the findings). (2) Concomitant with other serious systemic diseases (e.g., malignant tumors, severe liver or kidney dysfunction). (3) Any history of intracranial hemorrhage, including hemorrhagic stroke, before admission. (4) Incomplete clinical data or inability to obtain key research indicators. (5) Lactating or pregnant women. (6) Lost to follow-up.

Data collection

The general information and clinical data of patients were collected through the hospital's electronic medical record system. Baseline data included age, gender, body mass index, smoking history, alcohol consumption history, past medical history (hypertension, diabetes, atrial fibrillation, etc.), systolic blood pressure and diastolic blood pressure at admission, time from onset to admission, time from onset to recanalization, etc.

Imaging data: All patients underwent head CT scan and CT angiography after admission. The following indicators were independently evaluated and recorded by two experienced radiologists:

Alberta Stroke Program Early CT Score (ASPECTS): The standard 10-point scoring system was used to evaluate the degree of early ischemic changes.

Collateral circulation status: According to the results of CT angiography or digital subtraction angiography, collateral circulation was classified as good or poor.

Degree of vascular stenosis: According to the imaging results, the degree of stenosis of the responsible vessel was evaluated and classified as mild (< 50%), moderate (50-69%), severe (≥ 70%) or occlusion.

Laboratory indicators: Fasting venous blood was collected within 24 hours after admission. Blood routine indicators were measured by an automatic blood analyzer (e.g., Sysmex XN series). Blood glucose levels at admission were measured by the hexokinase method (biochemical analyzer, e.g., Roche Cobas series). Related serological markers were detected by enzyme-linked immunosorbent assay or chemiluminescence.

Prognostic indicators

Symptomatic intracranial hemorrhage: At 24-72 hours after operation, head CT was reviewed. According to the European Cooperative Acute Stroke Study II criteria, symptomatic intracranial hemorrhage was defined as imaging showing intracranial hemorrhage accompanied by neurological deterioration (National Institutes of Health Stroke Scale [NIHSS] score increase ≥ 4 points).

Neurological functional outcome: At 90 days after operation, neurological recovery was evaluated using the modified Rankin Scale (mRS) score. 0-2 points were defined as good outcome, and 3-6 points as poor outcome [10].

Hospitalization time: The total hospitalization days from admission to discharge were recorded.

Mortality during hospitalization: All-cause mortality during hospitalization was recorded.

Observation indicators

Primary outcome measure: The primary outcome was defined as CHS occurring within 7 days postoperatively, diagnosed according to the American Heart Association/American Stroke Association guidelines for the diagnosis of hyperperfusion syndrome after revascularization procedures. The diagnostic criteria were as follows:

Imaging criteria: Postoperative CT perfusion or transcranial Doppler examination showing CBF increased by ≥ 100% compared with preoperative baseline levels, or mean flow velocity of the middle cerebral artery increased by ≥ 100%.

Clinical criteria: Presence of at least one of the following new or worsening symptoms within 7 days after surgery: ipsilateral headache, seizure, focal neurological deficit (e.g., hemiparesis, aphasia), or altered mental status, in the absence of cerebral ischemia or hemorrhage on follow-up imaging.

Importantly, asymptomatic CHS (defined as imaging evidence of CBF increase ≥ 100% without corresponding clinical symptoms) was not included as a primary outcome event in this study. Only patients meeting both imaging and clinical criteria (i.e., symptomatic CHS) were assigned to the CHS group.

Clinical baseline data were compared between the CHS group and the normal group. Univariate and multivariate Logistic regression analyses were performed to identify independent risk factors for CHS after stent thrombectomy in patients with AIS-LVO.

Secondary outcome measures: (1) The incidence of postoperative symptomatic intracranial hemorrhage was compared between the two groups. (2) The rate of good neurological functional outcome at 90 days postoperatively was compared between the two groups. (3) Hospitalization time and in-hospital mortality were compared between the two groups.

Statistical methods

SPSS 26.0 statistical software was used for data analysis. All continuous variables were first tested for normality using the Shapiro-Wilk test. Measurement data conforming to normal distribution were expressed as mean ± standard deviation ($\bar{x}$ ± sd), and comparisons between two groups were performed using the independent samples t-test (with t values reported). Measurement data that did not con-

Table 1. Comparison of baseline data between the two groups of patients

Item	Normal group (n = 82)	Hyperperfusion group (n = 16)	χ^2/t value	*P* value
Demographic characteristics				
Age (years)	65.28 ± 10.45	66.13 ± 11.02	0.302	0.763
Male [n (%)]	48 (58.54)	10 (62.50)	0.087	0.768
Clinical data				
Time from onset to admission (h)	3.52 ± 1.38	3.61 ± 1.42	0.241	0.810
History of hypertension [n (%)]	46 (56.10)	11 (68.75)	4.877	0.027
History of diabetes [n (%)]	18 (21.95)	5 (31.25)	0.648	0.421
History of atrial fibrillation [n (%)]	29 (35.37)	6 (37.50)	0.026	0.872
Smoking history [n (%)]	34 (41.46)	7 (43.75)	0.029	0.864
Drinking history [n (%)]	26 (31.71)	5 (31.25)	0.001	0.971
Preoperative systolic blood pressure (mmHg)	145.32 ± 18.64	148.75 ± 19.23	0.678	0.499
Preoperative diastolic blood pressure (mmHg)	86.75 ± 11.32	88.19 ± 12.05	0.468	0.641
Laboratory indicators				
Total cholesterol (mmol/L)	4.58 ± 1.12	4.71 ± 1.21	0.428	0.670
Triglyceride (mmol/L)	1.65 ± 0.58	1.72 ± 0.63	0.441	0.660
LDL-C (mmol/L)	2.85 ± 0.92	2.94 ± 0.98	0.363	0.718
HDL-C (mmol/L)	1.18 ± 0.31	1.15 ± 0.28	0.361	0.719
Admission blood glucose (mmol/L)	6.85 ± 2.13	8.46 ± 2.42	4.036	0.003

Note: LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

form to normal distribution were expressed as median (interquartile range) [M (Q1, Q3)], and comparisons between groups were performed using the Mann-Whitney U test (with Z values reported). Categorical data were expressed as number (percentage) [n (%)], and comparisons between groups were performed using the chi-square (χ^2) test or Fisher's exact probability method, as appropriate (with χ^2 values reported). Variables with $P < 0.05$ in univariate analysis were entered into a multivariate binary logistic regression model using the stepwise regression method for variable selection. The inclusion significance level was set at $\alpha = 0.05$, and the elimination level was set at $\alpha = 0.10$, to identify independent influencing factors for postoperative hyperperfusion. The odds ratio (OR) and 95% confidence interval (CI) were calculated for each factor. A two-tailed $P < 0.05$ was considered statistically significant.

Results

Comparison of baseline data between the two groups of patients

As shown in **Table 1**, there were no significant differences between the CHS group and the normal group in terms of demographic characteristics including age, gender, and clinical variables such as time from onset to admission, history of atrial fibrillation, smoking history, drinking history, preoperative systolic and diastolic blood pressure, as well as laboratory indicators including total cholesterol, triglycerides, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol (all $P > 0.05$). Regarding the history of diabetes, although the proportion was numerically higher in the CHS group (31.25% vs. 21.95%), the difference did not reach statistical significance ($\chi^2 = 0.648$, $P = 0.421$). However, significant differences were observed between the two groups in the history of hypertension ($\chi^2 = 4.877$, $P = 0.027$) and admission blood glucose level ($t = 4.036$, $P = 0.003$), both of which were higher in the CHS group.

Comparison of liver and kidney function and peripheral blood inflammatory factors between the two groups of patients

The comparison of liver and kidney function and peripheral blood inflammatory factors between the two groups showed that there was no significant difference in liver and kidney function indexes such as alanine aminotransferase, aspartate aminotransferase, creatinine

Table 2. Comparison of liver and kidney function and peripheral blood inflammatory factors between the two groups of patients

Item	Normal group (n = 82)	Hyperperfusion group (n = 16)	t value	*P* value
Liver function				
Alanine aminotransferase (U/L)	24.56 ± 8.72	25.13 ± 9.04	0.242	0.809
Aspartate aminotransferase (U/L)	26.83 ± 9.45	27.42 ± 10.13	0.229	0.819
Renal function				
Creatinine (μmol/L)	72.45 ± 18.32	74.21 ± 19.56	0.353	0.725
Urea nitrogen (mmol/L)	5.38 ± 1.65	5.52 ± 1.73	0.316	0.753
Peripheral blood inflammatory factors				
Hypersensitive C-reactive protein (mg/L)	4.32 ± 2.15	4.89 ± 2.43	0.963	0.338
White blood cell count ($\times 10^9$/L)	7.85 ± 2.34	8.21 ± 2.51	0.568	0.571
Neutrophil count ($\times 10^9$/L)	5.62 ± 2.08	5.98 ± 2.21	0.641	0.523

Table 3. Comparison of imaging features between the two groups of patients

Item	Normal group (n = 82)	Hyperperfusion group (n = 16)	Statistical value (t/χ^2)	*P* value
ASPECTS score (points, Mean ± SD)	8.45 ± 1.23	7.31 ± 1.52	3.258	0.002
Poor collateral circulation [n (%)]	21 (25.61)	9 (56.25)	6.104	0.013
Moderate to severe vascular stenosis [n (%)]	28 (34.15)	11 (68.75)	6.817	0.009
Infarction site [n (%)]			0.158	0.691
Anterior circulation	65 (79.27)	12 (75.00)		
Posterior circulation	17 (20.73)	4 (25.00)		

Note: ASPECTS, Alberta Stroke Program Early CT Score; poor collateral circulation refers to American Society of Interventional and Therapeutic Neuroradiology/Society of Interventional Radiology grade 0-2; moderate to severe vascular stenosis refers to stenosis degree ≥ 50%.

and blood urea nitrogen (P > 0.05). In terms of inflammatory indicators, there was no significant difference in the levels of high-sensitivity C-reactive protein, white blood cell count and neutrophil count between the two groups (all P > 0.05), suggesting that the two groups were balanced and comparable in systemic inflammatory response status and liver and kidney function metabolism at admission (**Table 2**).

Comparison of imaging features between the two groups of patients

As shown in **Table 3**, the CHS group had significantly lower ASPECTS scores compared with the normal group (7.31 ± 1.52 vs. 8.45 ± 1.23, t = 3.258, P = 0.002). The proportions of patients with poor collateral circulation (56.25% vs. 25.61%, χ^2 = 6.104, P = 0.013) and moderate to severe vascular stenosis (68.75% vs. 34.15%, χ^2 = 6.817, P = 0.009) were significantly higher in the CHS group. However, no significant difference was observed in infarction site distribution between the two groups (χ^2 = 0.158, P = 0.691).

Multivariate analysis of symptomatic CHS after stent thrombectomy in patients with AIS-LVO

Variables with statistically significant differences in univariate analysis, including hypertension, admission blood glucose, ASPECTS score, poor collateral circulation, and moderate to severe vascular stenosis, were entered into a multivariate logistic regression model to identify independent predictors of symptomatic CHS after stent thrombectomy. The results demonstrated that hypertension (OR = 3.876, 95% CI: 1.452-8.934, P = 0.008), admission hyperglycemia (OR = 3.645, 95% CI: 1.387-8.512, P = 0.012), poor collateral circulation (OR = 2.368, 95% CI: 1.124-5.673, P = 0.026), and moderate to severe vascular stenosis (OR = 3.392, 95% CI: 1.468-7.856, P = 0.009) were independent risk factors, while a higher ASPECTS score (OR = 0.617, 95% CI: 0.412-0.896, P = 0.015) was an independent protective factor.

Table 4. Variable assignment for multivariate logistic regression analysis

Variable name	Meaning of variable	Description of assignment
Dependent variable		
Hyperperfusion	Whether hyperperfusion occurred within 7 days after operation	0 = no (normal group), 1 = yes (hyperperfusion group)
Independent variable		
Hypertension	Have a history of hypertension	0 = No, 1 = Yes
Hyperglycemia at admission	Blood glucose level on admission	Continuous variable; original value entered directly
ASPECTS score	Alberta Stroke Program Early CT Score	Continuous variable; original value entered directly
Poor collateral circulation	Classification of collateral circulation	0 = good (ASITN/SIR grade 3-4), 1 = poor (ASITN/SIR grade 0-2)
Moderate to severe vascular stenosis	The degree of responsible vascular stenosis	0 = mild (stenosis rate < 50%), 1 = moderate to severe (stenosis rate ≥ 50%)

Table 5. Multivariate Logistic regression analysis of postoperative hyperperfusion

Variables	B value	SE	Wald χ^2	OR value	95% confidence interval	*P* value
Hypertension	1.354	0.512	6.998	3.876	1.452-8.934	0.008
Hyperglycemia at admission	1.294	0.483	7.185	3.645	1.387-8.512	0.012
Poor collateral circulation	0.862	0.386	4.986	2.368	1.124-5.673	0.026
Moderate to severe vascular stenosis	1.221	0.467	6.835	3.392	1.468-7.856	0.009
ASPECTS score	-0.483	0.198	5.951	0.617	0.412-0.896	0.015
Constant	-2.876	0.892	10.392	0.056	-	< 0.001

Note: ASPECTS, Alberta Stroke Program Early CT Score; SE, standard error; OR, odds ratio.

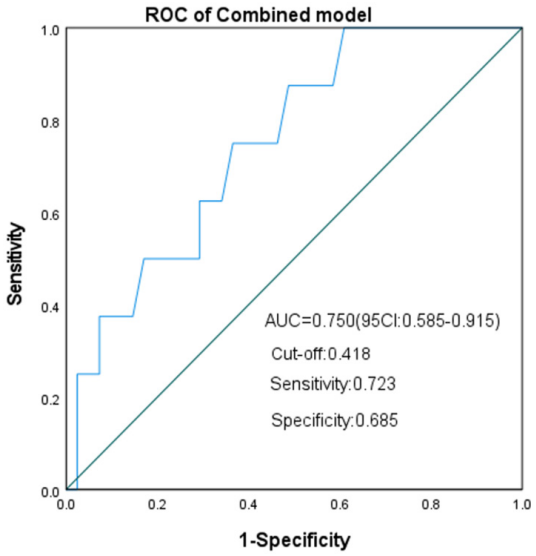

Figure 1. ROC curves of the combined model for predicting post-thrombectomy hyperperfusion. AUC, area under the curve; CI, confidence interval. The ROC curve analysis showed that the combined model had an AUC of 0.750. Using the optimal cutoff value of 0.418, the sensitivity and specificity of the combined model for predicting post-thrombectomy hyperperfusion were 72.3% and 68.5%, respectively.

Based on the multivariate logistic regression analysis, the prediction model for postoperative CHS was established as follows:

Logit(P) = -2.876 + 1.354 × (Hypertension) + 1.294 × (Hyperglycemia at admission) + 0.862 × (Poor collateral circulation) + 1.221 × (Moderate to severe vascular stenosis) - 0.483 × (ASPECTS score), where P represents the predicted probability of postoperative CHS. The predicted probability can be calculated as P = 1/[1 + exp(-Logit(P))]. This model may assist clinicians in identifying patients at high risk for CHS after stent thrombectomy (see **Tables 4** and **5**).

Establishment of a predictive model for symptomatic CHS after stent thrombectomy in patients with AIS-LVO

The results of this study showed that the area under the curve (AUC) of the CHS prediction curve after stent thrombectomy in patients with AIS-LVO was 0.750 (95% CI: 0.585-0.915), and the Hosmer-Lemeshow test chi-square value was 1.440 (P = 0.984), indicating that the model was stable (as shown in **Figure 1**).

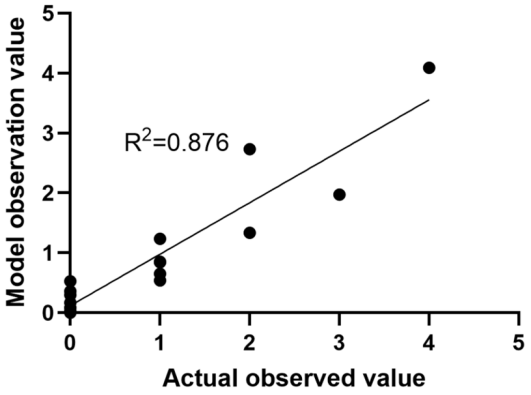

Figure 2. Correlation plot of predicted versus observed values. The diagonal line represents perfect agreement between predicted and observed probabilities. R^2 = 0.876, indicating good calibration accuracy.

Internal validation of the performance of the prediction model for symptomatic CHS after stent thrombectomy in patients with AIS-LVO

In this study, the accuracy of the prediction model was verified by the calibration curve. As shown in **Figure 2**, when compared with the observed probabilities, the probability distribution predicted by the model was very close to the diagonal, indicating a high degree of agreement between the predicted and actual values. The R^2 of the goodness-of-fit test was 0.876, indicating that the model explained 87.6% of the observed variation, confirming its good calibration accuracy. These results show that the prediction model established in this study not only has clinical identification ability but is also accurate and reliable, with high consistency between predicted risk and actual risk.

Postoperative intracranial hemorrhage and neurological function scores of the two groups of patients

The results of this study showed that the rate of intracranial hemorrhage in the CHS group was significantly higher than that in the normal group, while the 90-day mRS score (proportion of mRS ≤ 2) was significantly lower in the CHS group compared with the normal group (all P < 0.01) (see **Table 6**).

Comparison of hospitalization time and mortality between the two groups after operation

The results of this study showed that the length of hospital stay in the CHS group was significantly longer than that in the normal control group (P < 0.001). Statistical analysis showed that there was no significant difference in mortality between the two groups (P = 0.664) (see **Table 7**).

Discussion

In recent years, the incidence of AIS-LVO has been increasing, and stent thrombectomy, as a key treatment for restoring blood supply to ischemic brain tissue, has been widely used in clinical practice and achieved good results [11]. However, clinical work has found that some patients can be complicated with hyperperfusion after surgery, which can induce adverse outcomes such as intracranial hemorrhage and neurological deterioration, seriously affecting the prognosis of patients. Therefore, it is of great clinical significance to establish a reliable predictive model for early detection of high-risk patients and improvement of prognosis [12, 13].

Previous literature has confirmed that the incidence of CHS after stent thrombectomy is about 20%. The results of this study showed that the incidence of CHS within 7 days after operation was 16.33% in 98 patients, which was basically consistent with the incidence reported in previous studies [14]. The author's analysis of baseline data showed that the proportion of hypertension history and blood glucose level at admission in the CHS group were significantly higher than those in the normal group, suggesting that hypertension and hyperglycemia may be potential related factors for postoperative CHS, which is consistent with previous studies [15]. In addition, the analysis of imaging characteristics showed that the proportion of poor collateral circulation and moderate to severe vascular stenosis in the CHS group was significantly higher than that in the normal group, and the ASPECTS score was significantly lower than that in the normal group, suggesting that preoperative collateral compensatory ability, vascular stenosis and infarct core range were closely related to postoperative CHS. Multivariate Logistic regression analysis further clarified that hypertension, hyperglycemia at admission, poor collateral circulation, and moderate to severe vascular stenosis were independent risk factors for hyperperfusion after stent thrombectomy, while elevated ASPECTS score was an independent protective factor. The specific mechanism is as follows:

Table 6. Comparison of the incidence of symptomatic intracranial hemorrhage and 90-day prognosis between the two groups

Group	Number of cases	Incidence of symptomatic intracranial hemorrhage [n (%)]	Favorable prognosis rate (mRS ≤ 2) [n (%)]
Hyperperfusion group	16	5 (31.25)	6 (37.50)
Normal group	82	4 (4.88)	65 (79.27)
χ^2 value		8.647	11.034
P value		0.003	0.001

Table 7. Comparison of prognosis-related events between the two groups

Groups	Number of cases	Length of hospital stay (d, $\bar{x} \pm sd$)	Death during hospitalization [n (%)]
Hyperperfusion group	16	21.38 ± 5.62	1 (6.25)
Normal group	82	14.25 ± 4.17	1 (1.22)
t/χ^2 value		t = 4.216	χ^2 = 0.188
P value		< 0.001	0.664

patients with hypertension are in a state of elevated blood pressure for a long time, and the cerebrovascular autoregulation function is impaired. After stent thrombectomy, the blood vessels are reopened, and the local perfusion cannot be effectively adjusted after blood flow recovery, which easily leads to excessive perfusion of brain tissue. At the same time, long-term hypertension can lead to hardening of the cerebrovascular wall and decreased elasticity, further increasing the risk of hyperperfusion [16]. Hyperglycemia on admission can aggravate the oxidative stress response of ischemic brain tissue, damage cerebrovascular endothelial cells, and affect the automatic regulation of cerebrovascular function. At the same time, hyperglycemia can induce inflammatory response and aggravate cerebral ischemia-reperfusion injury, thereby increasing the incidence of CHS [17]. Poor collateral circulation and moderate to severe vascular stenosis, as mentioned above, directly increase the risk of CHS by affecting preoperative blood flow compensation and postoperative blood flow recovery rate. The increase of ASPECTS score indicates that the preoperative infarct core is small, the ischemic injury of brain tissue is mild, and the ischemic reperfusion injury after vascular recanalization is relatively mild. The cerebrovascular autoregulation function can better adapt to the changes of blood flow, thereby reducing the risk of hyperperfusion, which supports previous research reports [18, 19].

Previous studies have confirmed that the prediction model based on clinically accessible indicators can effectively identify patients with high risk of postoperative complications and provide a basis for clinical intervention [20]. In this study, five independent risk factors of hypertension, admission blood glucose, ASPECTS score, poor collateral circulation and moderate to severe vascular stenosis were used to establish a prediction model. The results showed that the AUC of the model was 0.750, suggesting that it had good clinical identification ability. At the same time, the model has good stability and high calibration. In addition, the advantage of this model is that the included indicators are all indicators that can be obtained by clinical routine examination and have high objectivity. They do not require additional examination costs, are easy to operate, and easy to be popularized and applied in medical institutions at all levels. It can help clinicians quickly identify patients with high risk of postoperative CHS, take intervention measures in advance, and reduce the incidence of CHS [21-23].

The author further analyzed the effect of postoperative CHS on the prognosis of patients. The results showed that the incidence of symptomatic intracranial hemorrhage in the CHS group was significantly higher than that in the normal group, the good prognosis rate at 90 days was significantly lower than that in the normal group, and the hospitalization time was significantly prolonged, suggesting that postoperative CHS can lead to poor prognosis and increase the hospitalization burden of patients, which is consistent with previous research results [24, 25]. The main mechanism of intracranial hemorrhage induced by CHS is that excessive perfusion leads to a sudden

increase in cerebral vascular pressure, and the damaged cerebral vascular wall cannot withstand the pressure change, and then rupture hemorrhage occurs. At the same time, ischemia-reperfusion injury caused by hyperperfusion will aggravate brain edema and vascular injury, further increasing the risk of intracranial hemorrhage [26]. Intracranial hemorrhage and brain tissue injury will directly affect the recovery of neurological function, leading to poor prognosis and prolonged hospital stay. It is worth noting that there was no significant difference in mortality between the two groups during hospitalization, which may be related to the small sample size and short follow-up time of this study, and the sample size needs to be expanded for further verification [27].

This study has several limitations. First, as a single-center retrospective study, selection bias and information bias were inevitable. Second, the sample size was relatively small (98 cases, with only 16 in the CHS group), which limited statistical power and generalizability. The small sample size not only increases the risk of type II errors (failing to detect true associations) but may also lead to instability and potential overestimation of the OR values derived from the multivariate logistic regression model. Therefore, the OR estimates should be interpreted with great caution, and the findings are primarily exploratory in nature. Consequently, internal validation (e.g., Bootstrap method) and subgroup analyses based on infarct site or stent type could not be performed. Third, the inclusion and exclusion criteria may have introduced bias, as patients with a history of cerebrovascular disease or surgery were excluded, and onset-to-reperfusion time was limited to within 24 hours without evaluating its impact on CHS. Fourth, the multivariate model did not adjust for important confounders such as surgical duration, Thrombolysis in Cerebral Infarction grading, postoperative blood pressure fluctuations, and past cerebrovascular history, nor did it examine the interaction between hypertension history and postoperative blood pressure control. Fifth, preoperative NIHSS scores were not collected, precluding analysis of the association between baseline neurological function and CHS risk or prognosis, and making it impossible to clarify the independent impact of CHS on neurological recovery. Sixth, different interventions and other potential risk factors (e.g., surgical approach, anesthetic management) were not analyzed. Seventh, the follow-up period was short, and long-term prognosis was not evaluated. Eighth, the construction and reporting of the prediction model have several limitations. Although the AUC, sensitivity, and specificity were reported, the complete regression prediction formula was not initially provided. Additionally, internal validation using the Bootstrap method was not performed due to the small sample size (only 16 cases in the CHS group), and external validation using an independent cohort was not conducted because of the single-center retrospective design. The model was also not transformed into visual tools (e.g., nomogram or risk scoring scale), limiting its direct clinical applicability. Therefore, the stability, reliability, and generalizability of the model require further verification. In summary, our findings should be interpreted as exploratory, and future multicenter prospective studies with larger sample sizes, standardized data collection (including preoperative NIHSS assessment and broader inclusion criteria), extended follow-up, external validation, and the development of user-friendly clinical tools are needed to refine the prediction model and validate the risk factors.

In summary, the incidence of CHS after stent thrombectomy in patients with AIS-LVO is high. Hypertension, hyperglycemia at admission, poor collateral circulation, and moderate to severe vascular stenosis are independent risk factors, and elevated ASPECTS score is an independent protective factor. The prediction model based on the above five indicators has good discrimination ability and calibration accuracy, which can effectively predict the risk of postoperative CHS. In clinical work, the above indicators of patients can be evaluated before surgery, high-risk groups can be identified, and targeted interventions (such as strengthening preoperative blood pressure and blood glucose control, optimizing surgical plans, etc.) can be taken to reduce the occurrence of postoperative CHS, decrease the risk of adverse outcomes such as intracranial hemorrhage, shorten the length of hospital stay, and improve the prognosis of patients.

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Disclosure of conflict of interest

None.

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