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Risk Factors of Post-Endarterectomy Hypertension and Influence on Clinical Outcome

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Abstract

Background: Discuss the risk factors for the occurrence of PEH and their influence on the clinical outcome by observing the influence of Post-Endarterectomy Hypertension (PEH) on the outcome of Carotid Endarterectomy (CEA).

Methods: A single-center retrospective cohort study was performed. The demographics, preoperative and postoperative outcomes of 140 patients receiving CEA were evaluated. Logistic regression analysis was performed to compare postoperative outcomes. Multivariate Logistic regression analysis was performed to determine the risk factors of PEH.

Results: 14 of 140 patients (10%) suffered PEH. Through univariate and multivariate logistic regression analysis, it was found that preoperative mean SBP>140 mmHg and glomerular filtration rate <90 ml/min may be the risk factors of PEH. In terms of clinical outcomes, patients with PEH had longer length of stay than patients without PEH (medians were 20 and 15 days respectively; P=0.002). There was no difference in perioperative complications during hospitalization (P=0.152). During the follow-up period, there was no significant statistical difference in the relevant postoperative complications (postoperative restenosis, reperfusion edema, nerve damage, and stroke) between the patients with PEH and the patients without PEH.

Conclusion: The length of stay of PEH patients increased significantly; however, among PEH patients, there was no significant difference in the adverse event rate between the perioperative period and the short-to-medium term. In addition, we concluded that preoperative mean SBP>140 mmHg and glomerular filtration rate <90 ml/min were the risk factors of PEH.

Keywords: Carotid endarterectomy; Post-endarterectomy hypertension; risk factors

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Introduction

In China, stroke (1.1 million) is the leading cause of death in the population, accounting for about one-sixth of the world's total deaths from stroke (6.5 million) [1]. It is estimated that 7~35% of ischemic strokes can be caused by extracranial carotid atherosclerotic disease [2], which is still a serious problem in the treatment of carotid artery diseases. Carotid Endarterectomy (CEA) is the main treatment method for patients with carotid artery stenosis, which can reduce the risks of ischemic stroke secondary to symptomatic moderate to severe carotid stenosis or asymptomatic severe carotid stenosis [3]. Current indications for treatment include symptomatic carotid artery stenosis ≥ 50% to 99%, and asymptomatic carotid artery stenosis ≥ 60% to 99% [4]. Previous studies have showed that Post-Endarterectomy Hypertension (PEH) usually occurs after CEA, and its risk factors include active smoking history, coronary heart disease history, or taking clopidogrel [5]. The pathogenesis of PEH may be the change in carotid baroreceptor function caused by cross-clipping of the carotid artery during operation, which may lead to congestive encephalopathy, cerebral hemorrhage or other complications [6,7]. This study aims to determine the risk factors of PEH and whether PEH will affect the short-term and medium-term outcomes of the patients.

Methods

Clinical data

A retrospective analysis was performed to the clinical data of patients with carotid artery stenosis who received CEA from August 2016 to June 2021.

Inclusion criteria: (1) Patients with carotid artery stenosis >50% as determined by imaging examination (carotid artery ultrasound, CTA) and with symptoms (TIA attack, etc.); (2) Patients with no obvious symptoms but with stenosis degree >70%; (3) Patients who did not receive other surgical treatment before CEA; (4) Patients who received blood routine examination on the day of admission or the next day; (5) Patients with complete clinical data. **Exclusion criteria:** (1) The position of carotid bifurcation is too high to effectively expose the field of view; (2) The intracranial segment of the internal carotid artery is completely occluded; (3) Severe cardiopulmonary diseases; (4) Severe dementia; (5) Coagulation disorders; (6) Progressive stroke within 3 months; (7) Patients who cannot tolerate anesthesia.

Finally, 140 eligible cases were included. Among them, there were 116 males (82.8%) and 24 females (17.2%), with an average age of 65.5 ± 7.9.

Perioperative treatment

The diagnosis of carotid artery stenosis was clear and the patients had the indications for surgery. The patients took antiplatelet drugs and lipid-lowering drugs before operation. Blood pressure was monitored twice a day. Blood pressure was strictly monitored after operation. ECG monitoring was given on the first day after operation, and subcutaneous drainage tube was removed on the second day after operation (as appropriate). For patients who had symptoms before operation, long-term or lifelong oral administration of antiplatelet drugs and lipid-lowering drugs is recommended after operation.

Surgical methods

After successful general anesthesia, the patient was placed in the supine position, with shoulder on the operation side raised and head tilted to the opposite side. The anterior edge of the sternocleidomastoid muscle was taken as the incision, sterile towel was laid after routine disinfection, the skin and platysma were incised and separated through the anterior edge of the sternocleidomastoid muscle, the facial artery was ligated and cut and carefully separated to the carotid sheath, and the hypoglossal nerves were protected. Basic Activated Clotting Time (ACT) of whole blood was measured, and about 60 U/kg ~ 80 U/kg heparin was intravenously injected for systemic heparinization, so as to expose common carotid artery, internal carotid artery, external carotid artery and superior thyroid artery. ACT was measured again, when the standard was reached (>250 s is required), the internal carotid artery was tried to be blocked, and TCD was performed to detect the intracranial blood flow. If the blood flows of the ipsilateral middle cerebral artery decreased by >50%, bypass was performed, and the blood pressure was increased to 20% ~ 30% of the basic value. Artery clamps were used to block the external carotid artery, superior thyroid artery, common carotid artery, and internal carotid artery respectively. The vessel was cut upward from the distal end of the common carotid artery to the proximal end of the internal carotid artery, the carotid artery intima and plaque were peeled off carefully and gently, and the lumen was fully flushed with sufficient heparin saline. The end of the intimal fragment was fixed with 6-0 Proline slip wire. If the diameter of the internal carotid artery is <4 mm, vascular patch and 5-0 Proline slip wire should be used to suture the carotid artery in full thickness, the internal carotid artery should be opened temporarily. After blood return was observed, complete suturing and knotting should be performed, and the internal carotid artery was blocked again. The external carotid artery, superior thyroid artery and common carotid artery were slowly opened. There was no blood leakage at the anastomosis site. After 1 min, the internal carotid artery was opened. Hemostatic microspheres and collagen sponge were placed around the anastomosis site to stop bleeding. There was no blood leakage at the anastomosis site. The pulsation of each artery was checked, which was good. After complete hemostasis, a drainage tube was inserted into the incision, which was led out from the lower end of the incision. After the devices were checked without error, the incision was sutured layer by layer.

Observation indicators

The patient's admissions Systolic Blood Pressure (SBP), preoperative mean SBP and peak SBP were recorded. The patient's preoperative hypertension is defined as the preoperative mean SBP ≥ 140 mmHg, and the patient's blood pressure was monitored 3 times a day during the postoperative hospitalization period. PEH is defined as an acute elevation of SBP>170 mmHg or a persistent SBP>150 mmHg in the ward, and for which a cardiovascular physician is consulted. The patients were advised to visit the hospital for reexamination at 1, 3, 6, 12, and 24 months. During the reexamination, duplex ultrasound examination was performed, and if necessary, cervical CTA was used to determine the degree of stenosis. Restenosis is defined as the stenosis PSV>220 cm/s (i.e., restenosis degree >70%) [8]. Perioperative complications were classified by Clavien complications [9] classification method (I: Complications which do not need drug, surgery, endoscopy and reflex interventional therapy occur after operation, but drug therapy antiemetics, antipyretics, analgesics, diuretics, dielectrics and physical therapy are included, and incision infections treated in the ward are also included; II: Patients who require drug therapy (excluding drugs used in phase I), incision infections require antibiotic treatment, blood transfusion and total parenteral nutrition are included; III: Surgery, endoscopy and interventional radiotherapy are required; IV: Life-threatening complications which require intermittent monitoring or ICU treatment; V: death). Vital organ dysfunction is defined as severe dysfunction of the heart, lung and kidney (e.g., myocardial infarction, acute kidney injury, pulmonary embolism, etc.). Stroke is defined as ischemic and hemorrhagic stroke, which is confirmed by neurologist after CT or MRI. Postoperative nerve damage is defined as the neurological dysfunction that occurs after awakening from anesthesia and with duration >24 h. Postoperative reperfusion edema is defined as severe headache, nausea and vomiting, disturbance of consciousness, cerebral edema or visual impairment and other clinical symptoms.

Statistical analysis

Statistical analysis was performed with SPSS25.0 statistical software. Telationships between variables were assessed using Pearson correlation for continuous variables and chi-squared or Fisher's exact tests for categorical variables. Student's t-test was used to compare means among groups for normally distributed variables. The associations between clinical characteristics of the study population and the endpoint of the study were tested with univariate analysis followed by multivariate analysis, multinomial logistic regression analysis was used for the analysis of risk factors of PEH and their influence on postoperative outcomes. A parsimony model with predictors associated with a p-value less than 0.1 was presented to improve precision and avoid over-fitting. Categorical variables were expressed as frequency and percentage; continuous variables were expressed as mean ± SD. The significance level was set at <0.05.

Results

Baseline characteristics

Comparison of general data between the two groups: Non-PEH

Table 1: Laboratory related data.

Variable	Non-PEH group (n=126)	PEH group (n=14)	P
Neutrophils	3.99 (3, 4.85)	4.38 (3.44, 5.33)	0.219
Lymphocytes	1.84 (1.45, 2.19)0	1.6 (1.17, 2.27)	0.455
Total cholesterol	3.97 (3.32, 4.63)	4.15 (3.79, 5)	0.265
Triglycerides	1.18 (0.94, 1.66)	1.4 (1.03, 1.99)	0.219
Low-density lipoprotein	2.48 (2.09, 3.05)	2.87 (2.47, 3.33)	0.194
High-density lipoprotein	1.05 ± 0.21	1.08 ± 0.21	0.6
Albumin mg/dl	40.32 ± 3.19	40.41 ± 6.10	0.925
Platelets	215.73 ± 52.69	218.07 ± 63.15	0.877
Lipoprotein a	184.3 (91.4, 427.9)	315.3 (98.65, 612.6)	0.301
Glomerular filtration rate ml/min/1.73 m^2	88.72 (78.58, 96.12)	76.76 (66.54, 87.03)	0.002

Table 2: Hypertension before and after CEA.

	Non-PEH	PEH	
Without high SBP before operation	80	2	82
With high SBP before operation	46	12	58
	126	14	140

Table 3: Preoperative SBP data.

	Non-PEH	PEH	P
Mean SBP mmHg	135.77 ± 14.9	155.00 ± 16.25	<0.001
Admission SBP mmHg	140.88 ± 19.95	162.86 ± 29.97	<0.001
Peak SBP mmHg	151.92 ± 18.30	173.00 ± 21.84	<0.001
Increase in drug types	21	3	0.09
Decrease in drug types	21	3	0.71

Table 4: Postoperative outcomes.

	Non-PEH	PEH	P	OR
Vital organ dysfunction	3	1	0.812	3.13 (0.3, 32.3)
Postoperative restenosis	8	2	0.441	2.46 (0.47, 12.92)
Stroke	3	0	0.456	-
Length of stay day	15 (12, 20)	20 (18, 25)	0.002	-
Postoperative nerve damage	4	1	0.414	2.35 (0.24, 22.59)
Postoperative reperfusion injury	13	1	0.917	0.89 (0.11, 7.54)

group, 126 cases, 105 males and 21 females, 65.11 ± 8.02 years old, BMI 25.02 ± 3.11 kg/m^2, 87 cases with hypertension, 39 cases with diabetes, 40 cases of smokers, 23 cases of alcohol drinkers, 38 cases with coronary heart disease, 8 cases using patch during CEA; PEH group, 14 cases, 11 males and 3 females, 69.07 ± 5.78 years old, BMI 25.22 ± 3.38 kg/m^2, 13 cases with hypertension, 5 cases with diabetes, 15 cases of smokers, 5 cases of alcohol drinkers, 7 cases with coronary heart disease, and 6 cases using patch during CEA. The general data of two groups had no statistically significant difference (P>0.05) and were comparable.

Comparison of laboratory data

We took venous blood for laboratory tests on the day of admission or the next day. Except for the difference in glomerular filtration rate between the non-PEH group and the PEH group, there was no significant difference in the other indicators (Table 1).

Perioperative complications

The non-PEH group had 5 cases of Grade I, 5 cases of Class II, 3 cases of Class III and 5 cases of Class IV, the PEH group had 0 case of Class I, 2 cases of Class II, 0 case of Class III and 2 cases of IV Grade; the two groups had no significant statistical difference in perioperative complications (P>0.05).

Table 5: Univariate logistic regression analysis of PEH.

Variable	P	OR (95% CI)
Age >65	0.083	0.31 (0.08, 0.31)
Gender	0.665	0.73 (0.19, 2.86)
Hypertension	0.095	5.83 (0.74, 46.12)
Coronary heart disease	0.14	2.31 (0.76, 7.06)
Diabetes	0.72	1.24 (0.39, 3.94)
Smoking history	0.76	1.19 (0.38, 3.79)
Drinking history	0.71	0.75 (0.16, 3.57)
Body mass index	0.72	1.03 (0.87, 1.22)
Glomerular filtration rate (>90 ml/min)	0.026	0.96 (0.12, 0.76)
Uric acid	0.187	1.00 (1.00, 1.01)
Lipoprotein a	0.128	1.00 (1.00, 1.003)
White blood cells	0.197	1.21 (0.91, 1.60)
Symptomatic carotid artery stenosis	0.778	0.85 (0.28, 2.60)
Preoperative high SBP (mean SBP>140 mmHg)	0.003	10.44 (2.24, 48.69)
Albumin	0.924	1.01 (0.86, 1.18)
Increase in drug types	0.092	2.78 (0.85, 9.13)
Decrease in drug types	0.655	1.36 (0.35, 5.31)
Whether patch is used	0.369	0.60 (0.20, 1.83)

Table 6: Multivariate logistic regression analysis of PEH.

Variable	P	OcR
Preoperative high SBP	0.016	7.16 (1.44, 35.77)
Hypertension	0.151	5.08 (0.81, 73.65)
Glomerular filtration rate (>90 ml/min)	0.035	0.1 (0.01, 0.85)
Age (>65)	0.338	2.06 (0.47, 9.06)
Increase in drug types	0.245	2.29 (0.57, 9.29)

Hypertension before and after CEA operation

There were 58 patients with hypertension and 82 patients without hypertension before CEA, 14 patients with hypertension and 126 patients without hypertension after CEA. See Table 2 for details.

Preoperative SBP and drug comparison before and after CEA

The preoperative SBP data were mainly divided into: (1) Admission SBP, (2) mean SBP, (3) peak SBP. At the same time, the types of relevant drug therapy received and the increase and decrease of drugs before and after the operation were also recorded. Table 3 for the preoperative SBP data and the drug adjustments before and after CEA of PEH patients.

Postoperative outcomes

Through logistic regression analysis, there was no significant statistical difference in postoperative restenosis (P=0.441), stroke (P=0.456), vital organ dysfunction (0.812), postoperative nerve damage (P=0.414) and postoperative reperfusion injury (P=0.917) between the two groups of patients. In terms of the length of stay, the median and interquartile range of the length of stay were 15 days (12 to 20 days) for the non-PEH group, and 20 days (17.5 to 27.5 days) for

the PEH group, which had significant statistical difference (P=0.002) (Table 4).

Analysis of PEH risk factors

Analysis of PEH risk factors: We performed univariate logistic regression analysis on some preoperative indicators, such as age, gender, lipoprotein A and preoperative high SBP, which showed glomerular filtration rate and preoperative high SBP (mean SBP>140 mmHg) were the risk factors of PEH after CEA. For further analysis, we included indicators with P<0.1 into the multivariate logistic regression analysis. The results showed that the preoperative mean SBP>140 mmHg and glomerular filtration rate <90 ml/min may be the risk factors of PEH (Table 5, 6).

Discussion

Postoperative hypertension is a common phenomenon of CEA. Previous studies have pointed out that 9% to 56% of patients reported significant postoperative hypertension after CEA [10-13]. Ten percent of the patients enrolled in our center suffered PEH, which was similar to the above-mentioned incidence. In this study, age, preoperative hypertension history, renal insufficiency and other indicators were studied. In order to improve the accuracy of the model, multivariate logistic regression analysis was used to minimize the influence of potential confounding factors on PEH. Finally, it was concluded that preoperative mean SBP>140 mmHg and glomerular filtration rate <90 ml/min were the risk factors of PEH.

Lehv [14] described PEH for the first time in the 1870s and pointed out that it was associated with increased perioperative morbidity and mortality after CEA. In the recent 30 years, many studies have analyzed the risk factors of PEH. Samuel Lee [15] included 221 patients undergoing carotid endarterectomy and retrospectively analyzed their clinical data. PEH is defined as postoperative SBP>160 mmHg, and for which intravenous antihypertensive drugs were used for antihypertensive treatment. Through analysis, it was concluded that the history of myocardial infarction and non-white people were the risk factors of PEH. Newman conducted a prospective study and included 106 patients undergoing CEA under general anesthesia. The 24 h ambulatory blood pressure, baroreceptor sensitivity, and cerebral blood flow velocity were recorded before the operation. Finally, it was concluded that PEH was related to poor blood pressure control before operation and impaired baroreceptor sensitivity. Other factors, including age >65, black race and arrhythmia, are also related to postoperative hypertension [16]. This paper analyzed various factors, including age and gender, and concluded that the above results had no obvious relationship with PEH.

In terms of surgical methods, many scholars have also conducted related studies. Serdar et al. [17] included 7 papers for meta-analysis. Compared with traditional CEA with or without patch plasty, the eversion CEA increased the risk of hypertension after CEA, while traditional CEA was more related to hypotension. When eversion CEA is used, more attention should be paid to postoperative blood pressure. On the contrary, a retrospective study [18] pointed out that eversion CEA caused lower blood pressure fluctuations than CEA patch plasty, but eversion CEA was not a risk factor of PEH. In this study, our center used the patch or traditional CEA, rather than eversion CEA. We are looking forward to uniting multiple centers to further confirm the influence of surgical methods on PEH.

Regarding the occurrence mechanism of PEH, a very important reason is that the carotid sinus baroreceptor may be damaged during CEA operation [19]. Lequn [20] retrospectively analyzed 102 patients undergoing conventional CEA, and discussed the effect of antihypertensive drugs on PEH. The results found that the use of β-receptor blockers during the perioperative period was a protective factor of PEH and helped stabilize the peak systolic blood pressure for 3 days after operation. The mechanism may be achieved by stabilizing the postoperative excessive sympathetic nerve activity caused by baroreceptor reflex dysfunction. The baroreceptor reflex is the most important neural mechanism in regulating blood pressure homeostasis. PEH will occur when the carotid sinus nerve is damaged during the dissection, or the baroreceptor afferent nerve endings are severed during endarterectomy [21]. The patient will be more likely to suffer PEH when the baroreceptor sensitivity is lower. In this study, due to limited conditions, the baroreceptor damage was not recorded. We hope to further determine the predictive value of baroreceptor damage in PEH in more prospective studies.

Limitations

This study has the following shortcomings: (1) Although a multivariate logistic regression analysis is performed, the retrospective nature of our study is not sufficient to support us to completely eliminate confounding factors; (2) This paper is a single-center study with a small sample size, so the conclusion drawn may be biased; (3) It is reported that the influence of CEA on blood pressure fluctuations can last for half a year, while this study only analyzes the data of the perioperative period after CEA, therefore, we cannot research the long-term effect of baroreceptors on postoperative hypertension.

Conclusion

The length of stay of the patients with PEH increased significantly; however, there was no significant difference in the adverse event rate between the perioperative period and the short-to-medium term among the PEH patients. In addition, we concluded that preoperative mean SBP>140 mmHg and glomerular filtration rate <90 ml/min were the risk factors of PEH.

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