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Complications and predictors associated with persistent hemodynamic depression after carotid artery stenting

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ABSTRACT

We aimed to investigate the complications and predictors associated with persistent hemodynamic depression (PHD) after carotid artery stenting (CAS). A total of 204 patients undergoing CAS in two centers between January 2011 and November 2013 were enrolled for study into two cohorts: PHD (systolic blood pressure <90 mm Hg and heart beat rate <60/min, which lasted more than 1 h) and non-PHD according to their periprocedure detections. The complications were recorded and compared between the two groups. The predictors of PHD were analyzed by univariate analysis and logistic regression model. 43 patients developed PHD, which lasted for 17.22 h on average. The complications occurred in 9 patients of PHD group (angina pectoris 2, myocardial infarction 1, cerebral infarction 3, transient ischemic attack 2 and intestinal obstruction 1), which was significantly more than non- PHD group (angina pectoris 1, cerebral infarction 1, transient ischemic attack 5, $p = 0.001$). Regression analysis revealed that diabetes, severe calcified plaque and a balloon dilation pressure of more than 8 atmospheres (atm) were the independent predictors for PHD after CAS. We concluded that PHD may be related to increased complications of CAS. Patients with diabetes, more severe calcified plaque and more balloon dilation pressure are more prone to develop PHD after CAS.

1. Introduction

Hemodynamic depression (HD), which includes hypotension and bradycardia, is a frequent phenomenon during and after carotid artery stenting (CAS) [1–15]. A recent review reported that the frequency of HD was 7.2–80% [1]. At present, many studies reported that HD was a process of CAS and did not significantly increase the periprocedural complications [1,5,11,13,15]. But in several large sample studies, persistent HD (PHD, defined as HD lasting more than 1 h, in spite of treating with fluid or vasoactive agent) was associated with more ischemic events, such as stroke and/or myocardial infarction (MI) [4,10,12]. So far, only a few studies analyzed the predictors associated with PHD [4,7], which reported the effect of clinical and vascular morphologic variables on PHD. We presumed that surgical factors may also affect the occurrence of PHD. Through study, this article reported the complications associated with PHD and further analyzed the predictors associated with PHD based on clinical, vascular morphologic and surgical factors. The definition of HD adopted in this study is the most popular definition: systolic blood pressure <90 mm Hg and heart beat rate <60/min [1,4,9,12,15,16–21].

2. Subjects and methods

We retrospectively analyzed 204 consecutive patients with carotid stenosis treated with CAS between January 2011 and November 2013 in Department of Neurology of the Third Affiliated Hospital of Soochow University and Dongfang Hospital. The inclusion criteria of patients who underwent CAS were symptomatic carotid stenosis >50% and asymptomatic >70%, and >45 years of age. Exclusion criteria were the following: thrombocytopenia ($<100 \times 10^9$/L), leukopenia ($<4 \times 10^9$/L), neutropenia, cerebral hemorrhage in the previous 3 months, allergy to aspirin and/or clopidogrel, or severe cardiac and pulmonary dysfunction. This study protocol was approved by the Medical Ethics Committee of the Third Affiliated Hospital of Soochow University and Dongfang Hospital. Informed consent was signed by patients or their legally authorized representatives. All patients underwent duplex ultrasound scanning and calcified plaques were recognized and recorded by expert doctors. The patients with calcified plaques underwent computed tomographic angiography. All patients received 100 mg of aspirin (Bayer, Germany) and 75 mg of clopidogrel (Sanofi-aventis, China) at least for 3 days before the

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procedure. During the procedure, patients were intravenously administered 4000–5000 u (70 u/kg) of heparin after successful femoral artery puncture and additional 2000 u heparin maintaining for 1 h in procedure. After the procedure, all patients were under treatment with 75 mg of clopidogrel for 6 months and 100 mg of aspirin for lifetime.

Baseline angiography was performed before the procedure. The stenotic ratio of the carotid artery was measured by the NASCET (North American Symptomatic Carotid Endarterectomy Trial) criteria [22]. An 8F guiding catheter was advanced through the sheath into the common carotid artery. The top of guide catheter was located at 10–15 mm from the lesion. If the diameter of the stenotic segment was <2 mm, a balloon catheter advanced over a microwire (0.014 in. diameter) and located at the stenotic segment for predilation. Angiogram was made after the dilation. Distal embolic protection devices (EPD) were then applied through the sheath (Cordis Corp., USA). If the diameter of the stenotic segment was more than 2 mm, we applied EPD prior to advancing the balloon catheter over the wire of EPD for predilation. A self-expanding stent was then placed across the dilated segment. The size of the stent was determined by baseline of the plaque. After stenting, the residual stenotic ratio was measured again by angiogram. The treatment was considered successful when the residual stenosis was <30%. If the residual stenosis was more than 30%, a balloon catheter was advanced for the postdilation. A final angiogram was performed to confirm the absence of complications such as dissection of the stenotic segment and thromboembolic events in the ipsilateral artery. The stents used in this study were all open cell, which were Precise stent (Cordis Corp., USA) and Protégé RX stent (eV3 Corp., USA). The balloon catheters were Maverick balloon (Boston Corp., USA) and Aviator balloon (Cordis Corp., USA). EPD used in this study was SpiderFX (eV3 Corp., USA), and Angioguard (Cordis Corp., USA).

Blood pressure and heart beats were measured in the left arm by sphygmomanometer and an automated electrocardiogram monitor during and after the procedure. When the HD did not spontaneously recover within 10 s, atropine was applied (max 0.5 mg) and an intravenous infusion of dopamine (3–10 ug/kg/min) was used to maintain the SBP higher than 90 mm Hg. The patients with continued HD received continuous normal saline infusion and vasopressor support with dopamine. Atropine was applied if necessary. All PHD were recorded.

After the procedure, the patients were closely monitored for 24 h after HD recovered. Blood pressure and heart beats were measured every 5–30 min. Once blood pressure and heart ratio were stable for at least 3 h, patients were monitored every 6 h thereafter.

We collected the baseline clinical data of the patients including age (i.e., >65 years old vs. <65 years old), sex, other risk factor profile. The classification of calcification was based on the calcium score [23] and categorized into two groups in reference to Rumberger et al. [24]. The categories of 0–2 recommended by Rumberger et al. [24] were defined as mild calcification and the categories of 3 and 4 were defined as severe calcification in this study. We also recorded the stenotic ratio (i.e., <70% vs. >70%) and the distance from carotid bifurcation to maximum stenotic lesion (i.e., <10 mm vs. >10 mm). Data regarding the technical factors emphasized in this study included maximal balloon diameter (none vs. 5 mm vs. ≥6 mm), maximal balloon length (none vs. 20 mm vs. more than 30 mm), the pressure of balloon dilation (none vs. <8 atm vs. >8 atm), duration of balloon dilation (none vs. <5 s vs. >5 s) and number of stent sides (unilateral vs. bilateral)

Statistical analyses were performed using SPSS 13.0. Continuous data are presented as mean ± standard deviation (M ± SD); categorical data are presented as the count (percentage). Univariate analysis was performed for each variable using the χ^2 test. Fisher exact test or Student's *t*-test were also used where appropriate. Logistic regression analysis models were used to assess the independent role of each variable on the occurrence of PHD. The criteria of the inclusion of variables in the final model were $p < 0.1$. A *p*-value of statistical significance was defined as <0.05.

3. Results

Of the total 204 patients, 139 were male and 65 were female. The mean age was 64.45 ± 8.84 years old. All of the patients had successful treatment of the carotid lesion by angioplasty and/or stenting. 34 patients received a simultaneous bilateral stenting. Out of 204 patients, 43 developed PHD (21.08%). In PHD group, the complications occurred in 9 patients (angina pectoris 2, MI 1, cerebral infarction (CI) 3, transient ischemic attack (TIA) 2 and intestinal obstruction 1), which was significantly more than non-PHD group (angina pectoris 1, CI 1, TIA 5, $p = 0.001$). The patients with angina pectoris received cardiac angiograph and were proved with coronary artery stenosis. All patients with TIA received regular antiplatelet therapy and 2 patients were processed to CI in PHD group. Patients with MI and CI were all received regular medical treatment and no deaths after the treatment. Table 1

Table 1
Single predictors analysis of persistent hemodynamic depression after carotid artery stenting.

Risk factors	PHD	Non-PHD	*p*-value
Age	–	–	0.489
<65 years, *n* (%)	16 (37.2)	71 (44.1)	–
≥65 years, *n* (%)	27 (62.8)	90 (55.9)	–
Sex	–	–	0.361
Male, *n* (%)	32 (74.4)	107 (66.5)	–
Female, *n* (%)	11 (25.6)	54 (33.5)	–
Hypertension	–	–	0.601
Yes, *n* (%)	28 (65.1)	97 (60.2)	–
No, *n* (%)	15 (34.9)	64 (39.8)	–
Diabetes	–	–	**0.011**
Yes, *n* (%)	21 (48.8)	45 (28.0)	–
No, *n* (%)	22 (51.2)	116 (72.0)	–
Smoking	–	–	0.120
Yes, *n* (%)	23 (53.5)	64 (39.8)	–
No, *n* (%)	20 (46.5)	97 (60.2)	–
Coronary heart disease	–	–	0.690
Yes, *n* (%)	12 (27.9)	38 (23.6)	–
No, *n* (%)	31 (72.1)	123 (76.4)	–
Degree of calcification	–	–	**0.000**
Mild, *n* (%)	16 (37.2)	115 (71.4)	–
Severe, *n* (%)	27 (62.8)	46 (28.6)	–
Degree of stenosis	–	–	0.138
<70%, *n* (%)	9 (20.9)	54 (33.5)	–
≥70%, *n* (%)	34 (79.1)	107 (66.5)	–
Distance away from sinus	–	–	0.668
≤10 mm, *n* (%)	33 (76.7)	130 (80.7)	–
>10 mm, *n* (%)	10 (23.3)	31 (19.3)	–
Maximal length of balloon	–	–	0.107
No, *n* (%)	0 (0.0)	14 (8.7)	–
20 mm, *n* (%)	25 (58.1)	90 (55.9)	–
≥30 mm, *n* (%)	18 (41.9)	57(35.4)	–
Maximal diameter of balloon	–	–	0.120
No, *n* (%)	0 (0.0)	14 (8.7)	–
≤5 mm, *n* (%)	20 (46.5)	68 (42.2)	–
≥6 mm, *n* (%)	23 (53.5)	79(49.1)	–
Maintain time of balloon dilation	–	–	0.123
No, *n* (%)	0 (0.0)	14 (8.7)	–
<5 s, *n* (%)	14 (32.6)	48 (29.8)	–
≥5 s, *n* (%)	29 (67.4)	99 (61.5)	–
Pressure of balloon dilation	–	–	**0.000**
No, *n* (%)	0 (0.0)	14 (8.7)	–
<8 atm, *n* (%)	11 (25.6)	102 (63.4)	–
≥8 atm	32 (74.4)	45 (27.9)	–
Number of stenting sides	–	–	**0.011**
Unilateral, *n* (%)	30 (69.8)	140 (87.0)	–
Bilateral, *n* (%)	13 (30.2)	21 (13.0)	–

$p < 0.1$ are in bold.