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The Relationship Between the Degree of Intraoperative Hypotension and the Onset of Postoperative Hypotension in Carotid Artery Stenting

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Abstract

Purpose: Intraoperative or postoperative hypotension has been reported to be associated with carotid artery stenting. However, few studies have so far investigated the relationship between intraoperative hypotension and the onset of postoperative hypotension following carotid artery stenting.

Materials and methods: The data from 64 cases of cervical carotid artery stenosis treated by carotid artery stenting between February 2009 and May 2010 were analyzed.

Results: Hypotension (systolic blood pressure; 90 mmHg or less) during carotid artery stenting was observed in 53 cases, and postoperative hypotension was noted in 20 cases. The onset of postoperative hypotension was 15–1232 minutes (min) after the operation (average: 165 min, median: 65 min). The diameter of the common carotid artery in the postoperative hypotension group (7.2 ± 0.9 mm) was narrower than that of the non-postoperative hypotension group (7.8 ± 1.0 mm). The onset of postoperative hypotension was significantly delayed in patients with an intraoperative systolic blood pressure less than 70 mmHg than in those with an intraoperative systolic blood pressure of 70 mmHg or higher.

Conclusion: Our findings indicate that there is a significant relationship between the common carotid artery diameter, the degree of intraoperative hypotension and the onset of postoperative hypotension. We think that the degree of the decrease in the intraoperative systolic blood pressure was related to the baroreflex sensitivity, and it is important to monitor the changes in the intraoperative systolic blood pressure and pulse rate to ensure better postoperative management.

Key words：**Carotid artery stenting, Hypotension, Baroreflex**

Introduction

Carotid artery stenting (CAS) has been evaluated as a substitute for carotid endarterectomy (CEA). CAS has been performed for high-risk CEA patients [1)] or randomly assigned patients [2)], and the results of these studies were found to be comparable to those of CEA.

Intraoperative or postoperative hypotension and bradycardia have previously been reported to be associated with CAS [3–13)]. The risk factors associated with these hemodynamic changes included lower baseline heart rates [1)], balloon use [1)], a smaller total plaque volume [8)], lesions involving the carotid bulb [6)], calcified plaques [4, 6)],

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age > 78 years [9], ejection fraction < 25% [9] and longer plaques [4]. CEA-related restenosis was associated with a reduced risk of hemodynamic depression [9]. With regard to the risk of the perioperative adverse clinical events, some reports revealed that hemodynamic instability following CAS was a risk factor, [6, 9] but another report revealed otherwise [4]. The onset of hypotension has been reported to occur during [10] or immediately after [13] the operation; most often just after stenting or balloon catheter dilatation [11].

Qureshi et al. reported that intraoperative hypotension and a history of myocardial infarction independently predicted post-procedural hypotension [14]. Further, Lavoie et al reported that 8% of the patients in their study had an onset of hypotension or bradycardia six hours (h) after CAS [15]. There have been some studies about postoperative hypotension-related CAS procedures; however, relatively few studies have investigated the relationship between intraoperative hypotension and the onset of postoperative hypotension following CAS.

In this study, we investigated the relationship between the degree of intraoperative hypotension and the onset of postoperative hypotension in 62 patients who underwent CAS. To the best of our knowledge, no previous report has described such a relationship.

Materials and Methods

Materials

CAS was performed 64 times to treat 62 patients (48 males, 14 females) with cervical carotid artery stenosis who visited our institution. The percentage of stenosis was calculated via angiography according to the criteria of the North American Symptomatic Carotid Endarterectomy Trial [16]. The adaptive criterion for CAS was defined as 50% stenosis for symptomatic lesions and 80% stenosis for asymptomatic lesions. All patients gave their prior informed consent for participation in the study, which was approved by the ethics committee of our institution.

Endovascular procedure

Patients received two of the following antiplatelet agents: aspirin (100 mg/day, at least three days before angioplasty), clopidogrel (75 mg/day, at least five days before angioplasty) or cilostazol (200 mg/day, at least three days before angioplasty).

A sheath was inserted into the femoral artery, following which, heparin (80 IU/kg) was injected intravenously. The distal side of the internal carotid artery was occluded using an inflated balloon with the PercuSurge system (Medtronic, Santa Rosa, CA, USA). This lesion was first pre-dilated with a balloon catheter (5 × 40 mm; Sterling, Boston Scientific, Natick, MA, USA) at 6 atm for 60 seconds (s), then a self-expandable stent (10 × 20 mm; Wallstent RP, Boston Scientific, Natick, MA, USA, or 10 × 24 mm; Carotid Wallstent, Boston Scientific, Natick, MA, USA) was deployed. Post-dilatation was performed with a balloon catheter (7 × 20 mm; Sterling, Boston Scientific, Natick, MA, USA) at 6 atm pressure for approximately 2 s. Once the debris close to the protection balloon was aspirated, the balloon was deflated. Angiography was then performed to evaluate the residual stenosis, and the sheath was withdrawn.

Measurement and management of vital signs

When preoperative hypertension was observed, we used oral anti-hypertensive drugs to control the blood pressure. During the operation, the blood pressure was measured at the upper arm every five minutes (min) with an automated sphygmomanometer. The intraoperative pulse was monitored with a sequential electrocardiogram.

Atropine sulfate (0.5 mg) was administered before pre-dilatation. When intraoperative hypotension or a sudden decrease of systolic blood pressure was observed, ephedrine was administered, and the quantity of the anesthesia drug was coordinated as appropriate.

Postoperatively, the blood pressure was measured every 15, 30, 60 and 120 min, and every 120 min thereafter up to 12 h after the operation. The postoperative pulse was monitored using a sequential electrocardiogram. When subjective symptoms, such as headache, were reported by the patient, or when the physical examination revealed abnormal findings, the vital signs were monitored and confirmed as required.

Measurement of the arterial diameter

We used echocardiography, computed tomography angiography (CTA), magnetic resonance angiography (MRA) or digital subtraction angiography (DSA) to measure the diameter of the common carotid artery (CCA) and internal carotid artery (ICA). We measured the diameter of the CCA to select an unaffected region proximal to the stenosis, and the diameter of the ICA to

select an unaffected region distal to the stenosis.

Definitions

Hypotension was defined as a systolic blood pressure of 90 mmHg or less (≤ 90 mmHg) in the absence of obvious hemorrhage or heart failure. Bradycardia was defined as pulse rate of 60 beats/min or less (≤ 60 beats/min). The intraoperative time was defined as the time between the insertion and withdrawal of the sheath. The postoperative time was defined as the time from the end of the CAS procedure after the withdrawal of the sheath.

Statistical methods

The Fissure's exact test was used to assess the differences in the patient history and the presence or absence of intraoperative hypotension. The Mann Whitney *U*-test was used to assess the relationship between the lowest intraoperative systolic blood pressure and the onset of postoperative hypotension. The Mann Whitney *U*-test was also used to assess the differences in age, the severity of stenosis, dose of ephedrine, diameter of the CCA and diameter of the ICA between the postoperative hypotension group and non-postoperative hypotension group. A value of $P > 0.05$ was considered to be statistically significant.

Results

Of the 62 patients who underwent CAS, 42 had symptomatic lesions, 50 had hypertension, 22 had diabetes mellitus and 12 had ischemic heart disease. None of the patients had severe calcified lesions or underwent endarterectomy. The stenting was successful in all cases. Two patients showed symptoms of postoperative neurological deficiency (3.0%); however, this was temporary, and no obvious neurological deficiency was found at the time of discharge.

Hypotension during CAS was observed in 53 of the 64 cases (81%). In all these patients, the blood pressure returned to the normal level without continuous vasopressor infusion by the end of the operation. Bradycardia during CAS was observed in nine of the 64 cases (14%). Ephedrine was used in 52 cases.

Postoperative hypotension was observed in 20 cases (31%). The onset of postoperative hypotension ranged from 15–1232 min after the operation (average: 165 min, median: 65 min) (Table 1).

Table 1 Cases of postoperative hypotension

No.	Age	Gender	Affected side	Onset time (min)	Lowest intraoperative blood pressure (mmHg)	Minimum intraoperative pulse rate (beats/min)	Preoperative (resting) pulse rate (beats/min)
1	82	M	R	15	80/40	70	80
2	73	M	L	25	70/40	80	80
3	58	M	R	26	80/40	70	60
4	80	M	R	27	80/50	70	60
5	53	F	R	30	70/30	40	100
6	60	M	R	35	80/40	60	50
7	79	M	L	45	60/40	80	50
8	74	M	R	45	80/50	70	70
9	86	F	L	46	70/40	80	70
10	77	M	L	55	90/50	100	70
11	65	F	L	75	80/60	90	60
12	82	M	R	95	60/30	80	70
13	77	M	L	110	70/50	80	60
14	83	M	R	130	60/30	80	70
15	65	M	R	204	90/50	80	60
16	82	M	L	213	50/30	100	60
17	74	F	R	228	60/40	80	70
18	60	M	L	268	60/30	70	60
19	71	M	R	410	60/30	40	80
20	68	M	L	1232 (20.32 hours)	60/40	50	80

The digits in the units place of the lowest blood pressure values and pulse rate were revised to zero.
M: male, F: femal, R; right, L; left

Table 2 Baseline characteristics and statistical evaluation of the cases

	Patients without postoperative hypotension	Patients with postoperative hypotension	*P* value
n	44	20	
Age	74 ± 7	72 ± 9	0.6
Male	34	16	0.5
Right lesion	28	10	0.2
Lesion involving carotid bulb	35	16	0.6
Severity of stenosis (%)	67 ± 14	62 ± 10	0.1
Dose of ephedrine (mg)	12 ± 9	18 ± 11	0.09
Diameter of CCA (mm)	7.8 ± 1.0	7.2 ± 0.9	0.02
Diameter of ICA (mm)	5.1 ± 1.2	4.9 ± 1.0	0.3
Symptomatic	29	13	0.5
Hypertension	37	13	0.08
Diabetes mellitus	14	8	0.8
Ischemic heart disease	9	3	0.4
Intraoperative hypotension	35	18	0.2

The Mann Whitney *U* test was used for age, severity of stenosis, dose of ephedrine, diameter of CCA, diameter of ICA and the Fissure's exact test was used to assess the other parameters.
CCA; common carotid artery, ICA; internal carotid artery

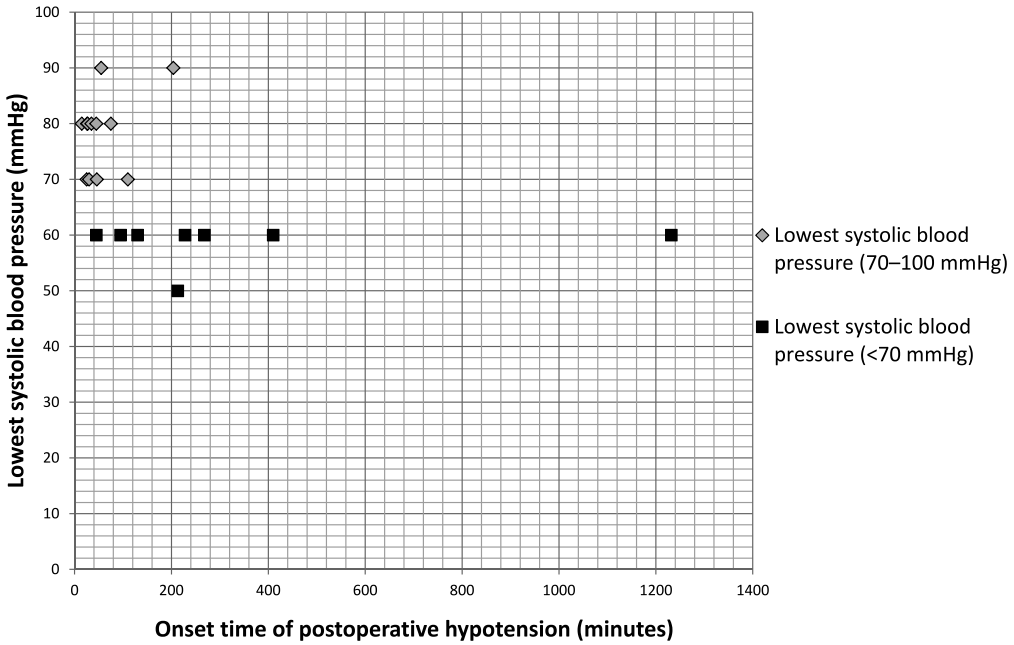

Fig. 1 The lowest systolic blood pressure during the operation and the onset of postoperative hypotension. In the 20 cases with postoperative hypotension, the lowest systolic blood pressure during the operation was less than 70 mmHg (<70 mmHg) in eight cases and 70 mmHg or higher (≥ 70 mmHg) in 12 cases. The onset of postoperative hypotension was significantly delayed in the <70 mmHg group compared to the ≥ 70 mmHg group.

Statistical evaluations

The postoperative hypotension group vs the non- postoperative hypotension group

We compared the patients in the postoperative hypotension group with those in the non-postoperative hypotension group. The diameter of the CCA in the postoperative hypotension group (7.2 ± 0.9 mm) was significantly narrower than that of the non-postoperative hypotension group (7.8 ± 1.0 mm). (Mann Whitney *U*-test; $p = 0.02$). There were no statistically significant differences in age, sex, the affected side, the severity of stenosis, dose of ephedrine, the diameter of the ICA,

Table 3 Characteristics of cases with the lowest systolic blood pressure ≥ 70 mmHg or <70 mmHg during the operation

	The lowest systolic blood pressure ≥ 70 (mmHg)	The lowest systolic blood pressure < 70 (mmHg)	*P* value
n	49	15	
Age	72 ± 7	76 ± 7	0.07
Male	38	11	0.4
Right lesion	31	7	0.1
Lesion involving carotid bulb	37	14	0.1
Severity of stenosis (%)	66 ± 13	67 ± 12	0.7
Dose of ephedrine (mg)	14 ± 9	20 ± 9	0.07
Diameter of CCA (mm)	7.7 ± 1.1	7.3 ± 0.8	0.3
Diameter of ICA (mm)	5.1 ± 1.2	4.9 ± 0.7	0.8
Symptomatic	33	9	0.4
Hypertension	38	12	0.5
Diabetes mellitus	16	6	0.7
Ischemic heart disease	9	1	0.2
Postoperative hypotension	39	8	0.04

The Mann Whitney *U* test was used for age, severity of stenosis, dose of ephedrine, diameter of CCA, and diameter of ICA; and the Fissure's exact test was used to assess the other parameters.
CCA; common carotid artery, ICA; internal carotid artery

the presence or absence of lesions involving the carotid bulb, symptoms, hypertension, diabetes mellitus or ischemic heart disease (with or without intraoperative hypotension) between the two groups. The basic characteristics of the patients and the results of the statistical evaluations are summarized in Table 2.

Onset of postoperative hypotension

In the 20 cases with postoperative hypotension, the lowest intraoperative systolic blood pressure was less than 70 mmHg (<70 mmHg) in eight cases and 70 mmHg or higher (≥70 mmHg) in 12 cases. The onset of postoperative hypotension tended to be significantly delayed in eight cases compared to the remaining 12 cases (Mann Whitney *U*-test; $p < 0.01$) (Figure 1).

Intraoperative systolic blood pressure

The lowest systolic blood pressure was <70 mmHg in 15 cases and ≥70 mmHg in 49 cases. In the postoperative hypotension cases, the intraoperative lowest systolic blood pressure tended to be <70 mmHg (Fissure's exact test; $p < 0.05$). There were no statistically significant differences in the age, sex, affected side, severity of stenosis, dose of ephedrine, diameter of the CCA and ICA, the presence or absence of lesions involving the carotid bulb, symptoms, hypertension, diabetes mellitus or ischemic heart disease (with or without intraoperative hypotension) between the two groups (Table 3).

Intraoperative bradycardia

We also investigated the onset of postoperative hypotension in the eight patients who showed an intraoperative systolic blood pressure of <70 mm Hg. These eight patients were further divided into two groups on the basis of their minimum pulse rate during the operation: less than 60 beats/min (<60 beats/min) (six patients) and ≥60 beats/min or more (≥60 beats/min) (two patients). We observed that the onset of postoperative hypotension was delayed in the first group compared to the second group (Table 4).

Discussion

We herein examined the incidence and onset of postoperative hypotension, and found a relationship between the intraoperative hypotension and the onset of postoperative hypotension.

Incidence of postoperative hypotension

The diameter of the CCA was related to the incidence of postoperative hypotension. In cases with a narrow diameter of the carotid artery, high pressure was applied to the wall of the carotid artery by the pressure of balloon inflation and radial force of the stent. A previous report indicated that hypotension tended to occur just after stenting or balloon catheter dilatation [11]. The mechanism responsible for the relationship between

Table 4 The minimum pulse rate and the onset time of postoperative hypotension in significant intraoperative hypotension cases

Minimum pulse rate of 60 beats/min or more during the operation (6 cases)

No.	Onset time (min)	Lowest blood pressure (mmHg)	Minimum pulse rate (beats/min)
7	45	60/40	80
12	95	60/30	80
14	130	60/30	80
16	213	50/30	100
17	228	60/40	80
18	268	60/30	70
Average	163		

Minimum pulse rate of less than 60 beats/min during the operation (2 cases)

No.	Onset time (min)	Lowest blood pressure (mmHg)	Minimum pulse rate (beats/min)
19	410	60/30	40
20	1232	60/40	50
Average	821		

The digits in the units place of the lowest blood pressure values and pulse rate were revised to zero.

the pressure on the carotid artery wall and the onset of postoperative hypotension is unknown, but the results of our study suggest that the effect of balloon inflation could be prolonged, and the pressure on the carotid artery induced by the radial force of the self-expandable stent may have been improved gradually after the operation.

Onset of postoperative hypotension

The onset of postoperative hypotension was significantly delayed in the group of patients whose lowest intraoperative systolic blood pressure dropped below 70 mmHg compared to the group with a lowest intraoperative systolic blood pressure greater than 70 mmHg. To the best of our knowledge, no report has described such a relationship before. The baroreflex control mechanism has been reported to affect the blood pressure or pulse [17]. In addition, it has been reported that the baroreflex sensitivity was decreased in patients of advanced age or with a history of coronary artery disease or hypertension [18, 19]. We think that the degree of the decrease in the intraoperative systolic blood pressure was related to the baroreflex sensitivity. The baroreflex sensitivity of the patients whose lowest intraoperative systolic blood pressure dropped below 70 mm was thought to be higher than that of the other cases.

In this study, the intraoperative blood pressure and the minimum pulse rate dropped below 70 mmHg and below 60 beats/min, respectively, in only two cases. The onset of postoperative hypotension was relatively delayed in these two cases. Further investigations are required to examine the mechanism underlying the occurrence of postoperative hypotension after CAS. We aim to continue our investigation on hypotension after CAS with a larger number of cases.

To conclude, we monitored the development of postoperative hypotension after 64 CAS procedures. The diameter of the CCA in the postoperative hypotension group was significantly narrower than that of the non-postoperative hypotension group. The onset of postoperative hypotension was significantly delayed in the patients with lower intraoperative systolic blood pressure. Therefore, it is important to monitor the changes in the intraoperative systolic blood pressure and the pulse rate during the operation to ensure better postoperative management.

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