Original Article

Impact of Aortic Arch Morphology on Periprocedural Neurologic Events during Carotid Artery Stenting

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Objective: To investigate the impact of aortic arch morphology on neurologic events and complications during and after carotid artery stenting [CAS].

Materials and Methods: This retrospective study enrolled 130 patients (144 procedures) with symptomatic or asymptomatic carotid stenosis that were treated at our center between January 2006 and December 2013.

Results: All 130 patients were at high risk for periprocedural neurologic events and death from carotid endarterectomy [CEA]. Baseline clinical characteristics, angiographic data, procedural characteristics, and periprocedural (30-day) neurologic events were assessed. The primary endpoint was the incidence of periprocedural neurologic events. Thirteen (9%) periprocedural neurologic events were observed, eight (5.5%) of which qualified as major stroke. The periprocedural neurologic events rate was higher in the elderly and occurred in 2.7% of patients with type I arch, 8.1% of patients with type II arch, and 25% of patients with type III arch. Heavily calcified lesion also increased the rate of periprocedural neurologic events. Multivariate analysis identified type III aortic arch (odds ratio [OR] 6.23, $p = 0.006$), presence of more than 50% common carotid stenosis (OR 4.33, $p = 0.035$), and heavily calcified lesion (OR 4.15, $p = 0.054$) as risk factors for a periprocedural event.

Conclusion: Type III aortic arch morphology is significantly associated with periprocedural neurologic events during and after CAS.

Keywords: Carotid artery stent, Aortic arch type, Periprocedural neurologic event

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Stroke is the fourth most common cause of death in the developed world[1]. Most stroke events are ischemic in nature. Carotid artery disease is one of the leading causes of ischemic stroke. Patients with symptomatic carotid artery stenosis have a worse prognosis than those with asymptomatic disease. The risk of ipsilateral stroke in symptomatic patients on medical therapy increases with the severity of stenosis[2-6].

CAS is an alternative to carotid endarterectomy [CEA] in patients with unfavorable anatomy, such as high cervical lesion, contralateral carotid artery occlusion, prior neck irradiation, and prior ipsilateral CEA[7]. CAS is also the preferred treatment option in patients with medical comorbidities, such as New York Heart Association class III or IV congestive heart failure, poor left ventricular ejection fraction, renal insufficiency, and significant history of coronary artery disease. The Carotid Revascularization Endarterectomy versus Stenting Trial [CREST] revealed similar composite outcomes of stroke, myocardial infarction, and/or death between CAS and CEA. However, in elderly patients (older than 70-years-old), the outcome was better for CEA than for CAS[8]. Lam et al found a higher incidence of unfavorable anatomy in patients aged older than 80 years[9].

There are few reports on the impact of aortic arch morphology on clinical outcome after CAS[10]. Difficult arch anatomy increases the technical difficulty and reduces the success rate of the procedure[11]. The risk of neurologic complications may be greater, and the CAS procedure may be made more difficult depending on the complexity of the patient's aortic arch anatomy[9,12]. The aim of this study was to investigate the impact of aortic arch morphology on neurologic events and complications during and after CAS.

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Materials and Methods

The protocol for this study was approved by the Siriraj Institutional Review Board [SIRB], Faculty of

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Medicine Siriraj Hospital, Mahidol University. All investigations were conducted in accordance with the principles set forth in the Declaration of Helsinki and all of its subsequent amendments.

This retrospective cohort study enrolled 130 consecutive patients with symptomatic or asymptomatic carotid stenosis who underwent carotid angioplasty and stenting in the catheterization laboratory of our center between January 2006 and December 2013. One hundred forty-four procedures were conducted in these 130 patients. Inclusion criteria were symptomatic or asymptomatic carotid artery stenosis on presentation and CAS performed in the region of the carotid bifurcation. All 130 patients in this study were at high-risk for periprocedural neurologic events and death from CEA due to medical comorbidities and/or unfavorable anatomy. The authors excluded patients whose medical records, including angiographic characteristics and procedural notes, were incomplete. Baseline clinical characteristics, angiographic data, procedural characteristics, and periprocedural events were collected and recorded.

Symptom definitions

Symptomatic patients were defined as those with stroke, transient ischemic attack [TIA], or amaurosis fugax that correlated to a vascular territory of that side of significant stenosis of carotid artery.

Amaurosis fugax (transient monocular blindness) was defined as transient monocular blindness caused by temporary reduction of blood flow to eye with loss of vision.

TIA was defined as a syndrome of acute neurologic dysfunction corresponding to a vascular territory that completely resolved within 24 hours and left no residual neurologic deficits.

Ischemic stroke was defined as an acute neurologic ischemic event, with focal signs and symptoms that had a duration of at least 24 hours. One or both of the following could be used as confirmatory evidence of a neurologic event, but not necessary for the definitive designation of stroke: 1) a 1-point increase in the National Institutes of Health Stroke Scale [NIHSS], and/or 2) an appropriate new or extended abnormality seen on computed tomography [CT] or magnetic resonance imaging [MRI].

Anatomic evaluation

Digital subtraction angiograms of all 144 CAS procedures were available for examination. Anatomic characteristics were based on North American Symptomatic Carotid Endarterectomy Trial [NASCET] criteria and included aortic arch anomaly, aortic arch type (normal/bovine), aortic arch morphology, aortic arch atheroma, common carotid artery [CCA] and internal carotid artery [ICA] tortuosity, lesion type at the site of carotid stenosis, and severity of carotid stenosis in the treated lesion. The CCA and ICA were assessed over their entire length, but only the extracranial portion the ICA (beyond the cavernous part) was treated.

Aortic arch types were defined as normal and bovine. A bovine arch was defined as when the innominate artery shares a common origin with the left CCA.

Aortic arch morphology was determined by the relational characteristics shared by the brachiocephalic (innominate) arterial trunk and the aortic arch. In a type I aortic arch, the origins of all three major vessels are situated in the horizontal plane defined by the outer curvatures of the arch. In type II, the brachiocephalic artery originates between the horizontal planes of the outer and inner curvatures of the arch. In type III, the brachiocephalic artery originates below the horizontal plane of the inner curvature of the aortic arch.

Aortic arch atheroma was defined as protruding or mobile atherosclerotic plaques of the aortic arch.

Lesion length was defined as the distance from the proximal to the distal shoulder of the lesion in the projection that best elongates the stenosis (only the portion in which stenosis was 50% or greater was measured).

Excessive tortuosity was defined as 90-degree or greater bends within 5 cm of the lesion (including ICA takeoff and CCA).

Significant calcification was defined as radiopacity under fluoroscopy (width 3 mm or greater).

Ulceration of a lesion was defined as a lesion comprising two or more craters of 3 mm or more in depth, or one lesion with poorly-defined edges and a hazy appearance.

Carotid stenting procedure

All patients were treated with aspirin 81 to 325 mg daily and clopidogrel 75 mg daily at least three days before the procedure. Weight-adjusted heparin boluses (70 to 100 units/kg) were administered intra-arterially or intravenously during the procedure to maintain an activated clotting time of approximately 250 to 300 seconds. Procedures were usually performed via the right femoral artery using a guiding catheter or sheath. A SpiderFX™ Embolic Protection Device

(Covidien/Medtronic Inc., Minneapolis, MN, USA) was applied in all but 16 cases. In those 16 cases, the interventionist was unable to advance the embolic protection device past an excessively tortuous proximal or distal ICA. Pre- and post-stenting balloon angioplasty was performed depending on the judgment of the interventionist. Almost all procedures used an over-the-wire self-expanding Nitinol stent. Blood pressure, heart rate, and heart rhythm were monitored and recorded during the procedure. In patients who developed intraoperative hypotension (20% or larger decrease in systolic blood pressure [SBP] from baseline or SBP of less than 100 mmHg in a non-hypertensive patient), vasopressors of any type were administered intravenously or intra-arterially and titrated to maintain mean arterial pressure between 65 and 70 mmHg. Acute hypertension (SBP greater than 180 mmHg or diastolic blood pressure greater than 110 mmHg) was treated with intravenous antihypertensive drugs titrated to maintain a mean arterial pressure 130 mmHg or less.

Post-CAS care

All patients were admitted to the intermediate cardiac care unit after completion of the CAS procedure. Vital signs and neurologic signs were recorded every four hours for at least 48 hours. Any post-procedure neurologic and/or cardiac events were reported directly to the interventionist and managed appropriately. Patients were treated with aspirin 81 to 325 mg indefinitely and clopidogrel 75 mg daily for at least four weeks after the procedure. The management of other medical comorbidities remained the same as the treatments and care given prior to the CAS procedure. The primary endpoint was to investigate the impact of type of aortic arch morphology on CAS-related periprocedural neurologic events. The secondary end point was to identify the impact of underlying medical comorbidities and procedural characteristics on CAS-related periprocedural neurologic events.

Periprocedural neurologic events

Qualifying events occurring less than 30 days from the date of operation were defined as periprocedural neurologic events. Stroke was defined as any non-convulsive, focal neurologic deficit of abrupt onset that persisted longer than 24 hours and that corresponded to a vascular territory. Severity of neurologic deficit was assessed using the NIHSS and the modified Rankin scale [MRS]. The NIHSS is a 15-item scale of neurologic impairment, with scoring that ranges

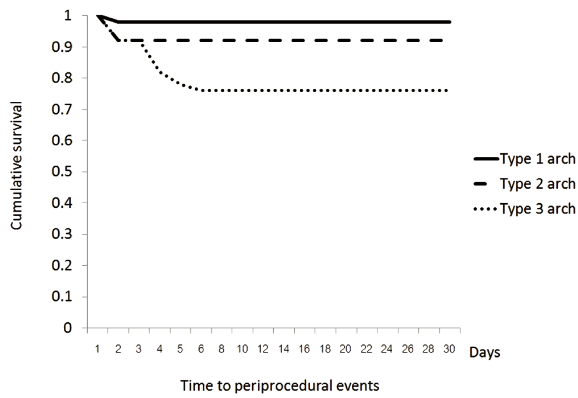

Figure 1.Kaplan-Meier plot of cumulative survival relative to time to periprocedural events showing a decrease in cumulative survival for all three types of aortic arch morphology, most notably aortic arch type III.

from 0 (no deficit) to 42 (quadriplegia and coma). The MRS is a disability scale with scoring that ranges from 0 (no symptoms) to 6 (death). Major stroke was defined as an NIHSS score of 9 or greater, or an MRS score of 3 or greater.

Statistical analysis

Subject baseline demographic and clinical characteristics are presented using descriptive statistics. Continuous variables are expressed as median (minimum, maximum) or mean ± standard deviation [SD]. Categorical variables are expressed as number and percentage. Bivariate analysis of periprocedural neurologic events and baseline, angiographic, and procedural characteristics were analyzed using the mean of crosstabs for categorical variables and comparison of means for continuous variables. Chi-square test and Fisher's exact test were used to compare each characteristic of interest with periprocedural neurologic events, and results were expressed as number and percentage for categorical variables and as mean ± SD for continuous variables. A *p*-value of less than 0.05 was considered to be statistically significant. Results of univariate and multivariate analyses were expressed as odds ratio [OR]. All statistical analysis was performed using SPSS Statistics version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

One hundred forty-four CAS procedures were performed in 130 patients, of whom 103 (79.2%) were men. Of 91 patients with symptomatic carotid artery stenosis, 56 (43%) had history of stroke, 22 (17%) had history of TIA, eight (6.2%) had retinal infarction or amaurosis fugax, and six (6.6%) had presented with two symptoms. Of 39 patients who had undergone CAS before undergoing coronary artery bypass graft [CABG], 13 had bilateral severe carotid stenosis (two of whom had undergone concomitant bilateral CAS), and one patient had undergone only percutaneous transluminal angioplasty [PTA] with balloon due to failed stent deployment. All patients had at least one feature that would place them at increased risk of perioperative complication and death after CEA, such as congestive heart failure (New York Heart Association class III or IV), presence of acute coronary syndrome within four weeks of presentation, severe pulmonary disease, or unfavorable anatomy (high ICA, CCA lesion below the clavicle, or previous neck surgery or irradiation)[13]. The technical success rate for completing the CAS procedure was 99% in this study. Carotid stenting was performed in the right ICA for 66 lesions (45.8%), in the left ICA for 59 lesions (41%), in the left CCA for 13 lesions (9%), and in the right CCA for six lesions (4.2%). The combination of 50% or more CCA stenosis with significant ICA stenosis at any site was seen in 16% of patients.

By the 30-day time point, eight major strokes (two fatal) had occurred for an overall major stroke/death rate of 5.5%. All strokes but one were ipsilateral. In addition, five (3.4%) minor strokes were observed. Half of qualified TIA/stroke events occurred more than 24 hours after the procedure (Table 1).

Baseline demographic and periprocedural neurologic events

Baseline demographic and clinical characteristics of patients with and without periprocedural neurologic events are shown in Table 2. Body mass index outside the normal range (less than 18.5 kg/m^2 or more than 25 kg/m^2) and older age (older than 70 years) were both found to be significantly associated with periprocedural neurologic events. Patients with poorly-control diabetes (HbA1c of 7 or more) had higher risk for periprocedural neurologic events than patients with HbA1c of less than 7. The authors also found that higher baseline systolic or diastolic blood pressure preceding the procedure was associated with a higher periprocedural neurologic events rate.

Aortic arch morphology and periprocedural neurologic events

Most patients (112 patients, 89.6%) had normal arch type. Bovine arch was found in 13 (10.4%) patients and arch anomaly was present in five (3.5%) patients. Type II arch was most common (62 patients; 42.3%), followed by type I arch (37 patients; 27.7%) and type III arch (24 patients; 16.2%).

Event rates were higher for bovine aortic arch and type III aortic arch morphology due to the complexity of arch anatomy (Tables 1 and 3). Periprocedural neurologic events occurred in one of 37 patients with type I arch (2.7%), in five of 62 patients with type II arch (8.1%), in six of 24 patients with type III arch (25%), and in two of 13 patients with bovine arch (15.4%). Incidence of death/major stroke was significantly higher in type III arch (16.6%) than in type I arch (0%) and type II arch (4.8%).

Procedural characteristics and periprocedural neurologic events

Results of analysis of angiographic and procedural characteristics are shown in Table 3 and 4. Periprocedural neurologic events increased in patients with significant calcification and concomitant CCA stenosis.

Table 1. Periprocedural events by number of cases, arch morphology and type, calcification, and CCA disease from 144 procedures in 130 patients

Periprocedural event	Frequency (n = 144)	Arch morphology			Bovine arch (n = 13)	Presence of significant calcification (n = 48)	CCA disease >50% (n = 25)
		Type I (n = 37)	Type II (n = 62)	Type III (n = 24)			
Death/major stroke	8 (5.5)	0 (0.0)	3 (4.8)	4 (16.6)	0 (0.0)	1 (2.0)	0 (0.0)
Death	2 (1.4)	0 (0.0)	0 (0.0)	2 (8.3)	0 (0.0)	1 (2.0)	0 (0.0)
Stroke/TIA (any)	13 (9.0)	1 (2.7)	5 (8.1)	6 (25.0)	2 (15.4)	9 (18.0)	6 (24.0)
Major ipsilateral	7 (4.8)	0 (0.0)	2 (3.2)	4 (16.6)	0 (0.0)	6 (12.6)	5 (20.0)
Major	1 (0.6)	0 (0.0)	1 (1.6)	0 (0.0)	0 (0.0)	1 (2.1)	0 (0.0)
Non-ipsilateral							
• Minor ipsilateral	3 (2.0)	0 (0.0)	2 (3.2)	1 (4.2)	2 (15.4)	1 (2.1)	1 (4.0)
• Minor non-ipsilateral	2 (1.4)	1 (2.7)	0 (0.0)	1 (4.2)	0 (0.0)	1 (2.1)	0 (0.0)

CCA = common carotid artery; TIA = transient ischemic attack

Data presented as number (%)

Table 2. Baseline demographic and clinical characteristics of patients with and without periprocedural neurologic events from 144 procedures in 130 patients

Characteristics	Frequency (n = 144)	Presence of periprocedural neurologic events (n = 13)	No periprocedural neurologic events (n = 131)	*p*-value
Male gender	114 (79.2)	12 (92.3)	100 (77.9)	0.221
Age >70 years	78 (54.2)	11 (84.6)	67 (51.1)	0.021
BMI				0.049
<18.5 kg/m^2	11 (7.6)	3 (23.1)	8 (6.1)	
18.5 to 24.9 kg/m^2	77 (53.5)	4 (30.8)	73 (55.7)	
>25 kg/m^2	56 (38.9)	6 (46.2)	50 (38.2)	
Underlying disease				
DM	65 (45.1)	6 (46.2)	59 (45.0)	0.939
HT	137 (95.1)	12 (92.3)	125 (95.4)	0.619
DLP	137 (95.1)	13 (100)	124 (94.7)	0.393
CAD	100 (69.4)	8 (61.5)	92 (70.2)	0.516
CKD	85 (59.9)	9 (69.2)	76 (58.9)*	0.470
Previous CABG	14 (9.7)	2 (15.4)	12 (9.2)	0.470
CHF NYHA class III/IV	16 (11.1)	1 (7.7)	15 (11.5)	0.681
Previous stroke	104 (72.9)	9 (62.9)	96 (73.3)	0.754
Previous TIA	21 (14.6)	2 (15.4)	19 (14.5)	0.655
Contralateral occlusion	18 (12.5)	3 (16.7)	15 (11.9)	0.568
Current smoker	70 (48.6)	7 (53.8)	63 (48.6)	0.776
Symptomatic carotid stenosis	97 (67.4)	10 (76.9)	87 (66.4)	0.441
SBP >160 mmHg	71 (49.3)	10 (76.9)	61 (46.6)	0.037
DBP >90 mmHg	28 (19.4)	6 (46.2)	22 (16.8)	0.011
Presence of AF	10 (6.9)	0 (0.0)	10 (7.6)	0.302

AF = atrial fibrillation; BMI = body mass index; CABG = coronary artery bypass grafting; CAD = coronary artery disease; CHF = congestive heart failure; CKD = chronic kidney disease; DBP = diastolic blood pressure; DLP = dyslipidemia; DM = diabetes mellitus; HT = hypertension; NYHA = New York Heart Association; SBP = systolic blood pressure; TIA = transient ischemic attack

* Data missing for two patients

Data presented as number (%); *p*-value <0.05 indicates statistical significance

Table 3. Descriptive analysis of anatomic factors of aortic arch type and morphology by event rate from 144 procedures in 130 patients

Procedural characteristics	Frequency (n = 144)	Presence of periprocedural neurologic events (n = 13)	No periprocedural neurologic events (n = 131)	*p*-value
Aortic arch anomaly	5 (3.5)	1 (7.6)	4 (3.4)	0.349
Bovine arch	13 (9.0)	2 (15.4)	11 (8.3)	0.300
Morphology[a]				0.060
Type I	37 (25.7)	1 (7.6)	36 (27.4)	
Type II	62 (43.0)	5 (38.4)	57 (43.5)	
Type III	24 (16.6)	6 (46.1)	18 (14.5)	
Angiographic finding				0.090
Ulceration	41 (28.5)	7 (53.8)	34 (25.9)	
Eccentric lesion	48 (33.3)	2 (15.4)	46 (35.1)	
Tortuosity of target lesion	61 (42.4)	5 (38.5)	56 (42.7)	0.765
Significant calcification	48 (33.3)	9 (69.2)	39 (29.7)	0.004
Presence of thrombus	3 (2.1)	0 (0.0)	3 (2.2)	0.508
Contralateral stenosis ≥50%	50 (34.7)	2 (15.4)	48 (36.6)	0.125
Disease of CCA >50% stenosis	25 (17.4)	6 (46.1)	19 (14.5)	0.040
Severe stenosis (≥80%)	47 (32.6)	7 (53.8)	40 (30.5)	0.087
Lesion length ≥15 mm	85 (59.0)	10 (76.9)	75 (57.3)	0.169

CCA = common carotid artery

[a] Aortic arch cineangiography could not determine arch morphology in 16 cases

Data presented as number (%); *p*-value <0.05 indicates statistical significance

Table 4. Procedural characteristics of patients with and without periprocedural events from 144 procedures in 130 patients

Procedural characteristics	Frequency (n = 144)	Presence of periprocedural neurologic events (n = 13)	No periprocedural neurologic events (n = 131)	*p*-value
Pre-dilation	108 (75.0)	11 (84.6)	97 (74.0)	0.401
Post-dilation	127 (88.2)	12 (92.3)	110 (87.3)	0.380
Successful EPD placement	125 (86.8)	10 (76.9)	115 (87.8)	0.270
Reference-vessel disease (mm)	5.3±1.21	5.4±1.41	5.3±1.19	0.765
Stent diameter	7.04±1.4	6.83±1.9	7.06±1.4	0.596
Stent length	36.71±9.3	41.42±14.9	36.28±8.6	0.068
Residual stenosis				<0.001
None	55 (38.2)	3 (23.1)	27 (20.6)	
<10%	57 (39.6)	4 (30.8)	51 (38.9)	
10 to 49%	2 (1.4)	4 (30.8)	53 (40.5)	
≥50%	0 (0.0)	2 (15.4)	0 (0.0)	
Use of inotrope	27 (18.8)	5 (38.5)	22 (16.8)	0.056
Use of vasodilator	40 (27.8)	3 (23.1)	37 (28.2)	0.692
Procedure time ≥90 minutes	64 (44.4)	9 (69.2)	55 (42.0)	0.050

EPD = embolic protection device

Data presented as number (%) or mean ± standard deviation; *p*-value <0.05 indicates statistical significance

Predictors of periprocedural neurologic events

Multivariate regression analysis identified the following three independent variables as predictors of periprocedural neurologic events, type III aortic arch morphology (OR 6.23, 95% confidence interval [CI] 1.7 to 22.9, $p = 0.006$), concomitant CCA stenosis (OR 4.33, 95% CI 1.1 to 16.9, $p = 0.035$), and presence of heavy calcification (OR 4.15, 95% CI 0.9 to 17.6, $p = 0.004$).

Discussion

In this study, type III aortic arch morphology, concomitant CCA stenosis, and heavily calcified lesion were found to be predictive of periprocedural neurologic events after CAS. Faggioli et al[14] studied brain diffusion-weighted MRI before and within 24 hours after CAS in 59 patients. Aortic arch type was classified as simple (type I and type II arch morphology) versus difficult (type III and bovine arch morphology). New brain lesions were frequently found (57.6%), although arch type was not correlated with number of brain lesions. However, volume of brain lesion was found to be greater in patients with difficult aortic arch[9]. Aortic arch atherosclerosis and vessel tortuosity also increased the likelihood of finding new brain lesion by diffusion-weighted MRI. In another study of 214 CAS patients by Faggioli et al[10], the rate of periprocedural neurologic events was higher in patients with aortic arch anomaly. Technical failure occurred in 12% of cases in that study. In the present study, the authors found that bovine arch increased the rate of periprocedural neurologic events but had less adverse impact than aortic arch type III. From another study, the incidence of any stroke or TIA was 15.4% for bovine arch, but 25% for aortic arch type III[14]. Heavily calcified lesions and concomitant CCA stenosis also increased the incidence of periprocedural neurologic events in the present study. Type III aortic arch, concomitant CCA stenosis, and heavily calcified lesions are factors known to increase the technical difficulty of performing CAS. Catheter maneuvers are difficult in a type III arch, and multiple catheter manipulations in the presence of atherosclerotic CCA stenosis can cause embolization. Our findings clearly show these three factors to be highly correlated with increased periprocedural neurologic complications. The 99% procedural success rate in this study came at a cost of increased periprocedural neurologic complications.

Although patients older than 70 years of age and patients with low body weight had increased incidence of periprocedural neurologic events, the effect of these factors was smaller than the effect of unfavorable anatomy. Lam et al reported that elderly patients had a higher incidence of unfavorable anatomy[9], in addition to the elderly tending to have more extensive systemic atherosclerosis. Bazan et al identified a positive correlation between age and aortic arch calcium content[15]. Although aging is highly correlated with unfavorable anatomy, advanced atherosclerosis, and heavily calcified lesions, its impact on periprocedural neurologic events is smaller than that of unfavorable anatomy. The learning curve for CAS also has been shown to influence the rate of periprocedural neurologic events[16]. In the present study, periprocedural complications occurred more often for interventionists with greater caseloads. This may be explained by an increased level of aggressive catheter manipulation in patients with difficult and complex carotid interventions.

Although baseline medical comorbidities were the same in patients with and without periprocedural neurologic events, the risk of events was greater in patients with poorly-controlled diabetes than in patients with well-controlled diabetes. High baseline SBP or high baseline diastolic blood pressure increased periprocedural neurologic events after CAS. Cerebral autoregulation becomes impaired after a long period of decreased cerebral blood flow that is caused by critical stenosis. Uncontrolled systolic and diastolic blood pressure after CAS can lead to reperfusion syndrome.

In conclusion, aortic arch type III morphology, concomitant CCA stenosis, and heavy calcification at the site of stenosis were found to be significant predictors of periprocedural neurologic events during or after CAS. The high technical success rate (99%) observed in our study cohort came at a cost of increased periprocedural neurologic events. These findings highlight the need for a strategic approach to performing CAS. Skilled catheter manipulation is important, especially in patients with unfavorable anatomy. However, knowing when to stop and look for alternative revascularization is perhaps more important. Although patients with aortic arch type III, concomitant CCA stenosis, and heavily calcified stenosis may undergo successful CAS, the neurologic complication rate is high.

Limitation

Consistent with the limitations inherent to a retrospective, single-center study, seventeen procedures were missing aortic arch-type information. In addition, three different interventionists performed the CAS procedures. As such, variations in periprocedural neurologic events among the interventions may have resulted from differences in technique and aggressiveness relative to catheter manipulation.

Impact on daily practice

Type III aortic arch, presence of greater than 50% common carotid stenosis, and heavily calcified lesion are strong predictors of 30-day periprocedural events during CAS. Management of these anatomical variants/lesions should be carefully and strategically planned, given the high potential for procedural complications.

What is already known on this topic?

CAS is an alternative to CEA, especially in patients at high-risk for CEA-related comorbidities. However, in elderly patients (older than 70 years of age), outcomes were better for CEA than for CAS.

What this study adds?

We identified type III aortic arch, presence of more than 50% common carotid stenosis, and heavy calcified lesion as predictors of 30-day periprocedural events in Thai patients. In our study population, type III aortic arch and significant calcification was found in 14.5% and 29.7% of patients, respectively.

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Potential conflicts of interest

The authors declare no conflict of interest.

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