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Effect of aortic arch type on technical indicators in patients undergoing carotid artery stenting

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Abstract

Objective: This study was performed to explore the effect of the aortic arch type on technical indicators in patients undergoing carotid artery stenting (CAS).

Methods: The data of 224 consecutive patients who underwent unilateral CAS from January 2011 to December 2012 were retrospectively analyzed. The requirement for placement of the guiding catheter into the common carotid artery with assistance of an angiographic catheter, fluoroscopy time, contrast agent dose, and adverse events were recorded.

Results: The fluoroscopy time was significantly longer and the contrast agent dose was significantly higher in patients with Type III than Type I and II arches. Significantly more patients with Type III than Type I and II arches required placement of the guiding catheter with assistance of an angiographic catheter (46.2% vs. 15.0%, respectively). The procedural success rate was significantly lower in patients with Type III than Type I and II arches (96.2% vs. 100.0%, respectively). The incidence of death, myocardial infarction, and all types of stroke was significantly higher in patients with Type III than Type I and II arches (7.7% vs. 1.7%, respectively).

Conclusions: The aortic arch type is an important influential factor in CAS. Type III arches are associated with more difficulties and complications.

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Introduction

With improvement in endovascular techniques and the development of embolic protection devices, carotid artery stenting (CAS) has shown more convincing perioperative and long-term results in preventing ischemic stroke than carotid endarterectomy, with a lower incidence of cranial nerve palsy and myocardial infarction.[1,2] Some small series have shown that the complexity of CAS is associated with the severity of carotid stenosis, the original abnormality, the degree of tortuosity, the aortic arch type, and other factors.[1,3–5] Among these factors, the aortic arch type has a strong influence on the technical success rate of CAS. This study was performed to investigate the influence of the anatomical morphology of the aortic arch on technical indexes of carotid artery stent implantation.

Patients and methods

Patient population

The clinical data of consecutive patients who underwent CAS from January 2011 to December 2012 at our hospital were retrospectively analyzed. All patients had a standard aortic arch (no abnormal origin of supra-aortic vessels or malformation of the aortic arch), underwent unilateral CAS alone, used an embolic protection device, and underwent no percutaneous intervention of other blood vessels. The indication for CAS was a carotid artery diameter reduction of >60% (symptomatic) or >80% (asymptomatic) as assessed by quantitative angiography using the North American Symptomatic Carotid Endarterectomy Trial methodology.[6] Before the CAS procedure, all patients provided written informed consent. The study was approved by the ethics committee of our hospital.

CAS procedure and medical protocol

Supra-aortic computed tomography (CT) angiography was performed in all patients scheduled to undergo CAS to detect the aortic arch type, the presence of an abnormal origin, and the degree of tortuosity of the supra-aorta vessels. Cranial plain CT/magnetic resonance imaging (MRI) was performed before CAS in all patients and after CAS if a new cerebrovascular event was suspected. The purpose of performing preinterventional cranial plain CT/MRI was to evaluate intracerebral lesions, exclude contraindications for CAS, and provide a reference if new cerebrovascular events occurred after CAS. An independent neurologist evaluated all patients according to functional testing with the modified Rankin score before, during, and after the procedure in case new cerebrovascular events occurred.

Before the procedure, all patients received aspirin (100 mg/d) and clopidogrel (75 mg/d) for at least 2 days plus a loading dose of clopidogrel (150 mg) if they had not previously been on clopidogrel. The patients still received their regular antihypertensive medications, with the exception of beta-blockers, on the morning of the

procedure. All CAS procedures were performed under local anesthesia via femoral access. An 8-Fr introducer sheath was positioned and heparin (1 mg/kg) was administered. Continuous arterial pressure monitoring and electrocardiographic monitoring were performed during the procedure. Cervical-cerebral angiography was performed using a diagnostic catheter (5-Fr Omni Flush; Cordis, Fremont, CA, USA) to determine the patency and completeness of the circle of Willis. An 8-Fr MPA1 guiding catheter (Cordis) was then placed into the common carotid artery with or without the assistance of an angiographic catheter (5 MPA1, Simmons or Bentson catheter). Distal embolic protection was performed in all patients during the CAS procedure using a FilterWire EZ system (Boston Scientific, Marlborough, MA, USA) or a Spider RX system (Medtronic/Covidien, Minneapolis, MN, USA). If the diameter reduction was $\geq$85%, the lesion was predilated by an undersized balloon (3–4 mm). If needed, the lesion was postdilated to achieve residual stenosis of $\leq$30% after stent deployment. Atropine (0.5–1.0 mg) was intravenously administered in advance to avoid or attenuate bradycardia in all patients with lesions located at the carotid bulb. If hypotension occurred, the patients received 2 to 3 mg of dopamine and rapid administration of additional fluids. We continued treatment with 100 mg of aspirin once daily as a permanent medication and 75 mg of clopidogrel once daily for at least 3 months after the CAS procedure.

Endpoints

The endpoints were the requirement for placement of the guiding catheter into the common carotid artery with assistance of an angiographic catheter, the X-ray exposure time, the dose of contrast agent, and adverse events during the hospital stay. The type of aortic arch was based on the relationship of the innominate artery to the aortic arch on CT angiography.[7] In a Type I aortic arch, the origin of all three great vessels is located in the same horizontal plane as the outer curvature of the aortic arch. In a Type II aortic arch, the innominate artery originates between the horizontal planes of the outer and inner curvatures of the aortic arch. In a Type III aortic arch, the innominate artery originates below the horizontal plane of the inner curvature of the aortic arch. Major stroke was defined as a modified Rankin score of $\geq$4 at 30 days after symptom onset. A minor stroke was defined as a Rankin score of $\leq$3 that resolved completely within 30 days.[8] Contrast-induced nephropathy (CIN) was defined as a >25% relative increase in the serum creatinine level from baseline or an absolute increase of $\geq$44.2 mmol/L within 72 h after the interventional procedure.[9]

Statistical analysis

Continuous variables were presented as mean $\pm$ standard deviation and were compared using Student's t test, while categorical data were presented as count and percentage and were compared using the chi-square test or Fisher's exact test. All probability values were two-sided, and a P value of <0.05 was considered to indicate statistical significance. All analyses were performed using SPSS Statistics for Windows, Version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Baseline clinical characteristics

In total, 224 patients were included in this study. The patients' baseline clinical characteristics are shown in Table 1. Type I and II aortic arches were present in 120 (53.6%) patients, and Type III aortic arches were

Table 1. Baseline characteristics according to aortic arch type.

Variable	Type I + II (n = 120)	Type III (n = 104)	P value
Age, years	64.9 ± 7.2	65.2 ± 8.9	0.405
Body mass index, kg/m^2	25.6 ± 7.9	26.4 ± 11.2	0.654
Male	89 (74.2)	84 (80.8)	0.266
Coronary artery disease	104 (86.7)	83 (79.8)	0.207
Hypertension	101 (84.2)	87 (83.7)	1.000
Previous stroke	37 (30.8)	36 (34.6)	0.570
Hyperlipidemia	102 (85.0)	86 (82.7)	0.716
Diabetes	52 (43.3)	37 (35.6)	0.274
Smoking	71 (59.2)	70 (67.3)	0.216
Serum creatinine, mmol/L	80.8 ± 18.5	82.5 ± 20.4	0.313

Data are presented as mean ± standard deviation or n (%).

Table 2. Procedure characteristics according to aortic arch type.

Variable	Type I + II (n = 120)	Type III (n = 104)	P value
Lesion side			0.688
Left	57 (47.5)	53 (51.0)	
Right	63 (42.5)	51 (49.0)	
Target lesion location			0.597
Common carotid artery	5 (4.2)	7 (6.7)	
Common/internal carotid artery	29 (24.2)	28 (26.9)	
Internal carotid artery	86 (71.6)	69 (66.4)	
Fluoroscopy time, minutes	9.1 ± 2.3	14.1 ± 5.1	<0.001
Contrast dose, mL	92.4 ± 14.2	130.1 ± 31.3	<0.001
Requirement for angiographic catheter assistance	18 (15.0)	48 (46.2)	<0.001
Technical success	120 (100)	100 (96.2)	0.045

Data are presented as mean ± standard deviation or n (%).

present in 104 (46.4%) patients. There were no statistically significant differences in any of the patients' baseline clinical characteristics according to the aortic arch type.

Procedure characteristics

The procedure characteristics of all patients according to the aortic arch type are shown in Table 2. The fluoroscopy time was significantly longer in patients with a Type III aortic arch than in those with Type I and II arches (14.1 ± 5.1 vs. 9.1 ± 2.3 minutes, respectively; $P < 0.001$). The contrast dose was significantly higher in patients with a Type III arch than in those with Type I and II arches (130.1 ± 31.3 vs. 92.4 ± 14.2 ml, respectively; $P < 0.001$). Significantly more patients with a Type III arch than Type I and II arches required placement of the guiding catheter into the common carotid artery with assistance of an angiographic catheter [48/104 (46.2%) vs. 18/120 (15.0%), respectively; $P < 0.001$]. The technical success rate was significantly lower in patients with a Type III arch than in those with Type I and II arches (96.2% vs. 100.0%, respectively; $P = 0.045$).

Table 3. In-hospital adverse events according to aortic arch type.

Variable	Type I + II (n = 120)	Type III (n = 104)	P value
Minor stroke	1 (0.8)	4 (3.8)	0.186
Major stroke	1 (0.8)	3 (2.9)	0.339
Myocardial infarction	0 (0.0)	1 (1.0)	0.464
Contrast-induced nephropathy	8 (6.7)	15 (14.4)	0.077
Death	0 (0.0)	0 (0.0)	NA
Death, myocardial infarction, and all types of stroke	2 (1.7)	8 (7.7)	0.048

Data are presented as n (%). NA, not applicable.

Endpoints

The in-hospital adverse events according to the aortic arch type are shown in Table 3. Ten (8.3%) adverse events occurred in patients with Type I and II arches, including one case of minor ischemic stroke, one case of major ischemic stroke, and eight (6.7%) cases of CIN. Twenty-three (22.1%) adverse events occurred in patients with a Type III arch, including 4 (3.8%) cases of minor stroke (1 hemorrhagic, 3 ischemic), 3 (2.9%) cases of major stroke (1 hemorrhagic, 2 ischemic), 1 (1.0%) case of myocardial infarction, and 15 (14.4%) cases of CIN. The incidence of death, myocardial infarction, and all types of stroke was higher in patients with a Type III arch than in those with Type I and II arches (7.7% vs. 1.7%, respectively; $P = 0.048$).

Discussion

The aortic arch is a major source of cerebral embolization during diagnostic and interventional procedures of supra-aortic vessels.[10] A complex aortic arch anatomy (i.e., Type III arch and/or bovine arch) may increase the technical difficulties of CAS and the risk of neurological complications via femoral access.[10–12] A study by Gray et al.[13] showed that more than 20% of stroke were related to catheterization difficulties, especially when procedures were performed by less experienced interventional physicians. Most of the currently available clinical data on percutaneous carotid revascularization reflects a normal aortic arch anatomy,[1,14] and the effects of the aortic arch type on technical indicators in patients undergoing CAS remain unclear. In the present study, patients with a Type III aortic arch had a longer fluoroscopy time and used a higher dose of contrast agent than patients with Type I and II arches (both $P < 0.001$). The incidence of death, myocardial infarction, and all types of stroke were also significantly higher in patients with a Type III arch ($P = 0.048$). Additionally, significantly more patients with a Type III arch required placement of the guiding catheter into the common carotid artery with assistance of an angiographic catheter than did patients with Type I and II arches ($P < 0.001$). Our results indicate that the aortic arch type is an important factor affecting carotid stent deployment and that it is crucial to select the appropriate treatment strategy for a Type III aortic arch.

Several techniques and approaches (transcervical, transradial, and transbrachial) have been proposed to facilitate cannulation of a guiding catheter into the common carotid artery. Montorsi et al.[15] and Fang et al.[16] described carotid angioplasty and/or CAS using a catheter looping and retrograde engagement technique via the brachial or radial approach in patients with a bovine aortic arch configuration.

Cardaioli et al.[17] proposed the "multi-wire technique" to facilitate selective cannulation of the common carotid artery in patients with anatomically hostile necks. Given the inherent limitation of embolic protection devices with the unprotected steps of arch, supra-aortic, and lesion navigation, especially for patients with a complex aortic arch anatomy, a technique for cerebral protection with flow reversal using the ENROUTE Transcarotid Neuroprotection System (Silk Road Medical, Inc., Sunnyvale, CA, USA) was reported by Criado et al.[18] and evaluated by Alpaslan et al.[19] In the PROOF study, 75 patients who underwent transcarotid artery revascularization with the ENROUTE System were evaluated. No device or procedure-related stroke, myocardial infarction, or death occurred, and the proportion of patients with new ispilateral cerebral lesions as evaluated by diffusion-weighted MRI scans was lower than that reported in the transfemoral CAS series.[19] In the RADCAR study, Ruzsa et al.[20] compared the outcome and complication rates of transradial and transfemoral CAS. Type III aortic arches occurred more frequently in the transradial group. There was no significant difference in the incidence of major adverse cardiac and cerebral events between the two groups. The authors recommended the performance of transradial CAS in patients with difficult common carotid artery cannulation (aortoiliac disease or severe tortuosity, bovine arch, and Types II and III aortic arch).[20]

In some patients in the present study, we encountered unsuccessful cannulation of the guiding catheter into the common carotid artery directly (mainly those with a Type III aortic arch). In such cases, a special diagnostic catheter (5-Fr Bentsen or Simmons) was selected to facilitate the introduction of a hydrophilic guidewire into the external carotid artery; the diagnostic catheter was then withdrawn with the guidewire placed in the external carotid artery, and a 125-cm 5-Fr MPA diagnostic catheter/8-Fr MPA guiding catheter system could be easily steered over the guidewire by the coaxial technique. Notably, however, four patients with a Type III aortic arch underwent unsuccessful CAS despite use of the above-described technique. In such cases, carotid endarterectomy may be an alternative treatment strategy.[21]

This study had three main limitations. First, it was a retrospective study, and such a study design had inherent limitations. Second, no median or long-term follow up was performed. Third, the hospital costs were not evaluated.

Conclusion

The aortic arch type is an important factor affecting CAS. The Type III aortic arch was associated with a longer fluoroscopy time, higher dose of contrast agent, and more adverse events. A full understanding of the anatomy of the aortic arch and formulation of the most appropriate intervention strategy are crucial to increasing the success rate of CAS and reducing operation-related complications.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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