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Risk Factors of Contralateral Microembolic Infarctions Related to Carotid Artery Stenting

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Abstract

This study sought to analyze the incidence of contralateral microembolic infarctions (MIs) on diffusion-weighted imaging (DWI) following protected carotid artery stenting (CAS) and compared the difference of risk factors between ipsilateral and contralateral lesions. From April 2010 to March 2017, 147 CASs in 140 patients were performed. All the patients underwent DWI within 1 week before and 24 hrs after the procedures. CAS was successfully completed in 145 (98.6%) of the 147 procedures. Forty-nine (33.8%) patients with new MIs revealed on postprocedural DWI were enrolled. They were divided into ipsilateral and contralateral groups based on the side of the CAS and MIs. The ipsilateral group indicates patients with MIs exclusively on the side of CAS. The contralateral group includes patients with MIs on the opposite side of the CAS or both sides. Patients with MIs at vertebrobasilar territory were excluded. Patient characteristics, morphology of the carotid artery and aortic arch, and procedural data were retrospectively assessed and compared between the two groups. Twenty-two (15.2%) and 14 (9.7%) patients were assigned to the ipsilateral and contralateral groups, respectively. Advanced age, left-sided stenosis, severe aortic arch calcification (AAC) on chest X-ray and contralateral carotid occlusion significantly increased the occurrence of contralateral MIs. On multivariable logistic regression analysis, severe AAC was statistically more frequent in the contralateral group. In the present study, the incidences of contralateral MIs after CAS is relatively not low. Advanced aortic atherosclerosis is statistically predictive for contralateral MIs. AAC on chest X-ray is a useful finding for estimating aortic atherosclerosis in candidates for CAS.

Key words: aortic atherosclerosis, carotid artery stenosis, carotid artery stenting, diffusion-weighted imaging, ischemic complication

Introduction

Carotid artery stenting (CAS) is an endovascular alternative to carotid endarterectomy (CEA) for prevention of ischemic stroke in patients with carotid artery stenosis. Distal cerebral embolism is an important technical complication with CAS. Even though embolic protection devices (EPDs), including distal balloon occlusion devices, proximal flow reverse devices, and filter EPDs, could achieve favorable clinical and radiographical outcomes, in the International Carotid Stenting Study (ICSS)–Magnetic Resonance Imaging (MRI) substudy, new microembolic infarctions (MIs) were discovered to have a 50% incidence after CAS in the trial compared with just 17% of patients receiving CEA.[1] The occurrence rate of MIs on diffusion-weighted imaging (DWI) has been reported to be 26.0–70.8% after CAS even with EPDs.[2–8] Clinical, procedural, and morphological parameters predictive of new MIs following CAS have been described previously. Simultaneously, these types of lesions outside the territory of the treated carotid artery have been reported.[3,5] Aortic arch manipulation is believed to be the primary reason for developing MIs in the

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contralateral hemisphere. In Endarterectomy versus Stenting in Patients with Symptomatic Severe Carotid Stenosis (EVA-3S) trial, 28.0% of the procedural complications after CAS occurred during navigation in the aortic arch before the supraaortic artery was cannulated.[9] However, risk factors have not been extensively identified. This study aimed to evaluate the incidence of contralateral MIs during protected CAS as well as to examine the risk factors including characteristics of aortic arch.

Materials and Methods

Study population

We conducted a retrospective study of patients with symptomatic [stenosis ≥ 50%, per North American Symptomatic Carotid Endarterectomy Trial (NASCET)] or asymptomatic (stenosis ≥ 80%, per NASCET) atherosclerotic carotid artery stenosis treated by CAS from April 2010 through March 2017 at our institute.[10] A total of 140 consecutive patients with 147 carotid artery stenoses were treated by protected CAS. No patients were treated for simultaneous bilateral or ostial carotid lesions. In 84 (57.9%) symptomatic cases, the CAS procedure was performed more than 6 weeks after onset.

The patients consisted of 117 males (80.7%) with a mean age of 72.2 years (age range: 58–83 years). Among the 147 CAS procedures, 84 and 63 CAS procedures were performed in the right and left carotid artery, respectively. No patients underwent cerebral angiography or neurointervention procedures within a month before CAS. All CAS procedures were performed with EPDs. All the patients underwent DWI within 1 week before and 24 hrs after the procedures. Among them, 49 patients (33.8%) with MIs on the DWIs were enrolled in this study. The findings of MIs were classified into the following two categories based on the side of the CAS and MIs: ipsilateral or contralateral groups. The ipsilateral group indicates patients with MIs exclusively on the side of CAS. The contralateral group includes patients whose MIs are detected on the opposite side of the CAS or bilaterally. Because ischemic mechanism of vertebrobasilar artery territory after CAS is supposed to differ from that of the internal carotid artery (ICA) territory, 13 patients (9.0%) with MIs in the brain stem or the cerebellum were excluded from the study.

Information regarding the factors including patient characteristics, morphology of carotid artery, and aortic arch, and procedural data was collected for each patient by reviewing their medical records. Reduced cerebral blood flow was defined as a decrease of <80% from the contralateral side. Hemodynamic instability was defined as a decrease of <90 mmHg in systolic blood pressure and a decrease of <50 beats/min in heart rate. The present study was approved by the ethics committee of St. Marianna University School of Medicine. Written informed consent was obtained from all the patients.

Imaging assessment

Characteristics of the carotid artery lesion were evaluated on digital subtraction angiography. The degree of stenosis was measured using the NASCET criteria.[10] Unstable plaque was defined as high intensity areas in the plaque compared with the sternocleidomastoid muscle detected by magnetic resonance plaque imaging or echo lucent plaque detected by carotid duplex ultrasound. The anatomical characteristics of aortic arch type[11] and supraaortic vessels were evaluated on 3D-computed tomography angiography. Angles of the supraaortic artery were defined as the angulated take off of the innominate artery (for right-sided lesions) and the left common carotid artery (for left-sided lesions). The presence of aortic arch calcification (AAC) was evaluated on chest X-ray and divided into four grades using the Shimada's criteria:[12] no visible calcification (grade 0), small spots or a single thin area of calcification (grade 1), one or more areas of thick calcification (grade 2), and circumferential calcification (grade 3). The presence of anterior communicating artery (ACoA), azygos and bihemispheric anterior cerebral arteries was evaluated on 3D-computed tomography and digital subtraction angiographies. Preoperative MRI including fluid-attenuated inversion recovery (FLAIR) images obtained within 1 week prior to the procedure were available for all the patients. Periventricular white matter high signal intensity signals as an index for chronic ischemic brain lesions were evaluated using the grading system proposed by Shinohara et al.[13] The grading system had five grades that ranged from 0 to 4, and the higher grades could indicate severe white matter lesions. Postprocedural DWI was performed within 24 hrs after the CAS procedure in all the patients.

The MRI devices used in this study were the Achieva Nova and the Achieva Nova-Dual 1.5T (Philips, Rastatt, Germany). MRI sequences included FLAIR and DWI. The FLAIR sequences were performed with the following parameters: repetition time (TR)/echo time (TE)/excitation 6,000 ms/120 ms/2, inversion time 2,000 ms, matrix 202 × 224, field of view (FOV) 230 × 230 mm^2, and section thickness 6 mm with intersection gap 0.6 mm. Total acquisition time was 3 min 36 s. DWI was performed using a spin-echo echo-planar sequence with the following parameters: b values 1,000 s/mm^2, TR/TE/excitation 3,000 ms/90 ms/2, matrix 127 × 128, FOV 230 × 230 mm^2, section thickness 6 mm with intersection gap 0.6 mm, and 22 slices. Total acquisition time was 1 min 3 s.

Independent neuroradiologists analyzed new MIs in the cerebral hemispheres by comparing the pre- and postprocedural DWIs for each CAS. Cerebral blood flow was measured by single-photon emission computed tomography with I^{123}-labeled *N*-isopropyl-*p*-iodoamphetamine and performed in all the patients.

Endovascular procedure

All the patients were premedicated with 100 mg of acetylsalicylic acid and 75 mg of clopidogrel or 200 mg of cilostazol for at least 10 days prior to the procedure without a loading dose. The procedures were performed by an experienced neurointerventional team. Systemic heparinization was achieved with target activated clotting times between 300 and 350 s during the procedure.

After gaining femoral (n = 112, 76.2%) or brachial access (n = 35, 23.8%) under local anesthesia, 8-Fr guiding catheters were advanced over the 6-Fr coaxial catheter-guidewire combination into ipsilateral common carotid artery proximal to the carotid stenosis. No patients underwent direct carotid puncture and diagnostic angiography at the aortic arch and the contralateral ICA prior to the procedure. A distal balloon protection (Carotid GuardWire PS; Medtronic, Santa Rosa, CA, USA) with or without proximal balloon was mainly used (n = 96, 66.2%), and filter protection (FilterWire EZ; Boston Scientific, Natick, MA, USA) was used for the others with ischemic intolerance (n = 49, 33.8%). The selection of the stent depended on the ICA morphology. Our stent selection strategy was as follows: Closed-cell stent (Carotid Wallstent Monorail; Boston Scientific Corporation, Natick) is mainly used (n = 95, 65.5%) for its superiority of close coverage for a vascular wall. Open-cell stent (Precise; Cordis Corporation, Miami Lakes, FL, USA) is suitable for cases of tortuous or calcified lesions (n = 50, 34.5%). In general, an EPD was initially introduced into the distal ICA. After an intravenous injection of 0.5–1.0 mg atropine, we performed predilation followed by stent placement. After postdilation for optimal dilation of the lesion, a routine aspiration method was performed. In each case, about 20–50 ml of blood was aspirated through an export aspiration catheter (Medtronic, Minneapolis, MN, USA) until the gross debris disappeared. Finally, the EPD was retrieved. After the completion of CAS, heparin was not reversed until its effect disappeared spontaneously. Dual antiplatelet therapy was continued for longer than 6 months after the procedure.

Statistical analysis

Continuous variables are reported as the mean ± standard deviation, and comparisons of these variables between groups were performed using the Mann–Whitney U test. Categorical variables are reported as percentages, and were compared using Fisher's exact probability test. Factors predictive in univariate analysis ($P \le 0.05$) were entered into a backward multivariate logistic regression analysis; P values of ≤0.05 were considered statistically significant. Receiver-operating characteristic (ROC) curve analysis of the AAC grade for prediction of developing MIs was then performed, and the area under the ROC curve (AUC), sensitivity, and specificity were determined. The threshold was then calculated as the optimum ROC operating point with equally attributed weights to specificity and sensitivity, and overall accuracy was estimated as AUC. All statistical analyses were performed with "EZR (Easy R)" software,[14] which is a graphical user interface for R (The R foundation for Statistical Computing, Vienna, Austria). More precisely, it is a modified version of R commander designed to add statistical functions frequently used in biostatics.

Results

Carotid artery stenting was successfully completed in 145 (98.6%) of the 147 procedures. Angiography immediately after the procedure revealed no evidence of distal embolization in the intracranial circulation in any of the patients. The mean percent stenosis, which was 78.0 ± 14.3% before CAS, improved to 17.3 ± 17.0% after CAS. Although ischemic and hemorrhagic stroke after CAS occurred in each patient (0.7%), they suffered transient minor symptoms. No major adverse events, such as major stroke, myocardial infarction, or death, were noted in the periprocedural period.

Overall, new MIs on postprocedural DWIs were observed in 49 patients (33.8%): ipsilateral hemisphere alone in 22 patients (15.2%), contralateral hemisphere alone in four patients (2.8%), and both hemispheres in 10 patients (6.9%). Finally, 36 patients (24.9%), excluding cases with brain stem or cerebellum infarctions (n = 13, 9.0%), were matched criteria specified and divided into 22 patients (15.2%) in the ipsilateral group (Fig. 1) and 14 patients (9.7%) in the contralateral group.

Baseline characteristics of the patients and morphological findings of the vascular structures, and procedural factors were summarized and

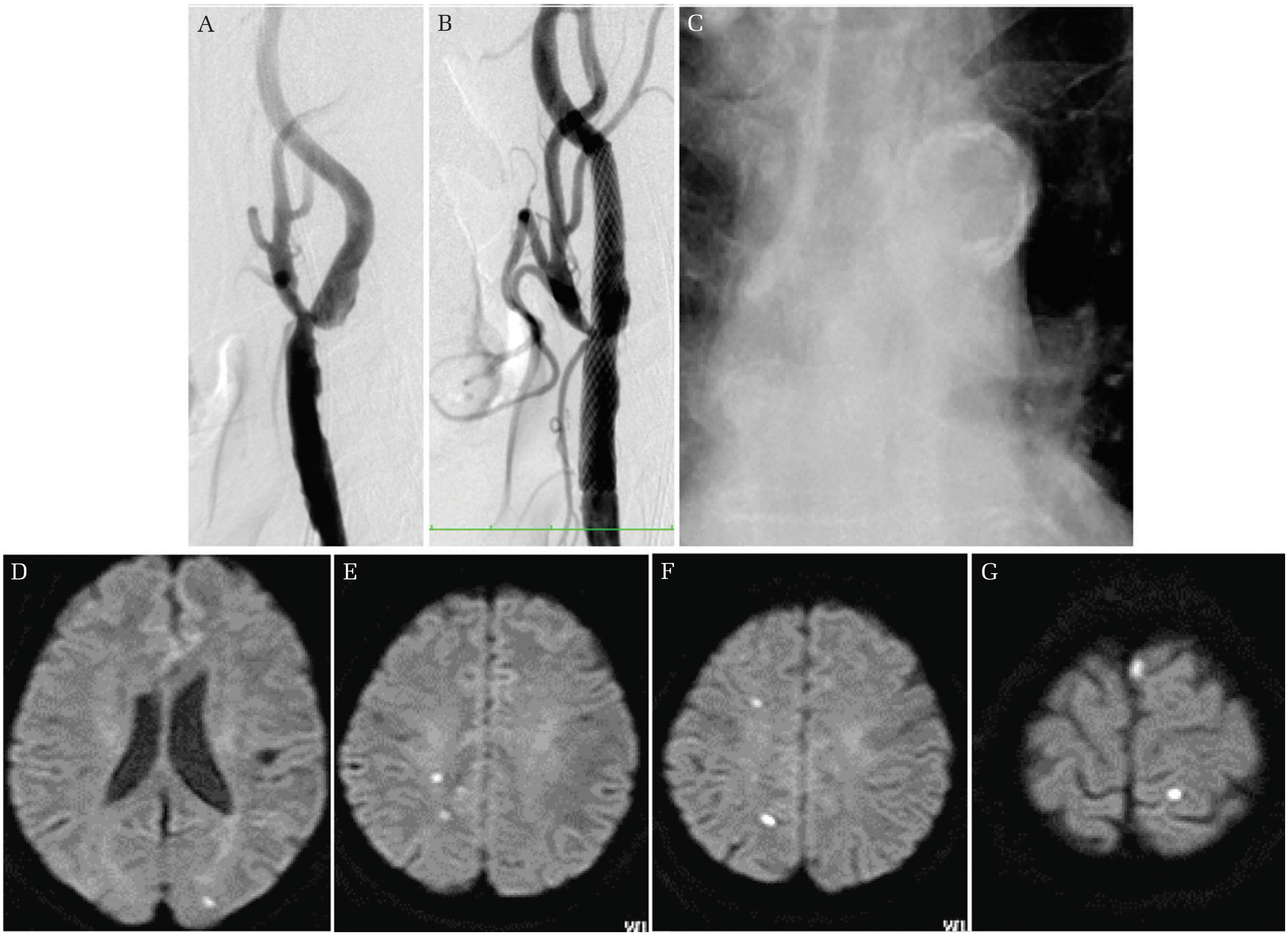

Fig. 1 Left-sided CAS was performed in an 81-year-old man who presented with a minor stroke. (A) Angiogram of the left carotid artery before stenting, showing a 65% stenosis of the internal carotid artery. (B) Angiogram after stenting shows successful dilatation of the carotid lumen. (C) AAC on chest X-ray indicated Shimada's grade 3. (D–G) Postprocedural diffusion-weighted magnetic resonance imaging showed multiple MIs in both cerebral hemispheres.

compared (Table 1). Age was significantly higher in the contralateral group compared to that in the ipsilateral group. There were no significant differences with respect to sex, medical comorbidities, previous stroke history, or the presence ratio of ACoA, azygos and bihemispheric anterior cerebral arteries between the two groups.

The mean degree of treated and contralateral carotid artery stenosis was 81.3% and 21.3% in the ipsilateral group and 73.9% and 38.3% in the contralateral group, respectively. No statistical differences were found between the two groups. There were four (2.8%) patients with complete occlusion of contralateral ICA who were all in the contralateral group that had reduced cerebral blood flow on the carotid occlusion side, and whose hemisphere was fed by the opposite ICA through ACoA (Fig. 2). Left-sided stenosis and severe AAC were significantly more frequent in the contralateral group compared with those in the ipsilateral group. The multivariate logistic regression analysis is shown in Table 2. Severe AAC was an independent predictor of developing postprocedural new contralateral MIs with an odds ratio of 4.75. The grade of AAC from the ROC curve had AUC > 0.8, and the optimal cut-off point was grade 2 (sensitivity 50.0%, specificity 86.4%).

Discussion

Diffusion-weighted imaging has proved to be superior to other MRI sequences and is now considered to be the best technique for the evaluation of cerebral ischemic lesions after carotid intervention. Cerebral ischemic event is one of the most frequent complications of CAS. Appearance rates of subclinical

Table 1 Baseline characteristics and analysis of risk factors for contralateral microembolic infarctions

Clinical information	Total (n = 145)	Postprocedural MI		P-value
		Ipsilateral group (n = 22)	Contralateral group (n = 14)	
Patient demographics				
Age, mean (SD)	72.2 (7.3)	70.6 (4.7)	73.6 (3.2)	0.031
Male, n (%)	117 (80.7)	20 (90.9)	11 (78.6)	0.287
Medical comorbidities, n (%)				
Hypertension	110 (75.9)	18 (81.8)	11 (78.6)	0.752
DM	43 (29.7)	9 (40.9)	6 (40.9)	0.589
Dyslipidemia	59 (40.7)	9 (40.9)	6 (40.9)	0.589
CAD	45 (31.0)	4 (18.2)	2 (14.3)	0.569
Smoking	21 (14.5)	11 (50.0)	7 (50.0)	0.47
Previous stroke history	84 (57.9)	11 (50.0)	8 (57.1)	0.633
Morphological factors				
Left side, n (%)	63 (43.4)	7 (31.8)	12 (85.7)	<0.01
Unstable plaque, n (%)	94 (64.8)	17 (77.3)	10 (71.4)	0.786
PreCAS stenosis rate (SD)	78.0 (14.3)	81.3 (11.9)	73.9 (13.5)	0.157
PostCAS stenosis rate (SD)	17.3 (17.0)	17.1 (15.7)	11.2 (11.6)	0.307
Contralateral stenosis rate (SD)	30.2 (29.9)	21.3 (15.6)	38.3 (33.2)	0.719
Contralateral occlusion, n (%)	4 (2.8)	0	4 (28.6)	0.017
Grade of deep white matter lesion, average	1.7	2	1.9	0.907
Reduced cerebral blood flow, n (%)	14 (9.7)	4 (18.2)	4 (28.6)	0.369
Aortic arch type, average	2.2	2.3	2.4	0.684
Grade of AAC, average	0.7	0.6	1.6	<0.01
Angle of supraaortic artery (SD)	55.6 (18.9)	58.1 (13.7)	41.8 (17.0)	0.055
ACoA, n (%)	121 (83.4)	18 (81.8)	11 (78.6)	0.597
Azygos or bihemispheric ACA, n (%)	13 (9.0)	2 (9.1)	1 (7.1)	0.669
Periprocedural information				
Transfemoral approach, n (%)	112 (76.2)	12 (54.5)	9 (64.3)	0.411
Distal balloon protection, n (%)	96 (66.2)	17 (77.3)	8 (57.1)	0.182
Closed-cell stent, n (%)	95 (65.5)	15 (68.2)	12 (85.7)	0.46
Hemodynamic instability, n (%)	42 (29.0)	7 (31.8)	5 (35.7)	0.544
Number of added catheter or guidewire, average	0.13	0.14	0.79	0.994

AAC: aortic arch calcification, ACA: anterior cerebral artery, ACoA: anterior communicating artery, CAD: coronay artery disease, CAS: carotid artery stenting, DM: diabetes mellitus, SD: standard deviation.

MIs after protected CAS of 26.0–70.8% have been reported.[2–8] Because new MIs after protected CAS in meta-analysis comprising >1,300 patients revealed 33%,[15] the present study revealing 33.8% was considered an acceptable result. Clinical, procedural, and morphological parameters predictive for MIs have been studied previously. Groschel et al.[16] evaluated a risk score to predict ipsilateral MIs following protected CAS and concluded advanced age, lesion ulceration, and long lesion were associated. Some investigators have reported other risk factors including: smoking history,[17] plaque calcification,[18] aortic arch anatomy[18,19] and atherosclerotic lesions,[20] internal/common carotid angle,[9] and the side of the procedure.[9]

Notably, about 30% of these lesions occur in the cerebral hemisphere contralateral to the target

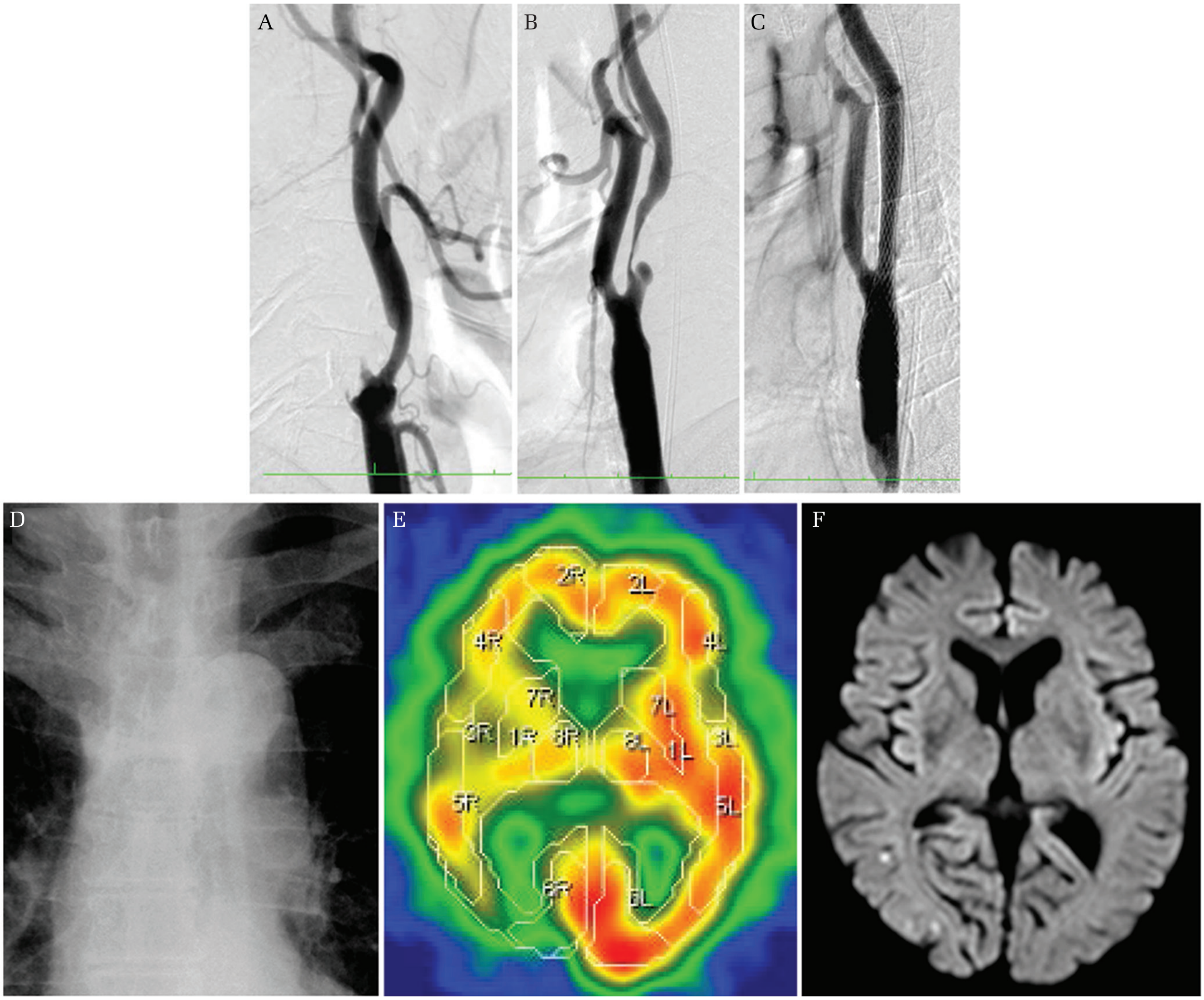

Fig. 2 Left-sided CAS was performed in an asymptomatic 75-year-old man. (A and B) An angiogram showing (A) the right carotid artery completely occluded and (B) the left carotid artery with 93% stenosis before stenting. (C) An angiogram of the left carotid artery shows successful dilatation of the carotid lumen after stenting. (D) AAC on the chest X-ray indicated Shimada's grade 0. (E) Preprocedural single-photon emission computed tomography with I^{123}-labeled *N*-isopropyl-*p*-iodoamphetamine showed reduced cerebral blood flow on the right side. (F) Postprocedural diffusion-weighted magnetic resonance imaging showed multiple MIs only in the right cerebral hemisphere.

Table 2 Multivariate analysis of the factors associated with microembolic infarctions

Variable	*P*-value	Adjusted OR	95% CI Lower	95% CI Upper
Age	0.951	0.99	0.735	1.33
Grade of AAC	0.029	4.75	1.17	1.93
Left side	0.076	7.46	0.809	6.89
Contralateral occlusion	Not estimable			

lesion.[3,4,7] Risk factors for contralateral lesions are different from those associated with ipsilateral lesions.[3] Lesion morphology, a predictor for ipsilateral lesions, was not a predictor for contralateral lesions in the present study. Some investigators hypothesize that MIs in the contralateral hemisphere occur during CAS maneuvers in the aortic arch and supraaortic vessels because they cannot be prevented with EPDs. While Bijuklic et al.[3] reported predictive factors including advanced age, >50% stenosis of the contralateral ICA, and the aortic arch type II. Thus, the risk factors for contralateral MIs have not been sufficiently studied or reported in the literature. In the present study, we evaluated the frequency of contralateral MIs following the protected CAS and analyzed the risk factors comparing ipsilateral MIs.

According to Busing et al.,[21] subclinical MIs detected on DWI following cardiac catheterization occur in 15–22% of patients. MIs are thought to be the result of dislodgement of atheromatous material as the catheter is aggressively maneuvered across areas of complex and severe atherosclerosis within the aorta.[22] Ameranco et al.[23,24] have reported a relationship between atheromatous aortic plaques in the aortic arch and development of multiple cerebral embolisms from their autopsy and transesophageal echocardiographic studies. Current studies showed an association between aortic plaques and catheter maneuvers.[6,9,18,20,25–29] Bazan et al.[25] reported high aortic arch calcium content, measured using special software with thoracic computed tomography, may be a marker of increased potential for MIs during arch manipulation. And Faggioli et al.[20] suggested that thick atherosclerotic plaques at the aortic arch evaluated by transesophageal echocardiography could increase the risk of contralateral cerebral embolism during protected CAS.

Although they are useful modalities to evaluate aortic arch plaques, quantifying calcium content from thoracic computed tomography is slightly arduous and transesophageal echocardiography is a semi-invasive method and cannot be performed for all the patients. In contrast, chest X-ray is a common and non-invasive screening test and simply demonstrates aortic arch composition. Shimada et al.[12] reported significant relationships between the degree of AAC on chest X-rays and mobile or ulcerated aortic plaques examined using transesophageal echocardiography in 178 patients with ischemic stroke. According to the CAS scoring system devised recently,[18,26] AAC is indicated as one of the risk factors of periprocedural complications in CAS. However, clear definition, determination, and evaluation of calcified lesions are still uncertain. Besides, the clinical data of the risk factors for contralateral MIs, especially about AAC, has never reported in Japanese population. In the present study, AAC on chest X-ray indicating Shimada's grades 2 and 3 was an independent predictive factor for contralateral MIs. To our knowledge, this is the first report making a detailed analysis of AAC on chest X-ray to adequately evaluate the risk of MIs.

In this study, advanced age was a significant risk factor for MIs in univariate analysis but was not significant in multivariate analysis. However, advanced age is a high risk factor of severe aortic plaques,[12] and could represent unfavorable aortic arch including types II or III, acute angles of supraaortic artery, common carotid/innominate stenosis, and common carotid tortuosity.[27] The contralateral group exhibited more acute angles of the supraaortic artery compared with that in the ipsilateral group. These unfavorable aortic arch configurations affect the difficulty of catheter maneuvering, prolonged duration of catheter navigation, the greater number of catheter exchanges, repeated endothelium traumas, and contrast injections with higher risks of emboli and thrombi. Muller et al.[6] reported the importance of aortic arch configuration as one of the risk factors for MIs. Muller et al.'s[6] results showed postprocedural MIs were statistically more frequent in patients with the targeted carotid artery that originated below the level of the outer curvature of the aortic arch.

Kim et al.[28] reported the incidence of contralateral lesions could be reduced by improving catheterization techniques in the aortic arch and the carotid artery. And Lin et al.[29] reported increased experience and overcoming the initial procedure-related learning curve are essential to reduce the procedural complications during catheter navigation in the aortic arch before cannulation to the supraaortic artery. In the present study, although AAC statistically predicted contralateral MIs, anatomical factors of the aortic arch, excluding left-sided lesions, were not significantly associated with it. Our results were thought to be influenced by the experienced neurointerventionalists' strategy and performance with appropriate selection of the access route and device. Moreover, the classification of the aortic configuration is different in each study. For further discussion, intensive analysis of aortic arch configuration is warranted.

Focusing on the side of targeted lesion, in the EVA-3S trial and substudy from the ICSS, stroke or more MIs were significantly noted in left-sided stenosis, and speculating increased difficult catheterization of the left common carotid artery compared with the brachiocephalic trunk on the right.[5,9,30] In the transbrachial or radial approach, catheterization of the left common carotid artery is equally difficult. Because the support of the catheter provided by the transverse aortic arch is unsuitable, catheters often prolapse into the ascending aorta, particularly in patients with a more rightward take-off of the left common carotid artery. Iwata et al.[31] reported the efficacy and safety of a novel sheath guide specifically designed for transbrachial carotid cannulation. It was like a modified Simmons catheter with a very soft tip for direct cannulation to the targeted common carotid artery and provided successful CAS in all 62 cases including 25 left-sided lesions.

This method might contribute the gentle aortic manipulation in patients developing a left carotid lesion with difficulty of catheter navigation.

In the cases of contralateral carotid occlusion accompanying reduced cerebral blood flow, all the patients developed contralateral MIs postprocedurally. It was unclear whether the embolic materials came from carotid lesion or aortic atherosclerosis, while embolic materials were speculated to pass through the ACoA. Such a mechanism might play a role in all cases in the contralateral group. However, the presence ratio of ACoA, azygos and bihemispheric anterior cerebral arteries was not significantly different between the two groups. This embolic mechanism was supposed to be characteristic phenomenon in the cases with contralateral carotid occlusion accompanying reduced cerebral blood flow. Kobayashi et al.[32] reported a case with an ischemic event caused by intraoperative MIs that developed following CEA in only the contralateral cerebral hemisphere, in which preoperative hemodynamic impairment was present. Aso et al.[33] demonstrated that preoperative cerebral hemodynamic impairment is significantly associated with the development of MIs on postoperative DWI secondary to microemboli generated during CEA. This mechanism showing impaired clearance of emboli was supported as a “washout theory” by the concept proposed by Caplan and corroborates our results.[34]

Limitations

There are some limitations in the present study. First, this study was a retrospective non-randomized study and the number of cases was small. Second, we did not evaluate the duration of the procedure or the total amount of contrast medium. These factors may influence contralateral MIs. Third, we were unable to examine platelet aggregation in all the patients using the VerifyNow system (Accumetrics Inc., San Diego, CA, USA). Poor response to antiplatelet drugs could be a risk factor of cerebral embolic complications.

Conclusion

Contralateral MIs are not rare during protected CAS. The aortic arch, which has one or more areas of thick or circumferential calcification (Shimada’s grades 2 and 3), was an independent risk factor for developing MIs including the contralateral hemisphere. AAC on chest X-ray was useful for estimating aortic atherosclerosis in candidates for CAS. For further evaluation, a prospective randomized study involving a greater number of patients may be needed to properly assess these results.

Conflicts of Interest Disclosure

There are no conflicts of interest regarding this article.

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