Insight into the Periprocedural Embolic Events of Internal Carotid Artery Angioplasty

A Report of Four Cases and Literature Review

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Key words: embolic events, ICA, stenosis, angioplasty, stenting

Summary

Thromboembolism is a major risk of carotid angioplasty and stenting (CAS). Although the incidence of distal embolism has been documented by MRI and TCD studies, the mechanisms and management of this complication are rarely reported. Here we describe four patients with periprocedural embolic events to demonstrate the mechanisms of thromboembolism in CAS. Different remedies were applied to these patients according to the underlying mechanisms of thromboembolism and good clinical outcomes were achieved.

Introduction

Carotid angioplasty and stenting (CAS) is an alternative therapy to carotid endarterectomy for patients with carotid artery stenosis. The major drawback of this technique is the possible production of embolic debris either from the rupture of atherosclerotic plaques or thrombus formation on endovascular devices. Despite the utilization of stringent credentialing criteria for the operators, a 3% stroke risk is still inherent in the procedure according to the recent CREST study¹. The incidence of new cerebral microembolic lesions detected by DWI following CAS ranges from 4%²-78%³ of cases. Most of these lesions are distributed in the ipsilateral hemisphere, whereas some of them may occur in the contralateral hemisphere⁴⁻¹⁰, or the posterior circulation^{7,8}. Most of these DWI-positive spots are asymptomatic, with only about 15% of the patients develop TIAs or stroke^{3,6-11}. Moreover,

the evidence from TCD monitoring studies has confirmed that the embolic debris can be generated at all stages of the procedure, including the placement of the guiding catheter, before and after the placement of embolic protection devices^{11,12}, angioplasty, the deployment of stent, and even in the weeks following successful stenting^{3,8,13-18}. Most of these studies focused on the MRI or TCD findings related to the morbidity or mortality of CAS, or the effect of embolic protective devices. The detailed mechanism of debris generation and the management of these events are lightly touched upon in the literature. In our institute, the number of CAS we performed was around 1000 in the last ten years, and the complication rate was less 3%. In order to illustrate the causes underlying the embolic events and how to manage and avoid them in future practice, we describe four typical cases of CAS with embolic events and provide our experience in managing this complication.

Case Reports

Case 1

A 76-year-old man with a history of diabetes presented with recurrent TIAs of right extremity weakness for three weeks. Laboratory data were all normal except for a high level of blood glucose. CT showed infarction in the left hemisphere (picture not shown). Digital subtraction angiography (DSA) showed >90% stenosis of left internal carotid artery (ICA) origin (Figure 1A). We performed CAS under local anesthesia. All patients discussed in this case series were placed on aspirin and clopidogrel before the pro-

Figure 1 DSA obtained from case 1. A) Severe stenosis (>90%) of the left ICA origin. B) Deployed with a 10x24mm stent (Wallstent, Boston) over the lesion. The immediate angiogram demonstrated nearly normal lumen of the stenotic segment. C) After retrieval of the protective device, we noted the occlusion of a frontal branch of the left MCA (arrow). D) After the embolus was pushed to a distal cortical artery with a microcatheter, blood to the paracentral branches was restored (arrow).

cedure. Double-antiplatelet therapy was continued for at least 30 days. Due to the tortuosity of his aortic arch (Type II), we spent 60 minutes to place an 8F guiding catheter (Cordis) into the left common carotid artery (CCA). After guiding catheter placement, we found an acute occlusion of the left ICA. A 0.014 microwire (PT Graphy, Boston Scientific) was navigated carefully through the occluded segment and a filter wire (Boston) was exchanged to the petrous segment of left ICA. After angioplasty of the left ICA origin with a 2.0x15 mm balloon (SeQuent, B. Braun, Melsungen, Germany), the occluded ICA was successfully recanalized. We then predilated the stenotic lesion with a 6x40 mm balloon, and deployed with a 10x24 mm stent (Wallstent, Boston Scientific) across the lesion. The angiogram obtained immediately after stenting demonstrated nearly normal lumen of the left ICA (Figure 1B). After retrieval of the protection device, we noted the occlusion of the paracentral branch of the left MCA (Figure 1C), and some debris was found in the protection device, which was particulate, atheromatous material histologically. We catheterized the occluded artery with a microcatheter, and carefully pushed the embolus more distally with the microcatheter. The follow-up angiogram showed nearly normal blood flow (Figure 1D). The patient recovered from anesthesia without focal neurological deficit.

Case 2

A 68-year-old right-handed man came to us with aphasia and recurrent TIA of right upper extremity weakness. He had a history of hyper-

tension and blood pressure was under good control. CT did not show any obvious infarction (picture not shown). DSA demonstrated severe stenosis at the origins of bilateral ICAs, worse on the left side (Figure 2A). We performed CAS of the left ICA with an embolic protective device (Angioguard, Cordis) under local anesthesia. The lesion was predilated with a 5x40 mm balloon (Angioguard, Cordis). A stent (9x30 mm, Cordis) was deployed, but did not cover the distal part of the plaque due to displacement of the stent itself. We inflated another balloon (5x20 mm, Angioguard, Cordis) distal to the stent, and immediate DSA showed nearly normal lumen (Figure 2B). There was no macroscopic visible debris in the protection device. The patient continued to have his previous symptoms. Repeated DSA one week later showed intraluminal filling defect distal to the stent (Figure 2C). We deployed a second stent to cover this segment (8x30 mm, Cordis) under distal embolic protection (Cordis) (Figure 2D). The patient had no further event in four years of follow-up.

Case 3

A 71-year-old man with a history of coronary artery disease presented to our hospital with left hemiplegia (4/5). The laboratory data were all normal except for a high level of blood glucose and platelet aggregation rate. DSA demonstrated a severe stenosis of the origin of the right ICA (Figure 3A). Under local anesthesia, an 8F guiding catheter was introduced into the right common carotid artery, and a distal protection device (Filterwire, Boston Scientific) was placed

Figure 2 DSA obtained in case 2. A) The angiography demonstrated severe stenosis of both ICA origins, the left (A) is worse than the right. B) A stent (9×30 mm, Precise, Cordis) was deployed missing the upper part of plaque. After another balloon was inflated, the lumen turned to normal. C) Angiography taken one week after stenting demonstrated a thrombus just distal to the stent. D) A second stent (8×30 mm, Precise, Cordis) was deployed under distal embolic protection, and the lumen appeared normal.

beyond the lesion. After predilation with a 6×40 mm balloon (Angioguard, Cordis) at 6 atm, we noticed slow blood flow and near occlusion distal to the lesion (Figure 3B). A stent (10×40 mm, Precise, Cordis) was rapidly deployed and the stenotic artery was recanalized without cut-off of intracranial vessels on DSA (Figure 3C). The retrieved protection filter was found to be filled with atherosclerotic particles. And the histological analysis detected particulate, atheromatous material characterized by lipid-rich macrophages, fibrin material, and cholesterol clefts. The patient developed 2/5 left arm and leg weakness, which improved to 4/5 over 12 days without any additional treatment. The DWI after stenting showed new ischemic lesions on the ipsilateral hemisphere (Figure 3D).

Case 4

A 71-year-old man came to us with recurrent TIAs of left upper extremity weakness. Carotid Doppler ultrasound showed a severe stenosis of right ICA with an echolucent plaque (Supplemental Figure 1A). MRI demonstrated multiple ischemic lesions in the ipsilateral hemi-

sphere (Supplemental Figure 1B). The pre-procedure DSA confirmed a severe stenosis at the origin of right ICA (Figure 4A), with stagnant blood flow in the distal artery (Supplemental Figure 1C). The angiogram from the left ICA showed patent anterior communicating artery (ACA) with collateral flow from left to right (Supplemental Figure 1D). Because of the narrow distal lumen (3 mm, image not shown) and the patent ACA, we decided not to use embolic protective devices or do any balloon dilation, but stented right ICA with a self-expanding stent (10×40 mm, Precise, Cordis) directly. The immediate angiogram showed less than 30% residual stenosis (Figure 4B) and improved intracranial perfusion (Supplemental Figure 1E). The patient developed left upper extremity weakness six hours later. Emergency angiogram found that the stent has completely expanded without intraluminal filling defect (Figure 4C), and further improvement of intracranial blood flow was noted (Supplemental Figure 1F). Head CT obtained 24 hours after stenting showed a small new lesion in the ipsilateral parietal lobe (Figure 4D). Ultrasound

Figure 3 DSA obtained in case 3. A) The pre-operative DSA demonstrated severe stenosis of the right ICA origin. B) The angiography obtained immediately after predilatation showed near occlusion of ICA beyond the lesion and very slow blood flow. C) A stent (10×40 mm, Precise, Cordis) was deployed quickly and the stenotic artery was recanalized. D) The DWI after stenting presented multiple new ischemic lesions on right frontal and parietal white matter (arrows).

Figure 4 DSA obtained in case 4. A) Pre-operative DSA confirmed severe stenosis of the initial segment of right ICA and stagnant blood flow in the distal artery. B) After a self-expanding stent (10×40 mm, precise, Cordis) was deployed, the immediate angiogram showed the residual stenosis was less than 30%. C) DSA obtained 6 hours after stenting showed completely expanded stent without intraluminal filling defect. D) The CT scan obtained 24 hours after stenting showed a small new lesion in the right hemisphere (arrow).

Supplemental Figure 1:
Case 4 explanation in the text.

showed patent stent with normal flow velocities one day later (Supplemental Figure 1G). His symptoms improved two weeks later without additional treatment.

Discussion

Factors associated with peri-procedural embolic events include excessive manipulation of devices^{19,20}, plaque instability^{21,22}, tortuosity of the aortic arch or common carotid artery (CCA)^{6,23,24}, atherosclerotic aortic lesions^{6,16, 25-29}, and delayed local thrombus formation³. The first two factors are the most common reasons for embolic events. Studies have documented the generation of embolic debris at all stages of the procedure, including the initial lesion crossing with a guidewire, balloon dilation and stent placement, and retrieval of the embolic protec-

tion device¹². Even the slight movement of an inflated balloon or deployed filter can facilitate the passage of embolic particles through the filter pore or the gap between balloon and artery resulting in distal embolism³⁰. The first patient in this case series had tortuous aortic arch (type II) which contributed to the repetitive maneuver of the guiding catheter to gain access to the CCA. The guidewire or tip of the guiding catheter could have dissected the plaque, resulting in acute occlusion of the carotid artery. The exchange technique (catheterization with a 5F diagnostic catheter and exchange for the larger guiding catheter), or coaxial technique (a 4 or 5F diagnostic catheter inside the 8F guiding catheter) may be beneficial for complex aortic artery (types II and III). Thrombolysis in the setting of acute carotid occlusion during CAS is rarely indicated because the embolus usually comprises plaque rather than fibrin clot³¹. In

our first and third case, we achieved recanalization with angioplasty and stenting and distal vessel recanalization with microcatheter and guidewire agitation. The intraluminal thrombus was pressed and fixed to the vessel with a stent in the second case. The incomplete covering of the plaque by a stent is a rare cause for embolic event. Angioplasty is a controlled dissection of the intima. If the lesion is not entirely covered by a stent, the dissection may grow to cause restenosis or become the source of delayed thrombosis and distal emboli as happened in our second case. The benefits of embolic protection devices (EPDs) remain controversial since Vitek et al.³² and Theron et al.³³ proposed the concept of cerebral protection in the 1980s. There is no Level-I clinical evidence to support the use of protection devices but Level-III and Level-IV evidence suggests benefit³⁴. Some authors reported no difference of embolic events between cases done with or without EPD^{35,36}. Embolic events occur as high as 1.2%-7% despite the use of EPDs³⁷. Moreover, there is no significant difference in protection against embolic events among the three types of EPD (distal occlusion, filters, and flow reversal systems)^{30,38}. In the third case, the distal filter was filled with atherosclerotic materials, some of which could have spilled out or slipped by the filter to occlude distal arteries. No current test can reliably predict the risk of showering of atherosclerotic material during CAS. Ultrasound and high-resolution MRI have been used to characterize plaques. Rosenkranz et al.²¹ analyzed plaque echolucency with B-mode ultrasound and computer-assisted measurement (gray scale median, GSM) to predict embolic events, suggesting that echolucent plaques are more vulnerable against endovascular manipulation than echogenic ones and that echolucency indicates plaque fragility. Theoretically, flow reversal devices may offer more protection against the shower of plaque debris. It remains to be seen if the flow reversal devices reduce the risks of distal embolism in patients with vulnerable plaques compared to the other types of EPDs. Applying aspiration to the guiding catheter before retrieval of the filter and partial capture of the

distal embolic protection device are other reasonable but unproven techniques to reduce the risk of embolism in the setting of unstable plaque. The embolic event occurred without distal protection in the fourth case. Although we cannot guarantee that the use of distal a protection device can prevent distal embolism, the small lumen in distal cervical ICA should not preclude the use of a distal protection device. As shown in this case, the distal ICA collapsed for the lack of flow. After angioplasty and stenting of the proximal flow-limiting lesion, the caliber of the distal cervical ICA quickly returned to normal. We have observed this phenomenon over and over again in our experience of 986 carotid stenting procedures. Another unusual feature of the fourth case is the omission of balloon angioplasty. We observed continued self-expansion of the stent, which could squeeze the unstable atherosclerotic plaque resulting in the extrusion of the plaque material through the struts of the stent, leading to distal embolism. This phenomenon is similar to what Aikawa et al. reported as intraprocedural plaque protrusion just after the retrieval of blocking balloon²⁰. To mitigate this problem, we recommend predilation with a larger balloon (4-5 mm) under embolic protection. These four cases also demonstrated the timing of embolic events associated with CAS. Thromboembolism happened before angioplasty and stenting in the first case, during angioplasty and stenting in the third case, and in a delayed fashion in the second and fourth case. If monitored with TCD, the embolic signals can be detected even at more than six months after stenting¹⁸.

Conclusions

Thromboembolism can occur in different stages of CAS by different mechanisms. There is currently no reliable predictor of thromboembolic events. The use of embolic protection does not eliminate this risk. Once embolism occurs, action should be taken promptly based on the underlying mechanism to minimize the clinical impact of this event.

References

- 1 Forbes, T.L. Preliminary results of carotid revascularization endarterectomy vs stenting trial (CREST). *J Vasc Surg*. 2010; 51: 1300-1301.
- 2 Roh HG, Byun HS, Ryoo JW, et al. Prospective analysis

- of cerebral infarction after carotid endarterectomy and carotid artery stent placement by using diffusion-weighted imaging. *Am J Neuroradiol*. 2005; 26: 376-384.
- 3 Rapp JH, Wakil L, Sawhney R, et al. Subclinical emboli-

- zation after carotid artery stenting: new lesions on diffusion-weighted magnetic resonance imaging occur postprocedure. *J Vasc Surg.* 2007; 45: 867-872; discussion 872-874.
- 4 Maleux G, Demaerel P, Verbeken E, et al. Cerebral ischemia after filter-protected carotid artery stenting is common and cannot be predicted by the presence of substantial amount of debris captured by the filter device. *Am J Neuroradiol.* 2006; 27: 1830-1833.
 - 5 du Mesnil de Rochemont R, Schneider S, Yan B, et al. Diffusion-weighted mr imaging lesions after filter-protected stenting of high-grade symptomatic carotid artery stenoses. *Am J Neuroradiol.* 2006; 27: 1321-1325.
 - 6 Hammer FD, Lacroix V, Duprez T, et al. Cerebral microembolization after protected carotid artery stenting in surgical high-risk patients: results of a 2-year prospective study. *J Vasc Surg.* 2005; 42: 847-853.
 - 7 Palombo G, Faraglia V, Stella N, et al. Late Evaluation of silent cerebral ischemia detected by diffusion-weighted mr imaging after filter-protected carotid artery stenting. *Am J Neuroradiol.* 2008; 29: 1340-1343.
 - 8 Piñero P, González A, Mayol A, et al. Silent ischemia after neuroprotected percutaneous carotid stenting: a diffusion-weighted MRI study. *Am J Neuroradiol.* 2006; 27: 1338-1345.
 - 9 Tedesco MM, Lee JT, Dalman RL, et al. Postprocedural microembolic events following carotid surgery and carotid angioplasty and stenting. *J Vasc Surg.* 2007; 46: 244-250.
 - 10 Barbato JE, Dillavou E, Horowitz MB, et al. A randomized trial of carotid artery stenting with and without cerebral protection. *J Vasc Surg.* 2008; 47: 760-765.
 - 11 Skjelland M, Krohg-Sørensen K, Tennøe B, et al. Cerebral microemboli and brain injury during carotid artery endarterectomy and stenting. *Stroke.* 2009; 40: 230-234. Epub 2008 Oct 16.
 - 12 Vos JA, van den Berg JC, Ernst SM, et al. Carotid angioplasty and stent placement: comparison of transcranial Doppler US-data and clinical outcome with and without filtering cerebral protection in 509 patients. *Radiology.* 2005; 234: 493-499.
 - 13 Markus HS, Clifton A, Buckenham T, et al. Carotid angioplasty. Detection of embolic signals during and after the procedure. *Stroke.* 1994; 25: 2403-2406.
 - 14 Fairman R, Gray WA, Scicli AP, et al. The CAPTURE registry. Analysis of strokes resulting from carotid artery stenting in the post approval setting: Location, severity of type. *Ann Surg.* 2007; 246: 551-558.
 - 15 Orlandi G, Fanucchi S, Fioretti C, et al. Characteristics of cerebral microembolism during carotid stenting and angioplasty alone. *Arch Neurol.* 2001; 58: 1410-1413.
 - 16 Mackinnon AD, Aaslid R, Markus HS. Ambulatory transcranial Doppler cerebral embolic signal detection in symptomatic and asymptomatic carotid stenosis. *Stroke.* 2005; 36: 1726-1730.
 - 17 Faggioli GL, Ferri M, Serra C, et al. The residual risk of cerebral embolism after carotid stenting: the complex interplay between stent coverage and aortic arch atherosclerosis. *Eur J Vasc Endovasc Surg.* 2009; 37: 519-524. Epub 2009 Feb 20.
 - 18 Censori B, Camerlingo M, Casto L, et al. Carotid stents are not a source of microemboli late after deployment. *Acta Neurol Scand.* 2000; 102: 27-30.
 - 19 Piñero P, González A, Martínez E, et al. Volume and composition of emboli in neuroprotected stenting of the carotid artery. *Am J Neuroradiol.* 2009; 30: 473-478. Epub 2008 Nov 27.
 - 20 Aikawa H, Kodama T, Nii K, et al. Intraprocedural plaque protrusion resulting in cerebral embolism during carotid angioplasty with stenting. *Radiat Med.* 2008; 26: 318-323. Epub 2008 Jul 27.
 - 21 Rosenkranz M, Wittkugel O, Waiblinger C, et al. Cerebral embolism during carotid artery stenting: role of carotid plaque echolucency. *Cerebrovasc Dis.* 2009; 27: 443-449. Epub 2009 Mar 19.
 - 22 Biasi GM, Froio A, Diethrich EB, et al. Carotid plaque echolucency increases the risk of stroke in carotid stenting: the Imaging in Carotid Angioplasty and Risk of Stroke (ICAROS) study. *Circulation.* 2004; 110: 756-762. Epub 2004 Jul 26.
 - 23 Tedesco MM, Lee JT, Dalman RL, et al. Postprocedural microembolic events following carotid surgery and carotid angioplasty and stenting. *J Vasc Surg.* 2007; 46: 244-250. Epub 2007 Jun 27.
 - 24 Qureshi AI, Luft AR, Sharma M, et al. Prevention and treatment of thromboembolic and ischemic complications associated with endovascular procedures: part II: clinical aspects and recommendations. *Neurosurgery.* 2000; 46: 1360-1375.
 - 25 Droste DW, Dittich R, Kemeny V, et al. Prevalence and frequency of microembolic signals in 105 patients with extracranial carotid artery occlusive disease. *J Neurol Neurosurg Psychiatr.* 1999; 67: 525-528.
 - 26 Stork JL, Kimura K, Levi CR, et al. Source of microembolic signals in patients with high-grade carotid stenosis. *Stroke.* 2002; 33: 2014-2018.
 - 27 Zuromskis T, Wetterholm R, Lindqvist JF, et al. Prevalence of micro-emboli in symptomatic high grade carotid artery disease: a transcranial Doppler study. *Eur J Vasc Endovasc Surg.* 2008; 35: 534-540.
 - 28 Faggioli GL, Ferri M, Freyrie A, et al. Aortic arch anomalies are associated with increased risk of neurological events in carotid stent procedures. *Eur J Vasc Endovasc Surg.* 2007; 33: 436-441.
 - 29 Faggioli G, Ferri M, Rapezzi C, et al. Atherosclerotic aortic lesions increase the risk of cerebral embolism during carotid stenting inpatients with complex aortic arch anatomy. *J Vasc Surg.* 2008; 49: 80-85.
 - 30 Kim SJ, Roh HG, Jeon P, et al. Cerebral ischemia detected with diffusion-weighted MR imaging after protected carotid artery stenting: comparison of distal balloon and filter device. *Korean J Radiol.* 2007; 8: 276-285.
 - 31 Hellings WE, Ackerstaff RG, Pasterkamp G, et al. The carotid atherosclerotic plaque and microembolisation during carotid stenting. *J Cardiovasc Surg.* 2006; 47: 115-126.
 - 32 Vitek JJ, Raymon BC, Oh SJ. Innominate artery angioplasty. *Am J Neuroradiol.* 1984; 5: 113-114.
 - 33 Theron J, Raymond J, Casasco A, et al. Percutaneous angioplasty of atherosclerotic and postsurgical stenosis of carotid arteries. *Am J Neuroradiol.* 1987; 8: 495-500.
 - 34 Macdonald S. The evidence for cerebral protection: an analysis and summary of the literature. *Eur J Radiol.* 2006; 60: 20-25. Epub Sep 12. Review.
 - 35 Theiss T, Hermanek P, Mathias K, et al. A prospective registry of carotid angioplasty and stenting. *Stroke.* 2004; 35: 2134-2139.
 - 36 Gray WA, Hopkins LN, Yadav S, et al. Protected carotid stenting in high-surgical-risk patients: the ARCHeR results. *J Vasc Surg.* 2006; 44: 258-268.
 - 37 Goodney PP, Schermehorn ML, Powell RJ. Current status of carotid artery stenting. *J Vasc Surg.* 2006; 43: 406-411.
 - 38 El-Koussy M, Schroth G, Do DD, et al. Periprocedural embolic events related to carotid artery stenting detected by diffusion-weighted MRI: comparison between proximal and distal embolus protection devices. *J Endovasc Ther.* 2007; 14: 293-303.

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