Locking between a Cerebral Protection Device and a Stent-Delivering Catheter during Carotid Artery Stenting

JONG HUN LEE, SUNG WON YOUN, HO KYUN KIM

Department of Radiology, Catholic University of Daegu School of Medicine; Daegu, Korea

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Summary

The cerebral protection device (CPD) itself may cause complications, including locking between the CPD and other devices, that may result in catastrophic outcomes requiring surgical removal of these locked devices. We describe a case of locking between a CPD and the stent-delivering catheter during carotid artery stenting, which was safely rescued by endovascular retrieval. The mechanism underlying locking with the CPD as well as preventive actions and maneuvers for rescuing the situation are discussed.

Introduction

The cerebral protection device (CPD), which filters the atheroembolic materials that may be released from carotid plaques, is effective at reducing the risk of embolic events during carotid artery stenting (CAS), and is increasingly being used to improve the safety of CAS procedures^{1,2}. However, the CPD itself may cause fatal complications, with mechanical or iatrogenic sequelae occurring with an incidence of 0.9% (4/442)^{1,3,4}. In addition to sequelae such as vascular spasm or dissection, some unpredictable mechanical accidents – such as locking between devices or incomplete stent expansion – may result in catastrophic outcomes requiring surgical removal of the locked devices⁵⁻⁷. Moreover, permanent locking between devices would be catastrophic, which has prompted consideration of CAS without the use of a CPD in order to prevent this possibility⁸⁻¹⁰.

The aim of the present study was to establish the mechanism underlying locking between the CPD and the stent-delivering catheter by correlating markers on photographs and fluoroscopy. Possible preventive actions and appropriate management procedures are also discussed.

Case Report

A 72-year-old man with a history of hypertension presented with slurred speech and clumsiness of the right upper extremity. Diffusion-weighted magnetic resonance (MR) imaging revealed acute multifocal embolic infarctions of the left middle cerebral artery territory. More than 90% stenosis was detected in the left carotid bulb on MR angiography. On conventional angiography, a filling defect was seen in the distal stenosed area, suggesting a thrombus. CAS was planned but delayed to allow dissipation of the thrombus by medical treatment with antiplatelet medications; these comprised aspirin at 100 mg/day and clopidogrel at 75 mg/day for three weeks before stent implantation. CAS was performed after confirming on computed tomographic angiography that the thrombus had disappeared.

A 7-Fr introducer (Flexor Shuttle, Cook, Bloomington, IN, USA) was placed into the left common carotid artery via the femoral approach under systemic heparinization (5,000 U). Baseline angiography revealed clearance of the clot and 85% stenosis of the carotid bulb. Although a small-caliber balloon (1.5×9 mm; Gateway, Boston Scientific, Natick, MA, USA) was expanded to facilitate passage of the CPD

Figure 1 A 72-year-old man undergoing stenting for severe carotid artery stenosis. A) The cerebral protection device (CPD) was placed at a location near the stenosis due to severe tortuosity of the internal carotid artery. B) The balloon pushed the CPD upward (white arrow), which caused the inner surface of its nose cone to become engaged with the outer surface of the CPD anchorage. These two devices were separated after a few attempts. C) The stent-delivering catheter inadvertently moved forward, which caused the inner surface of its nose cone to become locked with the outer surface of the CPD anchorage. Several attempts to separate these two devices were unsuccessful. D) A self-expandable stent was deployed. E) The 7-Fr introducer was gently advanced within the placed stent (black arrow), and the locked CPD-catheter complex was gently pulled back to the distal end of the stent (white arrow). F) The antegrade flow through the stent and CPD was intact. G) The metallic ring of the membrane filter was collapsed to enter the placed stent (white arrow), and the complex was further withdrawn into the 7-Fr introducer. H) The locked CPD-catheter complex was successfully removed, and a final angiograph revealed intact flow. *a*, metallic ring of the membrane filter; *b*, anchorage for attaching the metallic ring to the axial wire; *c*, marker on the axial wire; *d*, marker of the balloon/stent-delivering catheter. Interrupted arrows (*c* in A, and *b, c* in B and D-G) indicate that the markers were not clearly observed on fluoroscopy, and their location was presumed. Double-ended arrows (in B-H) mark the extent of the balloon/stent.

Figure 2 The markers of the stent-delivering catheter and the cerebral protection device (CPD) correlated with their photographic appearance. A,B) The markers on the CPD comprise a metallic ring (a), an anchorage for attaching the metallic ring to the axial wire (b), and a wire marker (c). The 14-mm-long nose cone of the stent-delivering catheter (double-headed arrow) has a proximal opaque marker (d) and a nonopaque tip end. C,D) The CPD-catheter complex retrieved endovascularly exhibited compact engagement between the outer surface of the CPD anchorage (b) and the inner surface of the nose cone of the catheter (double-headed arrow), due to the similarity of their outer and inner diameters, respectively. Marker d approaches markers a, b, and c as the stent-delivering catheter advances. Locking occurred when the inner surface of the nose cone of the catheter (double-headed arrow) was advanced to engage the outer surface of the CPD anchorage (b). The distances between the markers are as follows: a-b, 8 mm; b-c, 8 mm; c-d, 6 mm. Distance c-d should be greater than 6 mm to prevent locking. For convenience on fluoroscopy, distance c-d should be greater than distance a-b or b-c to prevent locking at marker b.

(Filter Wire, Boston Scientific), it remained difficult to pass the device across the lesion. Due to the severe tortuosity and stenosis of the proximal internal carotid artery, the device was deployed at a location near to the stenosis. After loading atropine, a balloon (5×30 mm; Aviator, Cordis, Miami Lake, FL, USA) was delivered without requiring careful observation of the markers. The balloon was moved forward with-

out taking sufficient care such that the inner surface of its nose cone became engaged with the outer surface of the CPD anchorage. The devices were separated after several attempts, but the markers were not observed carefully when the self-expandable stent (10×40 mm; PRECISE, Cordis) was advanced. The stent-delivering catheter was then also moved forward inadvertently, which caused the inner sur-

Table 1 Literature on the mechanical complications related to a cerebral protection device (CPD) during carotid artery stenting.

Author	Events (devices)	Management/outcomes
Cremonesi et al.* ¹	3 Dissections of internal carotid artery 1 Entrapment between CPD and stent	2 Stenting, 1 untreatable 1 Surgical removal
Shilling et al. ⁵	1 Entrapment of CPD (Accunet filter) within deployed stent (Acculink)	Surgical removal
Akgul et al. ^{† 6}	1 Incomplete expansion of stent (Wallstent) caused by displacement of metal ring marker (Filter Wire)	Surgical removal
Campbell et al. ⁷	1 Fusion of balloon (Aviator) and CPD (Accunet filter)	Endovascular rescue
Peel et al. ¹³	1 Membrane separated from nitinol scaffold (Emboshield), with attachment to stent (Acculink)	Surgical removal
Nguyen et al. ¹⁴	2 Membrane tear (Filter Wire EX)	No adverse events
Cardaioli et al. ¹⁵	1 Severe vasospasm	Slowly relieved after removal Minor stroke

* Incidence, 4 /442 (0.9%); † Device failure rather than procedural error

face of its nose cone to become locked with the outer surface of the CPD anchorage (Figure 1). Attempts were made to separate these two devices in two ways: (1) pushing the axial wire of the CPD forward while holding the stent-delivering catheter and (2) withdrawing the stent-delivering catheter while holding the CPD stationary. These maneuvers to separate the CPD and stent-delivering catheter were unsuccessful, so it was decided that the stent should be deployed first. The 7-Fr introducer was gently advanced within the placed stent as far as possible. Upon observing intact anterograde flow through the CPD, the complex was gently pulled back to the distal end of the placed stent. After confirming collapse of the membranous filter, the complex was further withdrawn into the 7-Fr introducer. Final angiography revealed a patent carotid artery without residual stenosis, and no embolic complications of the cerebral circulation. The patient progressed well without neurologic deficit. He was hemodynamically stable and discharged three days after CAS without any neurologic problems.

Discussion

The case reported herein represents an uncommon occurrence of engagement between the nose cone of the stent-delivering catheter and CPD anchorage. It was difficult to access the CPD along the severely tortuous cervical and stenotic carotid artery, and in this case the

CPD was deployed too close to the stenosis. This type of failure of CPD delivery has been reported in 3.5-11% of patients with complex carotid anatomy or severe stenosis^{3,11,12}. The distance between the CPD and the lesion was too short, necessitating aggressive pushing of the CPD while adjusting the stenting site. When the stent-delivering catheter was advanced forward, the inner surface of its nose cone engaged with the outer surface of the CPD anchorage due to their similar diameters. Three markers of the CPD (comprising a metallic ring, an anchorage for attaching the metallic ring to an axial wire, and a wire marker) and a marker of the stent-delivering catheter were viewed fluoroscopically while referring to their photographic appearance (Figure 2). The stent-delivering catheter has a nose cone with a proximal opaque marker and a nonopaque tip. As the catheter advances along the wire of the CPD, the marker of the catheter approaches the three markers of the CPD until the distance between the catheter marker and the wire marker is 6 mm, which is the point where locking occurs.

To prevent this complication, the patient's anatomic characteristics, including the tortuosity and stenosis of the internal carotid artery, should be observed carefully while simulating the procedure. If possible, the CPD should be positioned far from the stenosis. The distance between the anchorage marker of the CPD and the marker of the stent-delivering catheter should be greater than the length of the nonopaque nose cone (double-headed arrow in Fig-

ure 2). The length of the nose cone in the present case was 14 mm. For convenience on fluoroscopy, the distance between the wire marker of the CPD and the marker of the catheter should be greater than the length of the reference landmarks or the distance between the markers of the CPD (i.e., 8 mm). Several reports on the mechanical complications related to CPD have emphasized the importance of careful consideration of both the patient's anatomy and the devices' construction and dimensions (Table 1). The locking between the CPD and other devices may have serious consequences, with immediate surgical removal being essential^{1,5,6,13}. With the exception of partial opening of the stent by slippage of the metal ring marker⁶, these consequences arise from insufficient observation of the marker position or a deficient understanding of marker dimensions. This can be prevented by careful observation of the patient's anatomy and the markers visible in fluoroscopy.

Uniquely in the case reported herein, locking between the stent-delivering catheter and the CPD was resolved endovascularly without sequelae. Given the potential seriousness of the consequences of this problem, the management of locked devices demands an immediate decision in angiographic suite. Most of all, it is important not to perform aggressive maneuvers after only a few gentle attempts to separate the devices. Attempts to force them apart might further aggravate the situation, causing vasospasm or dissection. The most disastrous situation might be separation of the membranous component from the CPD¹³⁻¹⁵. In this context, most of the mechanical complications related to CPD necessitate surgical removal^{1,5,6,13}; only a case of a fused balloon and CPD has been rescued endovascularly⁷. In the present case, surgical removal of the device was considered the last resort. Since the patient was still stable and collapse of the wire ring seemed to be possible, we decided to first attempt endovascular rescue. The locked complex was gently withdrawn without sequelae by advancing the introducer sheath and collapsing the wire ring within the stented segment, in a maneuver sim-

ilar to that described by Campbell et al.⁷. However, advancing the introducer forward in a patient with a hostile arch anatomy or carotid bifurcation angulation may be difficult, or even dangerous since aggressive movement of the introducer could elicit plaque dislodgement or vascular dissection^{1,4,15}. Withdrawal of the CPD through the stent could produce tangling with the stent strut, which could exacerbate the problem^{1,5}. In the reported case it was very fortunate that advancement of the introducer and collapse of the wire ring worked well.

Conclusion

In summary, the potential risks associated with use of a CPD should not be underestimated. The mechanism of interlocking can be understood based on the fluoroscopically observed relationship between the inner surface of the nose cone of the stent-delivering catheter and the outer surface of the CPD anchorage, while referring to their photographic appearance. The anatomic characteristics of individual patients need to be considered when simulating the procedure, and a sufficient distance between three markers of the CPD and the stenosis must be confirmed before placing the CPD. While adjusting the stenting segment, the shortest distance between three markers of the CPD and one marker of the stent-delivering catheter should be borne in mind. We should also be aware of the possible rescue maneuvers in addition to these preventive actions. The endovascular removal of a locked CPD-catheter complex may be one of the more useful rescue maneuvers after advancement of the introducer sheath and collapsing the CPD.

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Sung Won Youn, MD
 Department of Radiology
 Catholic University of Daegu School of Medicine
 3056-6 Daemyung-4 Dong
 Nam-gu - Daegu 705-718 - Korea
 Tel.: +82-53-650-4076
 Fax: +82-53-650-4339
 E-mail: ysw10adest@cu.ac.kr