Observation Method of the Mesh-type Embolus Protection Filter for Carotid Artery Stenting

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Objective: Carotid artery stenting is performed increasingly with increases in atherosclerotic diseases. Since cerebral embolism is a problematic complication of stenting, preventive methods have been devised, and filters for distal protection have recently begun to be used. We have examined filters after the procedure and evaluated the relationships of the findings with preprocedural symptoms, imaging diagnosis, and flow impairment during treatment. While membrane filters have initially been used, mesh-type filters have also been introduced. Since mesh-type filters have an elastic structure in which wires are woven in, modifications of the conventional observation method are necessary.

Case Presentation: A 73-year-old man developed right hemiparesis and was referred to our department with a diagnosis of cerebral infarction. Marked stenosis was noted at the origin of the left internal carotid artery and was considered a responsible lesion as a result of close examination. On the 26th day of illness, stent placement was performed using a mesh-type filter. After stent placement, the filter was stained with hematoxylin and eosin. The mesh part was cutoff, mounted on a glass slide, a mounting medium was dripped, and a cover glass was applied. Both sides of the cover glass were fixed with clips. After the embedding medium dried (about 1 week), the clips were removed, and the completed preparation was examined microscopically. Many pieces of thrombotic debris were captured. At high magnification, organized components and slight precipitation of fibrin were also observed.

Conclusion: Examination of filters is useful because it makes the evaluation of debris properties and their relationships with preprocedural images and intraprocedural complications possible.

Keywords ▶ carotid artery stenting, embolus protection filter, hematoxylin–eosin stain, microscopical observation

Introduction

Since cerebral embolism due to debris released during the procedure is the most frequent complication of carotid artery stenting, methods to prevent intraprocedural distal embolization are indispensable.¹⁾ Distal protection was initially provided by balloon occlusion in Japan,²⁾ but the filters have begun to be used increasingly after their

introduction.³⁾ We have examined blood collected during treatment and debris attached to filters and evaluated their relationships with intraprocedural complications.^{4,5)} The early filters were membrane types, but mesh-type Spider FX (Covidien, Dublin, Ireland) was recently introduced. We modified the conventional method for the observation of filters by hematoxylin and eosin staining for the examination also of mesh-type filters. The modified method is described, and the results of observation are evaluated.

Case Presentation

The patient was a 76-year-old man with right-sided motor paralysis. He had a history of hypertension and was treated by oral medication. There was no particular family history.

The patient developed motor paralysis of the right upper and lower extremities and consulted a local physician on the next day. Head CT findings suggested cerebral infarction, and the patient was referred to our department.

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Fig. 1 Imaging study of the illustrative case. (**A** and **B**) MRI diffusion-weighted image shows multiple high-intensity lesions in the left white matter and cerebral cortex (**A**) corona radiata level, (**B**) centrum semiovale level. (**C**) Brain MR angiography shows no apparent occlusive lesion in the intracranial major arteries. (**D**) Cervical MR angiography shows left cervical ICA stenosis (arrow) as well as right ICA occlusion. (**E**) CT angiography shows high-grade stenosis at the origin of the left ICA (arrow). (**F**) High-resolution MRI T1-weighted image shows hyper-intensity lesion at the left ICA (arrow). ICA: internal carotid artery; MR: magnetic resonance

On admission, he showed a blood pressure of 120/60 mmHg, a heart rate of 80 bpm, a height of 160 cm, and a body weight of 58 kg.

Neurologic findings were right hemiparesis (Manual Muscle Test [MMT] 2/5), right facial palsy, dysarthria, and right-sided sensory disturbance. The National Institute of Health Stroke Scale (NIHSS) score was 8.

Concerning neuroradiologic examinations, head magnetic resonance (MR) diffusion-weighted imaging showed high-intensity areas from the left corona radiata to the cerebral cortex (**Fig. 1A** and **1B**). In fluid attenuated inversion recovery (FLAIR) images, chronic ischemic change in the bilateral deep cerebral white matters was observed, and the signal intensity was slightly increased in the high-intensity areas observed on diffusion-weighted imaging. While no occlusive lesion was detected in the intracranial major arteries on MR angiography (**Fig. 1C**), high-grade stenosis

was observed at the origin of the left internal carotid artery (ICA), and the right ICA was occluded at the origin (**Fig. 1D**). The patient was hospitalized and treated with antithrombotic medication, resulting in improvement of the symptoms. CT angiography showed marked stenosis at the origin of the left ICA, and the stenosed area was about 40 mm long, and its distal end reached the level of the lower margin of the 2nd cervical vertebra (**Fig. 1E**). On the evaluation of plaques by high-resolution MRI, the stenosed area at the origin of the left ICA showed high-signal intensity on T1-weighted imaging, and the plaques were considered to be vulnerable (**Fig. 1F**). Since the lesion at the origin of the left ICA was a symptomatic severe stenosis at a high position, and since the right ICA was occluded, stent placement was planned and executed on the 26th day of illness.

Intracranial endovascular treatment was performed as follows: An 8 Fr sheath was inserted into the right femoral

Fig. 2 Carotid artery stenting. (A) Left carotid angiography (lateral view) shows high-grade stenosis at the origin of the ICA. (B) Left carotid angiography shows positioning of the Spider FX (Covidien, Dublin, Ireland) (arrow) at the cervical portion of the ICA. (C) Image during the post-dilatation. (D) Post-carotid artery stenting angiography shows good dilatation of the ICA stenosis. ICA: internal carotid artery

artery. After heparinization, an 8 Fr guiding catheter was placed in the left common carotid artery. The lesion was confirmed by angiography (**Fig. 2A**). A Spider FX 5 mm was advanced through the lesion using a guidewire and deployed in a linear part at the 1st cervical vertebral level (**Fig. 2B**). Since the plaque was diagnosed as vulnerable, a Wallstent 10 × 31 mm (Stryker, Natick, MA, USA) was selected and placed from the ICA to the common carotid artery with sufficient coverage of the stenosed area. Since the lesion was located in a tortuous segment, ICA was straightened. Post-dilatation was added using a balloon catheter 5 mm in diameter and 30 mm in length (**Fig. 2C**). Intravascular ultrasound showed no migration of plaque into the stent. No intraprocedural flow impairment was noted. The Spider FX was recovered, and adequate dilatation of the stenosed area was confirmed (**Fig. 2D**). The treatment was ended after confirming the absence of abnormalities in the intracranial vessels.

Postprocedurally, there were no de novo symptoms other than right hemiparesis, which was observed at the onset. In head MR diffusion-weighted imaging performed on the 2nd day after treatment, spotty high-intensity areas were diffusely distributed in the bilateral cerebral hemispheres (**Fig. 3**). Right hemiparesis improved to MMT4/5, and the patient became able to walk with a stick. On the 37th day of illness, the patient was transferred to another hospital for rehabilitation.

The used filter was gently washed with distilled water (**Fig. 4A**) and immersed in eosin for 1 minute (**Fig. 4B**). It was then gently washed with distilled water, immersed in hematoxylin for 1 minute (**Fig. 4C**), and gently washed with distilled water again. In each step, the filter was handled protectively to avoid detachment of debris. The captured debris could be examined grossly by staining (**Fig. 4D**). The mesh part of the filter was cutoff and mounted on a glass slide, saturated with a mounting agent (Bioleit, Okenshoji, Tokyo, Japan), and embedded by applying a cover glass. Since the mesh of the filter was made of an elastic shape-memory alloy, the cover glass remained separated from the glass slide, so both of its sides were pressed against the glass slide using two clips (**Fig. 4E**). After about 1 week, when the embedding agent dried, the cover glass adhered to the glass slide, and the clips could be removed (**Fig. 4F**). Microscopy of the completed preparation showed many pieces of thrombotic debris captured on the Spider FX (**Fig. 4G**). The diameter of the debris ranged from 40 to 250 μm . At high magnification, organized components were observed. Slight fibrin precipitation was also noted (**Fig. 4H**).

Discussion

Carotid artery filters are prepared by making small pores about 100 μm in diameter in a polyurethane membrane

Fig. 3 Postoperative MRI (2 days later). Diffusion-weighted image (A) caudate head level, (B) paracentral lobule level shows some high-intensity spots indicating new minor infarction (arrows).

Fig. 4 Observation method for the mesh-type embolus protection filter. (A) A filter after the carotid artery stenting. (B) Eosin staining. (C) Hematoxylin staining. (D) A filter after hematoxylin and eosin staining. (E) Fixation of cover glass with two clips. (F) Completed glass slide. (G) Microscopical observation shows debris captured with filter (original magnification $\times 20$). (H) High-magnification micrograph of figure (G) shows thrombotic debris as well as organized component (arrows). Fibrin precipitation to the filter is also observed (arrow-heads) (original magnification $\times 50$).

with a laser. We have examined the membrane-type filters Angioguard XP (Cordis Corporation, Miami Lakes, FL, USA) and Filterwire EZ (Boston Scientific, Natick, MA, USA) by hematoxylin–eosin staining.^{3,5)} By observing filters, we have confirmed various types of debris and clarified that intraprocedural flow impairment is caused by filter obstruction and vasospasm due to stress exerted by the filter.⁴⁾ Concerning filter obstruction, fibrin was suspected to precipitate secondarily and set off a vicious cycle of flow impairment. In addition, its relationship with intraprocedural cerebral infarction could be evaluated.⁴⁾ In 2012, Spider FX, a mesh-type filter, was introduced to Japan. We also examined Spider FX by hematoxylin–eosin staining, but the preparation of its microscopic specimens was difficult because it is woven with a shape-memory alloy and has an elastic structure. The preparation of microscopic specimens has become possible by sandwiching the filter between the glass slide and cover glass using two clips and waiting until drying of the embedding agent (about 1 week). Since this method is simple and requires no special instrument, we tried to retain this advantage in its modification. Recently, there have been reports of the use of immunostaining for debris analysis and measurement of biomarkers and comparison of the results with periprocedural complications.^{6,7)} In this study, we did not perform immunostaining or measurement of biomarkers but, by hematoxylin–eosin staining, could evaluate tissue types to an extent and observe the state in which debris is captured by the filter, permitting estimation of the intraprocedural condition. By this technique, thrombotic debris, calcified debris, lipid debris, fibrous debris, and fibrin formation have been observed to date.⁵⁾

The patient was diagnosed with symptomatic left ICA stenosis with vulnerable plaques.^{8,9)} The right ICA was occluded, and stent placement was performed using Spider FX. On examination of the filter, thrombotic debris was captured, and organized parts were observed. Fibrin precipitation was slight, probably because the filter was coated with heparin, or because the blood flow through the filter did not become turbulent. Also, the filter is considered not to exert much stress to the vascular wall and to be unlikely to induce vasospasm because a filter matching the vascular diameter can be selected, and its fixation is flexible. While no de novo neurologic symptoms were noted after the procedure, spotty high-intensity areas were diffusely observed on MR diffusion-weighted imaging. Since the mesh size of the filter is small, about 80 μm , near the end but relatively

large, about 200 μm , in the margin, small debris may pass through the filter in the marginal areas. We aim to further clarify the characteristics of mesh-type filters by accumulating cases.

Conclusion

A method to examine mesh filters used for carotid artery stenting was reported. By examining the filter and retrieved debris, the relationships of the thrombus properties with preprocedural images and intraprocedural embolization can be evaluated.

Disclosure Statement

There are no conflicts of interest.

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