A Novel Method for Super-selective Coil Embolization Using an Extremely Soft Bare Coil through a Liquid Embolic Delivery Microcatheter

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Abstract
Endovascular coil embolization for intracranial aneurysms, arteriovenous malformations (AVMs), dural arteriovenous fistulas (AVFs), and hypervascular tumors are recognized as an effective adjunctive or curative treatment. In this setting, it is sometimes difficult to navigate a coil delivery microcatheter to the target point of a tiny, tortuous vessel. We herein present a case series of a novel method that enabled super-selective coil embolization using an extremely soft bare, electrodetachable coil (ED extrasoft® coil) through a liquid embolic delivery microcatheter (Marathon®). The Marathon® catheter was successfully placed at the target point of the tiny, tortuous vessel, and coil embolization was achieved in all 16 patients with 9 AVMs, 2 distal aneurysms, 2 AVFs, and 3 meningiomas. The primary ED extrasoft® coil and delivery wire have a very small radius, and the coil is rapidly detachable with an alarm notice from the generator even under Marathon® with one marker. We believe that this technique can provide safe and efficient embolization for selected patients.

Key words: coil, super-selective embolization, microcatheter

Introduction
Recent advances in endovascular coil embolization have expanded the indications for cerebrovascular diseases including intracranial aneurysms, arteriovenous malformations (AVMs), dural arteriovenous fistulas (AVFs), and hypervascular tumors. Although many embolic materials are currently available, including coils (fiber coils and detachable coils), particles [Polyvinyl alcohol, Gelfoam® (Pharmacia & Upjohn Co., Kalamazoo, Michigan, USA), and Embospheres® (Merit Medical Systems, Inc., South Jordan, Utah, USA)], and liquid embolics [Onyx® (eV3 Inc., Plymouth, Minnesota, USA) and n-butyl-cyanoacrylate (NBCA)], it is still important to navigate a microcatheter to the target point of the artery with no friction for safe and efficient embolization. Therefore, it is ideal to use a small, soft microcatheter with high flexibility, trackability, and crossability that advances distally and has the capacity for various embolic materials, especially in a lesion with a tiny, tortuous target vessel.

We herein present a case series involving a novel method that enabled super-selective coil embolization using an extremely soft bare coil [electrodetachable (ED) extrasoft® coil; Kaneka, Kanagawa] through a liquid embolic delivery microcatheter (Marathon®; ev3 Inc.) and discuss its clinical implications.

Methods
I. Patient selection
From January 2010 to March 2013, 16 patients who underwent coil embolization using ED extrasoft® coils through a Marathon® catheter were retrospectively analyzed. This strategy was chosen when the target artery was tiny with marked narrowing or a tortuous course, and when proximal feeder embolization was utilized to prevent migration of the liquid embolics into the venous system or normal branches in high-flow AVMs. This was also applied for hypervascular tumors with feeding arteries arising from the internal carotid artery or vertebralbasilar arteries.

II. Endovascular procedure
Coil embolization was usually performed under...
local anesthesia. All procedures were performed using a biplane C-arm angiographic system with 3D reconstruction. After placing the guide catheter, the patients were systemically heparinized, and activated clotting times were checked hourly. Using a triple coaxial technique, the Marathon® catheter was navigated into the lesion over a microguidewire. In some patients, a routine coil delivery microcatheter, which was larger than the Marathon® catheter, initially failed to be navigated to the target vessels. After successful deployment of the ED extrasoft® coils through the Marathon® catheter, an angiographic image was obtained to check coil placement before detachment. Additional ED extrasoft® coils were used until obliteration of the lesion was achieved. The patients with AVM or tumors were planned to undergo surgical removal 2 to 4 days later.

Results

Patient characteristics are summarized in Table 1. ED extrasoft® coils were successfully placed in

| Case No. | Age, Sex | Disease | Location | Target vessel | ED extrasoft® (diameter mm/length cm) | Combined with NBCA | Obliteration | Surgical Removal | GOS at discharge |
|----------|----------|---------|----------|--------------|--------------------------------------|--------------------|--------------|-----------------|------------------|
| 1.       | 31M      | Cerebral AVM (ruptured) | Frontal   | MCA          | 3/3, 2.5/3, 2/6, 2/4                  | No                 | Nidus occlusion | Yes             | MD               |
| 2.       | 17F      | Cerebral AVM (ruptured) | Temporal  | MCA          | 2/4, 2/3                              | No                 | Feeder occlusion | Yes             | MD               |
| 3.       | 16M      | Cerebral AVM (ruptured) | Frontal   | ACA          | 2/6, 2/4, 1.5/3                       | No                 | Feeder occlusion | Yes             | GR               |
| 4.       | 30M      | Cerebral AVM (ruptured) | Parieto-occipital | MCA | 3/6, 2.5/6, 2/6                  | Yes                | Feeder occlusion | Yes             | MD               |
| 5.       | 58M      | Cerebral AVM (ruptured) | Cerebellum | PICA | 1.5/3                              | Yes                | Feeder occlusion | Yes             | MD               |
| 6.       | 53M      | Cerebral AVM (ruptured) | Cerebellum | SCA | 4/8, 3.5/8, 2.5/4, 2/4                  | Yes                | Feeder occlusion | Yes             | MD               |
| 7.       | 67M      | Cerebral AVM (ruptured) | Parieto-occipital | MCA | 3.5/8, 3/8, 2.5/8, 2/8                  | Yes                | Feeder occlusion | Yes             | MD               |
| 8.       | 48F      | Cerebral AVM (ruptured) | Frontal   | MCA          | 3/6, 3/4                              | Yes                | Feeder occlusion | Yes             | GR               |
| 9.       | 57M      | Spinal AVM | C5 | Radiculomedullary A | 1.5/1                              | No                 | Feeder occlusion | No              | GR               |
| 10.      | 31F      | Distal AICA AN | AICA | AICA | *16/15, *16/10, 1.5/2                  | Yes                | Aneurysm obliteration | No             | MD               |
| 11.      | 61F      | Distal MCA AN (ruptured) | MCA | MCA | 2.5/6, 1.5/3                       | No                 | Aneurysm obliteration | No             | GR               |
| 12.      | 62M      | Dural AVF | Anterior fossa | Ophthalmic A | 1.5/2                              | No                 | Feeder occlusion | No              | GR               |
| 13.      | 74F      | Dural AVF | Cavernous sinus | MMA, Aph A | 2/6, 2/4, 1.5/3                  | Yes                | Feeder occlusion | No              | GR               |
| 14.      | 78M      | Meningioma | Occipital | MCA | 2.5/6, 2/3, 1.5/3                  | No                 | Feeder occlusion | Yes             | GR               |
| 15.      | 55M      | Meningioma | Cerebellum | PICA | 2/6, 2/4                              | No                 | Feeder occlusion | Yes             | GR               |
| 16.      | 52F      | Meningioma | Temporal | MHT | 1.5/1                              | No                 | Feeder occlusion | Yes             | GR               |

*ED Infini extrasoft® coil. A: artery, ACA: anterior cerebral artery, AICA: anterior inferior cerebellar artery, AN: aneurysm, AphA: ascending pharyngeal artery, AVF: arteriovenous fistula, AVM: arteriovenous malformation, ED: electrodetachable, F: female, GOS: Glasgow Outcome Scale, GR: good recovery, M: male, MCA: middle cerebral artery, MD: moderate disability, MHT: meningohypophysial trunk, MMA: middle meningeal artery, PICA: posterior inferior cerebellar artery, SCA: superior cerebellar artery.
Super-selective Coil Embolization through Marathon® Microcatheter

16 patients with 9 cerebral/spinal AVMs, 2 distal aneurysms, 2 AVFs, and 3 meningiomas. Secondary ED extrasoft® coils of various sizes (1.5–4 mm) and lengths (1–8 cm) were smoothly introduced through the Marathon® catheter, and super-selective embolization was achieved. An ED Inifini extrasoft® coil (Kaneka, Kanagawa), which had a large loop design with a longer length, was also successfully applied in a patient with a distal anterior inferior cerebellar artery aneurysm (Case 10). In the selected case, NBCA was applied combined with an ED extrasoft® coil through the same Marathon® catheter (Cases 4–8, 10, and 13). Surgical removal was applied in all cerebral AVMs (Cases 1–8) and meningiomas (Cases 14–16), and successful removal of the lesion was achieved without any complications.

Illustrative Cases

I. Case 10
A 31-year-old female patient was found to have an irregular aneurysm at the distal part of the right anterior inferior cerebellar artery (AICA) during a brain check-up (Fig. 1A). A Marathon® catheter was navigated into the aneurysm, and aneurysm embolization was performed using ED Inifini extrasoft® (16 mm/15 cm, 16 mm/10 cm) and an ED extrasoft® coil (1.5 mm/2 cm), which resulted in body filling (Fig. 1B). Further embolization was undertaken using 33% NBCA through the same microcatheter, and complete obliteration of the aneurysm was achieved (Fig. 1C). Unfortunately, postoperative angiogram showed delayed appearance of distal AICA (Fig. 1C), and postoperative magnetic resonance (MR) imaging showed a fresh cerebellar infarction in the distal AICA territory. The patient complained right facial palsy (House-Brackmann grade 2), which gradually improved during the follow-up.

II. Case 12
A 62-year-old male patient presented with progressing headache for 1 month. Digital subtraction angiography revealed an anterior fossa AVF draining into the superior sagittal sinus (Fig. 2A, B). A coil delivery microcatheter was distally navigated to the ophthalmic artery, but failed because of tortuosity of the vessel. Next, a Marathon® catheter was smoothly navigated distally to the shunting point beyond the origin of the central retinal artery (Fig. 2C). An ED extrasoft® coil (1.5 mm/2 cm) was successfully detached to occlude the recurrent meningeal artery (Fig. 2D).

Discussion

Recently, endovascular therapy has greatly enhanced the care of neurosurgical patients. Progress in technology and techniques continue to push forward the boundaries of what is deemed “treatable,” assuming acceptable risk. Numerous devices and embolic materials are currently available, and clinicians should be aware of the characteristics of each material. The choice of embolic materials depends on the occlusion point, vasculature, flow pattern of the target artery, and microcatheter size.

Marathon® is a liquid embolic delivery catheter that is often used for AVM embolization in combination with the liquid agent NBCA or Onyx.

Fig. 1 A 31-year-old female patient with a distal aneurysm at the anterior inferior cerebellar artery (AICA) (Case 10). Anteroposterior right vertebral artery angiogram showing an aneurysm at the distal part of the AICA (A). A Marathon® catheter was smoothly navigated into the aneurysm, and the aneurysm was embolized with an ED Inifini extrasoft® and ED extrasoft® coil (arrow in B) in combination with 33% NBCA (C), achieving complete obliteration of the aneurysm.

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A microcatheter has one marker that cannot be used for the delivery of detachable coils with the exception of the ED extrasoft®. The ED extrasoft® coil is a bare platinum coil with excellent handling properties attributable to the following features.

1. First, the coil is extremely soft due to an unprecedentedly small diameter of the element wire and very flexible pusher wire system. Second, detachment of the coil is rapid and secure based on the ED system, with a polyvinyl alcohol rod at the junction of the platinum coil and delivery wire. In addition, it is easy to find the detachment point with an alarm notice from the generator. Therefore, it is not necessary to adjust the delivery wire to the second marker of the microcatheter in an ED extrasoft®. The ED extrasoft® also has the lowest profile (1.5 mm in diameter and 1 cm in length), which facilitates embolization of small lesions. With this technique, ED extrasoft® coils and NBCA can be delivered from the same microcatheter in one session, if necessary. This could reduce the operating time and radiation dose, which is beneficial especially for complicated cases involving local anesthesia.

Some pitfalls should be addressed in this technique. This microcatheter has a 1.5-F smaller distal tip (0.013 inch), which enables further navigation to the intracranial arteries. However, a liquid agent is uncontrollable, and it is sometimes difficult to obliterate an AVM with an aneurysm or a high-flow AVM. Moreover, liquid embolics have a risk of distal migration into the venous system or normal branches in such cases. To address these issues, detachable coils that can be delivered through the Marathon® catheter provide safe and efficient embolization for selected AVMs, as well as for distal aneurysms, AVFs, and hypervascular tumors with tortuous and narrow vessels.

We herein report the successful demonstration of a valuable technique using ED extrasoft® coils through a flow-guided Marathon® microcatheter. Some soft detachable coils with a very small primary diameter, such as the ED extrasoft® (0.01 inch), Target-10 ultrasoft® (0.01 inch; Stryker, Osaka), Micrusphere-10® (0.0098 inch; J&J Codman, San Jose, California, USA), Complex-10 soft® (0.0095 inch; Microvention, TERUMO, Tokyo), and Axium (0.0115 inch, Covidien, eV3, Tokyo) could be size-compatible with Marathon®. However, only the ED extrasoft® is available for Marathon® because this microcatheter has one marker that cannot be used for the delivery of detachable coils with the exception of the ED extrasoft®.

The ED extrasoft® coil is a bare platinum coil with excellent handling properties attributable to the following features. First, the coil is extremely soft due to an unprecedentedly small diameter of the element wire and very flexible pusher wire system. Second, detachment of the coil is rapid and secure based on the ED system, with a polyvinyl alcohol rod at the junction of the platinum coil and delivery wire. In addition, it is easy to find the detachment point with an alarm notice from the generator. Therefore, it is not necessary to adjust the delivery wire to the second marker of the microcatheter in an ED extrasoft®. The ED extrasoft® also has the lowest profile (1.5 mm in diameter and 1 cm in length), which facilitates embolization of small lesions. With this technique, ED extrasoft® coils and NBCA can be delivered from the same microcatheter in one session, if necessary. This could reduce the operating time and radiation dose, which is beneficial especially for complicated cases involving local anesthesia.

Some pitfalls should be addressed in this technique.
First, ED extrasoft® coil has a delivery wire with smaller diameter (0.012 inch) compared with other coils. Second, straightening phenomenon has been reported in ED extrasoft® coils due to coil folding. Therefore, ED extrasoft® coils with small diameter and shorter length might be better to stabilize the tip of Marathon® catheter. Advanced type of ED extrasoft® coils (type R) have 0.014 inch diameter delivery wire and longer pusher wire (180→187 cm), which improved pushability of coils. ED extrasoft® coils (type R) will figure out these technical pitfalls above and therefore could be a good candidate for the delivery through Marathon®.

**Conclusion**

Super-selective coil embolization using extremely soft bare coils (ED extrasoft® coils) through a liquid embolic delivery microcatheter provides safe and efficient obliteration of the feeding arteries in AVMs, AVFs, hypervascular tumors, and distal aneurysms. This method is very useful for feeder embolization in selected cases.

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**Conflicts of Interest Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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