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Case Report

Trans-Cell Technique through Mesh of Pipeline Embolization Device: A Case Report

Shinya Sonobe,[1] Masayuki Ezura,[1] Ayumi Narisawa,[1] Naoto Kimura,[2] Hiroshi Uenohara,[1] and Teiji Tominaga[3]

Objective: We report a case of coil embolization using trans-cell technique through mesh of a pipeline embolization device (PED).
Case Presentation: A 55-year-old female developed a left cavernous carotid aneurysm (CCA) with left abducens nerve palsy. The abducens nerve palsy improved gradually after PED deployment for the aneurysm. Sixty-nine days after the procedure, the patient suddenly presented with a severe headache, left abducens nerve palsy, left eyelid edema, and left pulsatile tinnitus. Digital subtraction angiography (DSA) revealed left direct carotid cavernous fistula (dCCF) due to rupture of the aneurysm, and the patient underwent endovascular treatment. A Marathon was guided into the left internal carotid artery, and a guidewire via the Marathon passed through the mesh of the PED. Then the Marathon advanced over the guidewire into the aneurysm through the mesh of the PED, with assistance of a distal access catheter and a balloon catheter. Transarterial intra-aneurysmal coil embolization using trans-cell technique was performed, and the shunt blood flow was diminished. After subsequent transvenous embolization (TVE), the shunt blood flow disappeared, and all neurological symptoms improved. When PED is deployed linearly at a diameter 0.5 mm smaller than the nominal diameter, the average strand spacing is calculated to be approximately 0.2 mm. Since PED is a braided stent, the spacing can be large. It is theoretically reasonable for Marathon with an outer diameter of 0.59 mm to pass through the mesh of the PED.
Conclusion: In some cases, trans-cell technique through mesh of PED can be performed using a small diameter microcatheter.

Keywords▶ pipeline embolization device, trans-cell technique through mesh of flow diverter, coil embolization through Marathon, cavernous carotid aneurysm, direct carotid cavernous fistula

Introduction

We report a case of direct carotid cavernous fistula (dCCF) treated with coil embolization using trans-cell technique through mesh of a pipeline embolization device (PED; Medtronic Neurovascular, Irvine, CA, USA) that had been deployed for a cavernous carotid aneurysm (CCA).

[1]*Department of Neurosurgery, NHO Sendai Medical Center, Sendai, Miyagi, Japan*
[2]*Department of Neurosurgery, Iwate Prefectural Central Hospital, Morioka, Iwate, Japan*
[3]*Department of Neurosurgery, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan*

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Corresponding author: Masayuki Ezura. Department of Neurosurgery, NHO Sendai Medical Center, 2-11-1, Miyagino, Miyagino-ku, Sendai, Miyagi 983-8520, Japan
Email: sotta-n@nsg.med.tohoku.ac.jp.

Case Presentation

A 55-year-old female developed left CCA with left abducens nerve palsy. Digital subtraction angiography (DSA) revealed a left CCA protruding downward from the medial wall of the left carotid artery (**Fig. 1A**); the maximum diameter of the aneurysm body was 14.1 mm and the maximum diameter of the aneurysm neck was 6.9 mm (**Fig. 1B**). A 4.5 mm × 30 mm PED was deployed across the aneurysm (**Fig. 1C**). Around the aneurysm, the PED was deployed linearly without any deviation of strands and the resulting width of the PED was 4.0 mm. DSA after PED deployment showed a significant flow diversion effect with typical eclipse sign (**Fig. 1D**). The abducens nerve palsy improved gradually after the procedure and recovered completely 14 days after treatment.

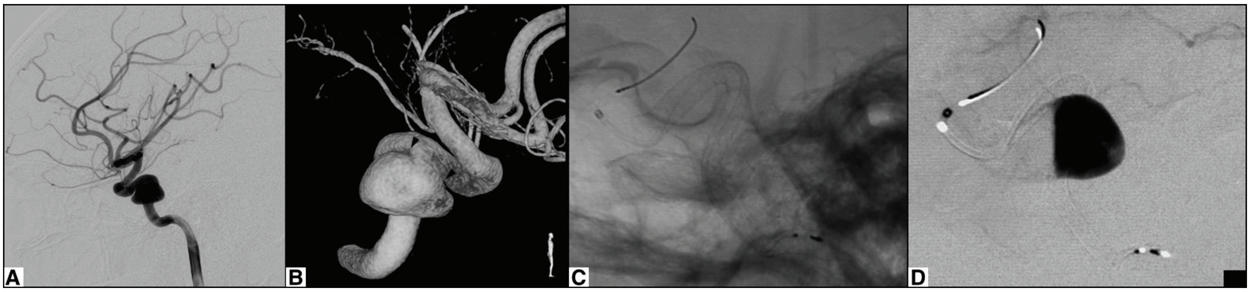


Fig. 1 Intraprocedural images of PED deployment for a left cavernous carotid aneurysm protruding downward from the medial wall of the left carotid artery. (**A**) Lateral view with DSA, before deployment. (**B**) Lateral view from the right of three-dimensional reconstruction image of rotational angiography. Arrowheads indicate the proximal neck and the distal neck of the aneurysm. (**C**) Lateral view with X-ray fluoroscopy, immediately after deployment. (**D**) Lateral view with DSA, immediately after deployment. A 4.5 mm × 30 mm PED was deployed across the aneurysm. Around the aneurysm, the PED was deployed linearly without any deviation of strands and the resulting width of the PED was 4.0 mm. A significant flow diversion effect was observed with typical eclipse sign after deployment. DSA: digital subtraction angiography; PED: pipeline embolization device.

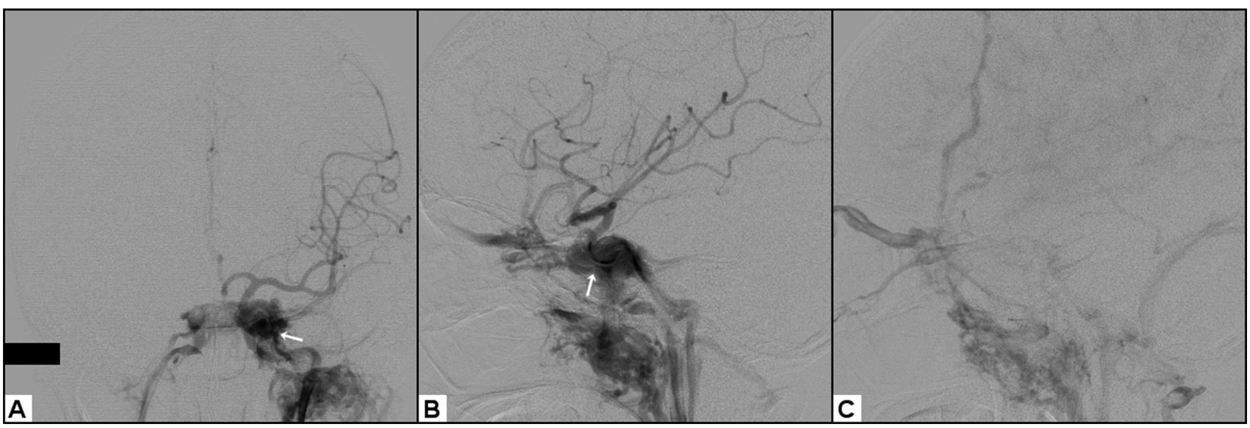


Fig. 2 DSA after development of left direct carotid cavernous fistula due to rupture of a left cavernous carotid aneurysm. (**A**) Frontal view, early phase. (**B**) Lateral view, early phase. (**C**) Lateral view, late phase. Arrows indicate the rupture point. Draining vessels were the left superficial middle cerebral vein, the left deep middle cerebral vein, the left superior ophthalmic vein, the left inferior ophthalmic vein, the left superior petrosal sinus, the left inferior petrosal sinus, the left pterygoid plexus, and the intercavernous sinus. Some vessels are detected clearly in early phase, and others in late phase. DSA: digital subtraction angiography

Sixty-nine days after the procedure, the patient suddenly presented with a severe headache, left abducens nerve palsy, left eyelid edema, and left pulsatile tinnitus. DSA revealed left dCCF due to rupture of the aneurysm; the rupture point was lower anterolateral of the aneurysm. Draining vessels were the left superficial middle cerebral vein, the left deep middle cerebral vein, the left superior ophthalmic vein, the left inferior ophthalmic vein, the left superior petrosal sinus, the left inferior petrosal sinus, the left pterygoid plexus, and the intercavernous sinus (**Fig. 2A–2C**). The patient underwent endovascular treatment the next day.

Transarterial embolization (TAE) was performed. A 7-Fr Roadmaster (Goodman, Nagoya, Aichi, Japan) was inserted into the left internal carotid artery via the right femoral artery. First, a 4-Fr Cerulean (Medikit, Bunkyo-ku, Tokyo, Japan) was placed in the petrous segment of the left internal carotid artery; an Echelon 10 (Medtronic) was guided into the PED. A 0.012-inch GT Wire (Terumo, Shibuya-ku, Tokyo, Japan) was reached the mesh facing the neck of the aneurysm via the Echelon 10, and the tip of the GT Wire was pressed against the mesh. Torque was applied to the GT wire with the Echelon 10 in place; then the GT wire passed through the mesh. Subsequently, the Echelon 10 was attempted to advance over the GT Wire into the aneurysm; however, pushing the Echelon 10 caused its tip to form a loop on the distal side without passing through the mesh. Next, the Echelon 10 was removed and microcatheter was changed to a Marathon (Medtronic). In addition, the 4-Fr Cerulean was advanced to the lacerum segment of the left

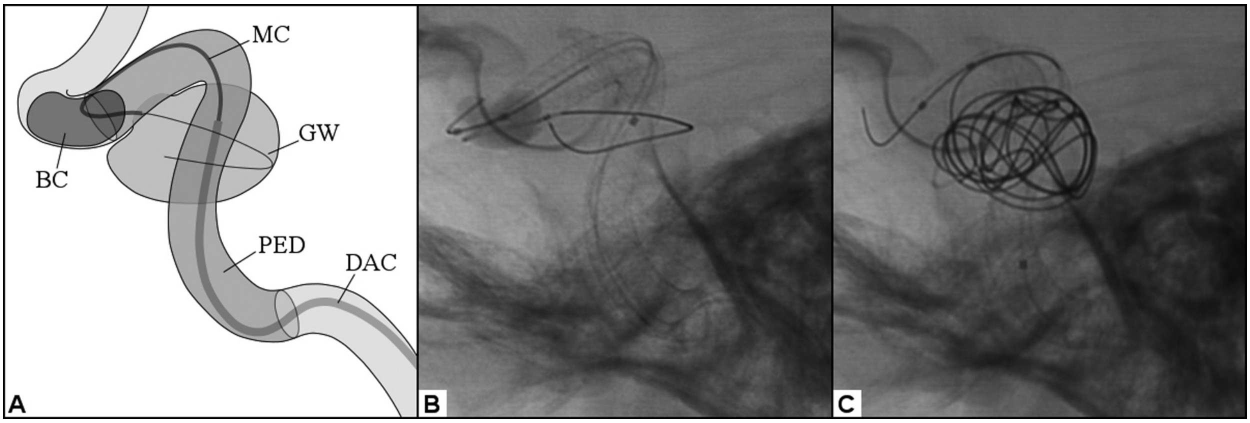


Fig. 3 Intraprocedural images of embolization for left direct carotid cavernous fistula. (**A**) Illustration of lateral view. A DAC was placed in the lacerum segment of the left internal carotid artery. A BC was dilated at the distal side of the aneurysm. A Marathon (MC) was guided into the deployed PED, and a GW via the Marathon passed through the mesh of the PED. (**B**) Lateral view with X-ray fluoroscopy. The tip of the Marathon was pressed against the mesh of PED without forming a loop at its tip. (**C**) Lateral view with X-ray fluoroscopy. The Marathon passed through the mesh of the PED. A coil inserted via the Marathon was deployed within the aneurysm. BC: balloon catheter; DCA: distal access catheter; GW: guidewire; PED: pipeline embolization device

internal carotid artery, and a Super-Masamune (Goodman) was placed at the distal side of the aneurysm and dilated (**Fig. 3A**). The Marathon was guided into the PED and attempted to pass through the mesh as in the previous procedure. The Marathon could be pushed harder than when attempted with the Echelon, without forming a loop at its tip (**Fig. 3B**); then the Marathon advanced over the GT Wire into the aneurysm through the mesh. Subsequently, the GT Wire was removed, and an ED coil-10 infini Soft (Kaneka Medix, Osaka, Japan) was inserted via the Marathon; this coil was deployed within the aneurysm (**Fig. 3C**). Additional embolization was performed with ED coil; 29 coils totaling 580 cm were deployed within the aneurysm as a result. As soon as the last coil was fully inserted into the aneurysm, the tip of the marathon was pushed back through the mesh into the PED. Transarterial intra-aneurysmal coil embolization using trans-cell technique described above diminished the shunt blood flow of the dCCF (**Fig. 4A**).

Transvenous embolization (TVE) was performed following TAE. A 6-Fr FUBUKI (Asahi Intecc, Seto, Aichi, Japan) was inserted into the left internal jugular vein via the left femoral vein, and a 4-Fr Cerulean was placed in the left inferior petrosal sinus. An Excelsior SL-10 (Stryker, Kalamazoo, MI, USA) was guided into the left superior ophthalmic vein, and the vessel was embolized with 12 coils totaling 97 cm. Then, the Excelsior SL-10 was guided to the lower outside of the aneurysm, which was the rupture site, and target embolization was performed around there with three coils totaling 26 cm. TVE further diminished the shunt blood flow of the dCCF (**Fig. 4B**).

The patient had a good postprocedural course; the left eyelid edema and the left pulsatile tinnitus improved immediately after the procedure. Subsequently, two sessions of TVE, one is via the right femoral vein and the other is via the left superficial middle cerebral vein, were performed to the draining vessels at intervals of several months. Eventually, the shunt blood flow disappeared (**Fig. 4C**); all neurological symptoms recovered immediately after the last TVE.

Discussion

As a treatment for cerebral aneurysm, neck bridge stent-assisted coil embolization is widely used, and flow diverter deployment has become widespread in recent years. In neck bridge stent-assisted coil embolization, both jailing technique and trans-cell technique are used. In contrast, when using flow diverter deployment and coil embolization together, only jailing technique is used. In the present case, coil embolization using trans-cell technique through mesh of PED was performed.

PED is a braided stent composed of 0.03 mm wide strands; mesh consists of cells made up of intersecting strands. When deployed at a nominal diameter, cell shape is rhombic, metal coverage ratio is 30%–35%.[1)] When PED is deployed at a diameter 0.5 mm smaller than a nominal diameter, cell shape is almost square and metal coverage ratio drops to approximately 24%.[2,3)] Therefore, when PED is deployed linearly at a diameter 0.5 mm smaller than a nominal diameter, average strand spacing is calculated to be approximately 0.2 mm (**Fig. 5**). Since strands constituting

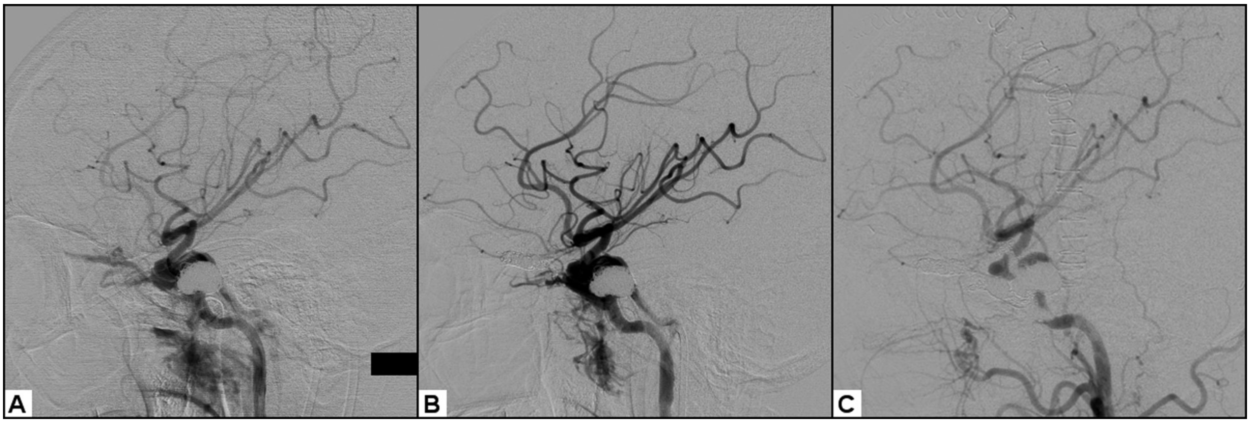
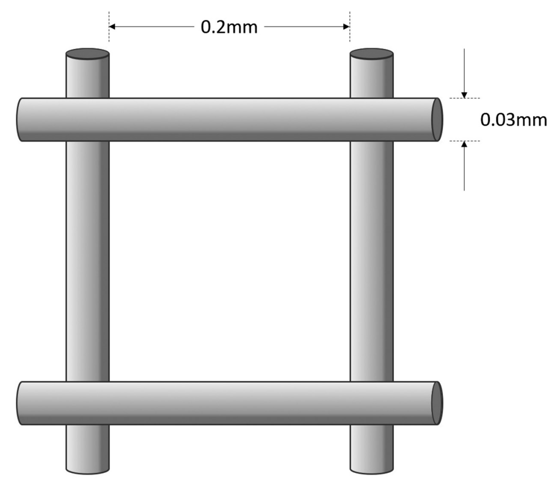


Fig. 4 (**A**) Lateral view with DSA after transarterial intra-aneurysmal coil embolization using trans-cell technique. The shunt blood flow was diminished. (**B**) Lateral view with DSA after subsequent TVE. The shunt blood flow was further diminished. (**C**) Lateral view with DSA after subsequent several transvenous embolization. Eventually, the shunt blood flow disappeared. PED: pipeline embolization device; DSA: digital subtraction angiography; TVE: transvenous embolization

cells are mobile, cell size can be changed when strands are displaced by a guidewire or a microcatheter. In the present case, the PED was deployed at a diameter 0.5 mm smaller than a nominal diameter, therefore strand spacing was estimated to be approximately 0.2 mm. In this situation, displacement of four strands that make up a certain cell can theoretically form a square cell with four 0.6-mm sides. It is reasonable that the GT wire with an outer diameter of 0.30 mm and the Marathon with an outer diameter of 0.59 mm could pass through the mesh of the PED and the Echelon 10 with an outer diameter of 0.66 mm could not in the present case.

To displace strands of PED by a microcatheter, the microcatheter needs enough support to push the strands. In the present case, a distal access catheter was placed as distally as possible, and a balloon catheter was dilated at the distal side of the aneurysm; then a microcatheter advanced over a guidewire into the aneurysm through mesh of a PED without forming a loop. Stability of the microcatheter by these measures may have contributed to the passage through the mesh.



Metal coverage ratio (%) = $\{ 1 - (0.2 \times 0.2) / (0.23 \times 0.23) \} \times 100 \fallingdotseq 24.4$

Fig. 5 A schema of deployed PED. PED is a braided stent composed of 0.03 mm wide strands; mesh consists of cells made up of intersecting strands. In case that cell shape is square and strand spacing is 0.2 mm, metal coverage ratio is calculated as 24%. PED: pipeline embolization device.

Including the present case, 14 cases of dCCF due to rupture of CCA previously treated with PED deployment have been reported (**Table 1**); parent artery occlusion (PAO) or TVE has been performed in preceding 13 cases.[4–10] PAO is not recommended in such cases because it can cause cerebral ischemia even if balloon occlusion test shows ischemic tolerance.[8] Oishi et al.[9] pointed out that TVE may result in sinus packing of cavernous sinus in such cases, which disturb improvement of abducens nerve palsy. Therefore, in such cases, embolization within an aneurysm or target embolization around rupture site should be performed. It is desirable to guide the microcatheter into an aneurysm *transvenously*, which is not easy for structural reasons. In the present case, microcatheter was guided into the aneurysm *transarterially* using trans-cell technique; then coil embolization within the aneurysm was performed, which diminished the shunt blood flow of the dCCF. After subsequent TVE, the shunt blood flow disappeared without resulting in sinus packing, and the abducens nerve paralysis improved. Therefore, in the present case, TAE using trans-cell technique through the mesh of the PED may have contributed to the improvement of abducens nerve palsy.

Marathon is a small diameter flow directed microcatheter developed for Onyx delivery and may be able to reach sites that cannot be reached with other microcatheters. On the other hand, intra-aneurysmal coil embolization through Marathon

Table 1 Summary of reported cases of direct carotid cavernous fistula after flow diverter placement for cavernous carotid aneurysm

Author (year)	Age	Sex	Aneurysm size (mm)	Interval to rupture	Flow diverter	Treatment	Reference
Mustafa (2010)	39	Female	17.6	2 weeks	Silk	TVE	4
Kulcsár (2011)	74	Female	20	3 days	Silk	PAO	5
Kulcsár (2011)	48	Female	24	110 days	Silk	PAO	5
Tanweer (2014)	N/A	N/A	N/A	1 day	PED	TVE	6
Lin (2015)	Middle age	N/A	10	<5 weeks	PED	TVE	7
Lin (2015)	Middle age	N/A	17	3 days	PED	TVE	7
Roy (2017)	N/A	N/A	17.4	11 days	PED	PAO	8
Roy (2017)	N/A	N/A	14.5	11 days	PED	PAO	8
Roy (2017)	N/A	N/A	31	3 days	PED	PAO	8
Roy (2017)	N/A	N/A	19	6 days	PED	PAO	8
Roy (2017)	N/A	N/A	18.8	7 days	PED	PAO	8
Oishi (2017)	86	Female	20	6 weeks	PED	TVE	9
Nakae (2018)	81	Female	18	10 days	PED	TVE	10
Present case	55	Female	14.1	69 days	PED	TAE and TVE	

N/A: not available; PAO: parent artery occlusion; PED: pipeline embolization device; TAE: transarterial embolization; TVE: transarterial embolization

has two limitations. First, coils that can be inserted through Marathon are limited to ED coil and Barricade coil (Balt USA, Irvine, CA, USA). This is because inner diameter of Marathon is small. Second, in situations where it is difficult to visually recognize a tip of a microcatheter, such as after multiple coils deployment, it may not be safe to use coils which require visual information for detaching. This is because Marathon does not have second marker and it is necessary to visually recognize a tip of a microcatheter when detaching coil. In view of these limitations, only ED coil has an advantage of being safe to use in intra-aneurysmal coil embolization through Marathon because ED coil detects the appropriate position of detachment as a change in electrical resistance and notifies it with audio signal. In fact, in the present case, TAE was performed with ED coil only. However, ED coil also has a disadvantage that embolic effect is relatively low. In fact, in the present case, despite using many coils, TAE alone did not achieve disappear of the shunt blood flow. In this regard, i-ED coil, which is the successor to ED coil, has improved hardness and shape, and is expected to solve this disadvantage.

This report is not a report that recommends trans-cell technique through mesh of flow diverter. Trans-cell technique through mesh of flow diverter has many issues to consider and may not be a safe procedure. Flow diverter may deform or move improperly, which may cause unintended thrombus formation. A microcatheter may jump into an aneurysm after passing through mesh and may penetrate aneurysmal wall. It will be not always possible to restore if a tip of a microcatheter is pushed back through mesh into flow diverter while deploying a coil. Fortunately, in the present case, there was no trouble caused by the trans-cell technique. When performing trans-cell technique through mesh of flow diverter, limitations and expected effects must be considered in advance, and risks and benefits should be compared with those of alternative procedures.

Conclusion

In some cases, coil embolization can be performed using trans-cell technique through mesh of PED. Using a small diameter microcatheter and assisting with distal access catheter and balloon catheter may contribute to passage of mesh. When performing trans-cell technique through mesh of flow diverter, limitations and expected effects must be considered in advance, and risks and benefits should be compared with those of alternative procedures.

Informed consent

Informed consent has been obtained from the patient for this report.

Disclosure Statement

There is no conflict of interest for any of the authors.

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