Editors' Choice

ORIGINAL PAPER

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Initial experience with in vivo "endovascular shaping" technique that utilizes the vascular configuration for small cerebral aneurysm coiling

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ABSTRACT

Optimal shaping of a microcatheter tip is a key factor in cerebral aneurysm coiling. However, safe cannulation and stabilization of a microcatheter can be technically challenging with small aneurysms requiring precise microcatheter shaping. We devised a new microcatheter shaping technique which bends a microcatheter tip in the intended direction by placing and keeping the tip in the selected branch of the parent artery for 5 minutes: endovascular shaping technique. Our method can complete microcatheter shaping only inside the patient's body; an endovascularly shaped microcatheter will never face a straightening deformity and rotation problem associated with catheter reinsertion. The aim was to assess the feasibility and safety of endovascular shaping for small aneurysm coiling. Clinically, 10 consecutive challenging small terminal-type aneurysms (<5 mm) treated with endovascular shaping were included. We retrospectively analyzed the newly acquired bend angle of a microcatheter tip after the shaping, the procedural success, and clinical outcomes. An artificial vascular model was used to confirm our findings. In all the 10 patients (three middle cerebral artery, four anterior communicating artery, and three basilar artery aneurysms), the endovascularly shaped microcatheters were bent toward the placement branch at an average of 21.7° and excellently guided into the aneurysms. Coil embolization was successfully accomplished without any complications. The results of the vascular model experiment demonstrated that an endovascularly shaped microcatheter acquired new bend angle toward the placement branch. Endovascular shaping was feasible and safe for small terminal-type aneurysm coiling. Our method can provide accurate shaping and stability during aneurysm coiling procedure.

Keywords: cerebral aneurysm, coil embolization, microcatheter tip, shaping

INTRODUCTION

The shape of a microcatheter tip is the most important factor for a successful aneurym coiling procedure. Several methods have been reported for shaping microcatheters.[1-5] However, safe cannulation and stabilization of a microcatheter are sometimes difficult in small aneurysm coiling because a conventional in vitro steam-shaped microcatheter produces a straightening deformation following

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coaxial microcatheter insertion through a guiding catheter or microguidewire manipulation.[6]

Once the microcatheter is placed and maintained in a patient's vessel, the microcatheter bends according to the actual vessel's shape as a result of its thermoplasticity.[5] We invented a new microcatheter tip shaping technique which bends a microcatheter tip in the intended direction by placing and keeping the tip in the selected branch of the parent artery for 5 minutes: in vivo "endovascular shaping" technique. The whole procedure is performed strictly inside a patient's body. This means that our endovascularly shaped microcatheter is not associated with any straightening deformation. To the best of our knowledge, no study has reported microcatheter shaping strictly inside a patient's body with cerebral aneurysm coiling. Present study assessed the feasibility and safety of an endovascularly shaped microcatheter in small terminal-type aneurysm coiling. Additionally, using an artificial vascular model, we evaluated the newly acquired bend angle of a microcatheter tip toward the placement branch after the endovascular shaping depending on the length of microcatheter tip inserted into the branch and placement time.

MATERIALS AND METHODS

Patient Selection

We applied the endovascular shaping technique to the patients with a small cerebral aneurysm (<5 mm) which failed to cannulate into the aneurysm with an Excelsior SL-10 straight microcatheter (Stryker, Fremont, CA, United States). Between January 2018 and December 2018, 55 consective patients (55 aneurysms) with intracranial aneurysms underwent endovascular coil embolization at our institute. Of these, 10 terminal-type aneurysms[7] treated with endovascular shaping were included in this study.

This study was approved by the Institutional Review Board, and performed in accordance with the Declaration of Helsinki. Written informed consent regarding treatment was obtained from all patients and/or their families before the procedure was initiated.

Endovascular Shaping and the Cannulation Technique

Initially, the SL-10 straight microcatheter was navigated just proximal to the aneurysm with the aid of a microguidewire. Then, the SL-10 microcatheter was shifted toward the aneurysm, and the direction of the microcatheter tip against the aneurysm neck was confirmed (Fig. 1A). We selected the "placement branch" that ran opposite to the direction of the microcatheter tip

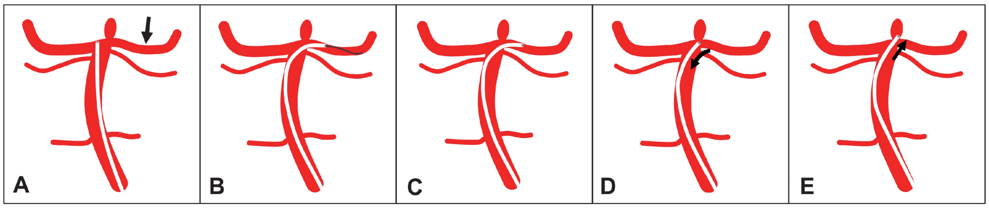

Fig. 1 A schematic drawing showing the endovascular shaping and its cannulation technique
Fig. 1A: The microcatheter is shifted distally toward the aneurysm. The placement branch (arrow) that runs opposite to the direction of the microcatheter tip against the aneurysm neck is selected.
Fig. 1B, 1C: A microguidewire is advanced to the placement branch, followed by the microcatheter. The microguidewire is pulled to the parent artery and the microcatheter is parked inside the branch for 5 minutes.
Fig. 1D: Simple pull motion. The endovascularly shaped microcatheter acquires new bend angle of the catheter tip toward the placement branch.
Fig. 1E: Simple push motion.

against the aneurysm neck. A microguidewire was advanced to the placement branch, and this was followed by the insertion of the SL-10 microcatheter (Fig. 1B). The microguidewire was pulled into the parent artery (Fig. 1C). The SL-10 microcatheter was intentionally kept inside the placement branch for 5 minutes to establish the microcatheter tip shaping. Subsequently, the SL-10 microcatheter was advanced into the aneurysm using either a simple pull motion (direct proximal shift from the placement branch to the aneurysm; Fig. 1D) or simple push motion (distal shift from the parent artery into the aneurysm; Fig. 1E).[3] When both cannulation techniques failed, the SL-10 microcatheter was inserted into the aneurysm with a microguidewire: guidewire navigation.[3] The accuracy of the microcatheter shaping was assessed to be "excellent" in the case of a simple pull or simple push motion, and it was "moderate" in the case of guidewire navigation.[3]

Assessment

We retrospectively analyzed the following: 1) the newly acquired bend angle of the microcatheter tip toward the placement branch after endovascular shaping, 2) the success rate of cannulation into the aneurysm, 3) the cannulation technique (the accuracy of the microcatheter shaping), and 4) the clinical outcomes (success rate and perioperative complications). Based on the Modified Raymond-Roy Classification (MRRC) system,[8] we assessed intracranial aneurysm occlusion using postprocedural angiography. Stroke and death within 30 days were considered perioperative complications. Patients with a new focus on magnetic resonance imaging within 30 days after treatment and neurological symptoms persisting for ≥24 hours were defined as having had a stroke.

Artificial Vascular Model Validation

We performed a hollow vessel model experiment to confirm a newly acquired bend angle of a microcatheter tip after endovascular shaping. An artificial vascular model made of vinyl chloride resin that had an inner diameter of 4 mm and SL-10 straight microcatheters were used in this validation experiment. All catheters that were used in the experiment were new and were not used previously. The model was filled with saline solution warmed to 37°C. A placement branch

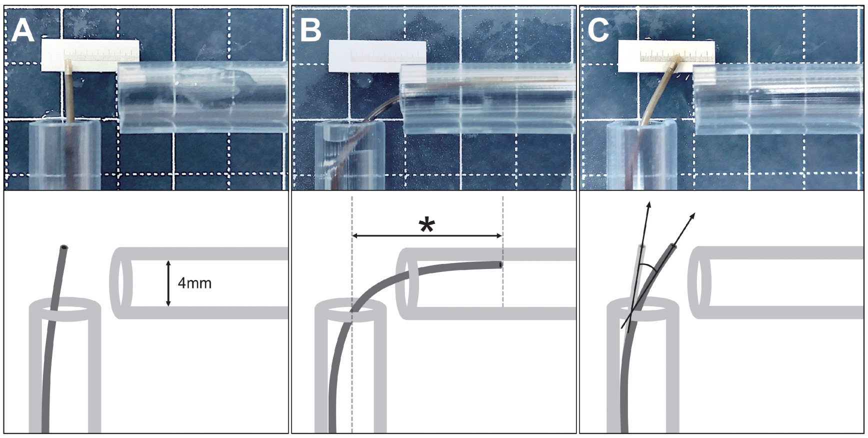

Fig. 2 Conformation of endovascular shaped microcatheter tip using a vascular model
Fig. 2A: The SL-10 straight microcatheter is inserted into the model as control.
Fig. 2B: The SL-10 straight microcatheter is advanced beyond the 90° curve to prescribed distance (asterisk), and maintained for 5 minutes in saline warmed to 37°C (simulating in vivo temperature in human).
Fig. 2C: The microcatheter is pulled and the angle of the newly acquired bend angle is measured.

at a right angle to the parent artery was created (Fig. 2A). The microcatheter was inserted into the model and distally advanced through this 90° angle into the placement branch for 1.0, 1.5, and 2.0 cm, and the SL-10 microcatheter was placed for 1, 2, and 5 minutes within the model, respectively (Fig. 2B). Each microcatheter was proximally pulled, and the newly acquired bend angle was measured in each case (Fig. 2C).

RESULTS

Clinical characteristics of all patients are shown in Table 1. The mean age was 70.8 ± 11.8 years and the mean aneurysm size was 3.9 mm. Regarding locations of the aneurysms, three had a middle cerebral artery aneurysm, four had an anterior communicating artery aneurysm, and three had a basilar artery aneurysm. The endovascularly shaped SL-10 straight microcatheter acquired new bend angle of the microcatheter tip toward the placement branch in all 10 cases (mean: 21.7°). Microcatheters were cannulated into the aneurysm with a simple pull motion for two (20%) patients and a simple push motion for eight (80%) patients without re-shaping; the accuracy of the microcatheter shaping was excellent in all 10 cases. Coil embolization was completed successfully with MRRC Class I for 5 (50%) patients and II for 5 (50%) patients. The endovascularly shaped SL-10 straight microcatheters were maintained as stable until the completion of the procedure. There were no perioperative complications in all 10 cases.

Illustrative Case

Case 1: An 86-year-old woman who presented with a ruptured small basilar artery tip aneurysm was treated (Fig. 3A). The SL-10 straight microcatheter was inserted toward the aneurysm. However, the catheter then advanced to the right side against the aneurysm neck (Fig. 3B). We applied the endovascular shaping technique using the left posterior cerebral artery as a placement branch (Fig. 3C). After 5 minutes, the SL-10 microcatheter was pulled into the basilar artery (Fig. 3D) and smoothly inserted into the aneurysm with a simple push motion cannulation technique (Fig. 3E).

Table 1 Patients with an intracranial aneurysm treated with endovascular shaping technique

Case	Age (years)	Sex	Aneurysm			Placement branch	Newly acquired bend angle	Cannulation technique	Accuracy of the micro-catheter shaping	Emboli-zation result
			Location	Rupture or unrupture	Size (mm)					
1	86	F	BA tip	Rupture	2.8	PCA	24°	Push	Excellent	Class I
2	74	M	ACoA	Unrupture	4.5	A2	21°	Push	Excellent	Class I
3	49	M	ACoA	Rupture	4.1	A2	21°	Push	Excellent	Class I
4	81	F	BA tip	Rupture	2.7	PCA	26°	Pull	Excellent	Class I
5	74	F	ACoA	Rupture	3.7	A2	18°	Push	Excellent	Class II
6	80	F	MCA	Rupture	3.7	M2	24°	Pull	Excellent	Class II
7	59	F	MCA	Rupture	3.9	M2	19°	Push	Excellent	Class II
8	55	M	BA tip	Unrupture	4.5	PCA	21°	Push	Excellent	Class I
9	80	F	MCA	Unrupture	4.8	M2	21°	Push	Excellent	Class II
10	70	F	ACoA	Unrupture	4.3	A2	22°	Push	Excellent	Class II

A2: anterior cerebral artery second segment, ACoA: anterior communicating artery, BA: basilar artery, F: female; M: male, M2: middle cerebral artery second segment, MCA: middle cerebral artery, PCA: posterior cerebral artery.

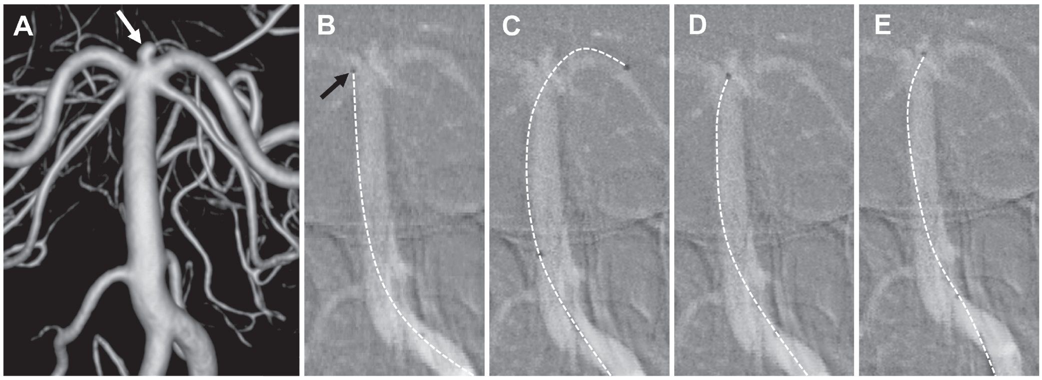

Fig. 3 Illustrative Case 1: A ruptured small basilar artery tip aneurysm
Fig. 3A: Preoperative three-dimensional rotational angiogram. Basilar artery tip aneurysm is observed (white arrow).
Fig. 3B: SL-10 straight microcatheter is advanced toward the aneurysm. However, the catheter tip guided to the right side against the aneurysm neck (black arrow).
Fig. 3C: SL-10 microcatheter is guided to the left posterior cerebral artery, and kept for 5 minutes in order to ensure an enough time for endovascular shaping.
Fig. 3D: SL-10 microcatheter is pulled to the basilar artery. The tip of SL-10 microcatheter is bent toward the left posterior cerebral artery.
Fig. 3E: SL-10 microcatheter is smoothly cannulated into the aneurysm by simple push motion.

Table 2 Newly acquired bend angle of the SL-10 straight microcatheter tip after endovascular shaping in the artificial vascular model

Inserted length[b] (cm)	Placement time[a] (min)		
	1	2	5
1.0	15°	19°	22°
1.5	15°	22°	24°
2.0	19°	25°	32°

[a] The time of the SL-10 straight microcatheter tip maintained inside the placement branch.
[b] The length of the SL-10 straight microcatheter tip inserted into the placement branch.

Results of the Artificial Vascular Model Validation

As a result of the vascular model validation (Table 2), the newly acquired bend angle of the SL-10 straight microcatheter tip depended on both: 1) the "length" of the catheter tip inside the placement branch, and 2) the "placement time" within the model. Accordingly, the newly acquired bend angle of the SL-10 straight microcatheter tip was proportionate to the placement length and time into the branch; the deeper the insertion or the longer the placement time, the larger the bend angle toward the placement branch.

DISCUSSION

Our results demonstrated that endovascular shaping is a feasible and safe method for small cerebral terminal-type aneurysm coiling. The endovascularly shaped SL-10 straight microcatheter acquired new bend angle of the catheter tip toward the placement branch in all 10 cases. The microcatheter cannulation into the aneurysm and the subsequent procedure were successfully achieved without any complications for all 10 patients treated.

Conventional In Vitro Steam Shaping

For successful coiling, an optimal catheter tip shape is an indispensable prerequisite for providing a stable catheter position, enabling proper placement of coils into the intracranial aneurysm.[1-5] Several methods for selection and shaping of the microcatheter used in an aneurysm coiling procedure have been described. Namba et al[4] reported that a three-dimensional printer was used to make a patient-specific vascular model that corresponded to the actual size of the patient's own vessels, and the shape of the microcatheter was determined from that model. However, as a major limitation, such vascular models are not hollow and cannot imitate the actual curves inside the patient's body. Yamaguchi et al[5] reported that the SL-10 straight microcatheter, placed in the patient's vessel for 5 minutes, acquired the actual shape of the patient's own vessel as a result of its thermoplasticity. In their study, 1) the SL-10 straight microcatheter was advanced to the site of the aneurysm, 2) the catheter was positioned through the neck of the aneurysm (the distance through the neck of the aneurysm was the same distance that the tip of the catheter needs to reach to be in the appropriate position within the aneurysm, after the tip of the catheter has been shaped with steam) and maintained for 5 minutes, 3) the catheter was pulled out and the acquired shape was compared with the shape obtained by three-dimensional rotational angiography of each patient, 4) the tip of the catheter was steam-shaped for optimal positioning within the aneurysm, and 5) the newly shaped catheter was reinserted and advanced toward the aneurysm.[5] They confirmed that each microcatheter trailed the long axis of the parent artery faithfully after intravascular placement. They applied this method to 15 cases and succeeded in guiding the microcatheter into the aneurysm in 13 cases. However, simple pull or push motions (excellent guiding) were used in only 5 of 13 cases and guidewire navigation (moderate guiding) in 8 of 13 cases. Their method had two technical limitations regarding reinsertion after the steam-shaped microcatheter: 1) straightening deformation of the microcatheter; and 2) a rotation problem of the microcatheter inside the patient's body. Abe et al[6] reported that the microcatheter lost its shape through a guiding catheter or during passing of microguidewire due to straightening deformation of the microcatheter; reinsertion of the in vitro steam-shaped microcatheter caused a microcatheter deformity. Moreover, the optimal shaping of the microcatheter could not be utilized effectively because reinsertion of the microcatheter triggered rotation of the microcatheter inside the patient's body.[5]

Novel In Vivo Endovascular Shaping

In the present study, all endovascularly shaped microcatheters were excellently guided into the aneurysm, and all aneurysms were successfully treated without re-shaping. In vivo endovascular shaping is a simple technique that utilizes the patient's body temperature and patient's own vascular configuration without an additional device or additional shaping outside the patient's body. Our method can complete microcatheter shaping only inside the patient's body; an endovascularly shaped microcatheter will never face a straightening deformity and rotation problems of the microcatheter. Moreover, the endovascular shaping can shape not only the microcatheter tip in the intended direction, but also longitudinal axis of the microcatheter depending on the actual parent artery, which contributed to microcatheter stability during the procedure. Therefore, our method can provide accurate shaping and stability during microcatheter cannulation into the aneurysm and the subsequent procedure in aneurysm coiling.

Yamaguchi et al[5] reported that the SL-10 straight microcatheter was easily shaped using intravascular placement and a newly acquired angle stabilized after 5 minutes. We also applied

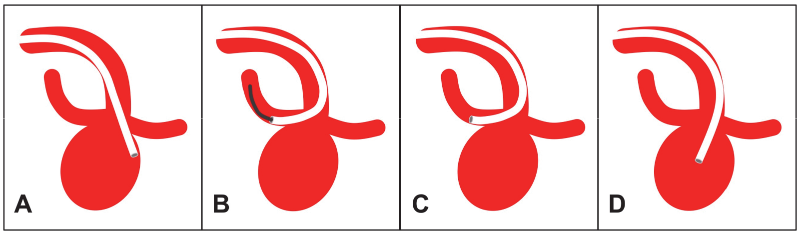

Fig. 4 The correction method of the microcatheter tip inside the aneurysm using endovascular shaping
Fig. 4A: The microcatheter tip inside the aneurysm is at an inappropriate position.
Fig. 4B, 4C: The microcatheter is advanced to the placement branch, and kept for 5 minutes to establish endovascular shaping.
Fig. 4D: The microcatheter is shifted proximally into the aneurysm. The microcatheter tip is located at the center of the aneurysm.

a SL-10 straight microcatheter and 5-minute shaping time for endovascular shaping. In the case of excessive bending of the microcatheter with endovascular shaping, the tip shape may be corrected to some extent with intentional straightening by passing the microguidewire into the shaped microcatheter. When the microcatheter inside the aneurysm is in an inappropriate position, the microcatheter tip can be moved in the intended direction using endovascular shaping (Fig. 4).

Newly Acquired Bend Angle of the Microcatheter Tip after Endovascular Shaping

In our clinical experience, the endovascular shaping acquired new bend angle of the microcatheter tip up to 26° angle, approximately equal to the validation experiment. Our artificial vascular model validation supports our clinical results regarding newly acquired bend angle of the microcatheter tip after endovascular shaping.

Limitations

First, the number of aneurysms treated was small and drawing a solid conclusion was limited. Second, our study was based on a SL-10 straight microcatheter only and may not be applicable to other microcatheters with different features or pre-shaped microcatheters. Third, our method cannot be applied to the patients without any placement branch that runs to the intended direction. Fourth, our method should not be applied to avoid arterial injury and ischemic events when the placement branch is narrow or tortuous. Fifth, when a neck-bridge stent is already deployed, this method cannot be effectively carried out. Sixth, it is challenging to accurately predict the bend angle of the microcatheter with our method because the angle between the placement branch and the parent artery and the diameter of the branch are different in each case. Finally, assessment of microcatheter stability was a subjective judgment and may suffer from bias.

CONCLUSIONS

Based on our initial experience, in vivo endovascular shaping was a feasible and safe method for small cerebral terminal-type aneurysm coiling. Our method can move the microcatheter tip in the intended direction without straightening deformity and rotation problem associated with microcatheter reinsertion. An endovascular shaping technique can provide accurate shaping and stability during small aneurysm coiling procedure.

CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

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