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Original Article

Utility of a Steerable Microcatheter for the Selective Transvenous Embolization of Dural Arteriovenous Fistulas

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Objective: Selective transvenous embolization (sTVE) is an effective technique for treating dural arteriovenous fistulas (DAVFs); however, selective catheterization into the shunted pouch is often difficult due to the acute angle of the access route between the target pouch and dural sinus. We present our initial experience using a steerable microcatheter (SM) to manually control the tip angle for selective catheterization and sTVE of DAVFs.

Methods: Thirteen consecutive cases of DAVFs and 16 procedures that involved sTVE using SM between October 2016 and October 2018 were reviewed. SMs were used for selective catheterization of shunted venous pouches and/or the affected sinus and coil embolization. We evaluated the maneuverability of the SM, the success of selective catheterization into the target lesions, and the results of endovascular treatments.

Results: Endovascular procedures were performed in a single session in 10 cases and in two staged sessions in 3 cases. There was no difficulty in maneuverability of the SM. Successful selective catheterization was achieved in 26 of 27 target lesions. Immediately after embolization, angiography showed complete occlusion in 10 cases and marked reduction in 3 cases. During 40.9 months of mean follow-up, 12 cases showed complete occlusion and one case showed a small residual shunt on MRI. Procedure-related complications of spontaneous thrombosis of the affected sinus were observed in one case. There were no cases of recurrence or exacerbation during follow-up.

Conclusion: SM is useful for selective catheterization for target lesions during sTVE of DAVFs.

Keywords ▶ dural arteriovenous fistula, transvenous embolization, transarterial embolization, steering microcatheter

Introduction

Selective transvenous embolization (sTVE) is an effective technique for the treatment of dural arteriovenous fistulas (DAVFs).[1)] It allows occlusion of the DAVF with preservation of the dural sinuses. However, selective catheterization into the target shunted pouch is often difficult due to the acute angle of the access routes, particularly for small target lesions from a large dural sinus. In such cases, it is thus necessary to adequately shape the tip of the microcatheter or guiding catheter with heat for successful catheterization. However, adequately shaping the tip for each shunted pouch is sometimes difficult and time consuming. Furthermore, DAVFs usually have multiple shunted pouches.

The steerable microcatheter (SM) (SwiftNINJA; Sumitomo Bakelite, Tokyo, Japan), which was developed in 2014,[2)] has a remote-controlled flexible tip and two steering wires located diagonally in the catheter wall from the handle to the distal tip (**Fig. 1A** and **1B**). Tension is applied to either one of the wires by turning the steering dial for manipulation of the tip direction. Once the direction of the steerable tip is determined, the steering dial lock is used to maintain the intended direction. Four sizes of the SM are available (tip/shaft: 2.4/2.9F, 2.0/2.4F, 2.4/2.6F, and 2.9/2.9F). A high-flow type (2.9/2.9F) is available as a double coaxial

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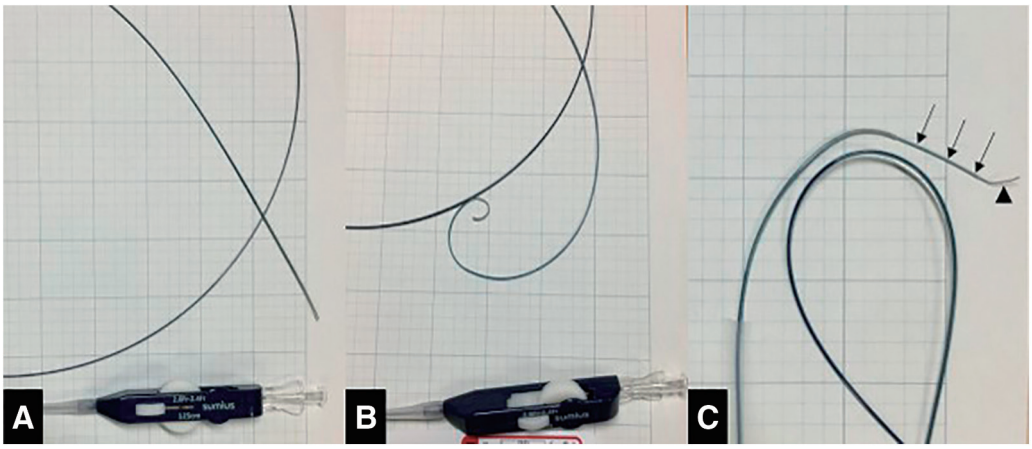

Fig. 1 The flexibility of the SM. (**A**) Normal state. (**B**) Tip movement. (**C**) The picture shows that a 1.9F microcatheter (black arrowhead) is inserted into a 2.9F SM (black arrows). SM: steerable microcatheter

microcatheter system with a 1.6F or 1.9F microcatheter (**Fig. 1C**). The SM has been approved for endovascular treatment during neuroendovascular procedures in Japan.

There are some reports of the clinical use of SM in abdominal intervention.[2–5] However, there are no reports of using an SM for the sTVE of DAVFs. Here, we describe our initial experience on using the SM for sTVE of DAVFs.

Material and Methods

The research described herein was approved by the Ethics Institutional Review Board of Oita University. We retrospectively reviewed 13 consecutive patients with DAVFs treated with sTVE using the SM at our institutions from October 2016 to October 2018. Among the 13 patients, 10 patients were treated in a single session and 3 patients were treated in two-staged sessions; the 16 total procedures were retrospectively reviewed in this study. The clinical findings of the 13 patients are summarized in **Table 1**. There were 8 females and 5 males, and the age ranged from 49 to 83 years (mean age, 70.2 years). Symptoms included pulsatile tinnitus in 7 patients, headache in 2 patients, and hyperemia, chemosis, and epilepsy in one patient. Locations of DAVFs were transverse-sigmoid sinus in 9 patients, cavernous sinus in 3 patients, and superior petrosal sinus in one patient. The SMs were used for selective catheterization for shunted venous pouches and/or the isolated sinus involved by DAVFs. In this study, a high-flow-type SM (2.9/2.9F) or a standard type SM (2.4/2.6F) was used. We evaluated the maneuverability of the SM and the success of selective catheterization into the target legions and results of endovascular treatments.

Results

The surgeons did not experience any difficulty in maneuverability of the SM, and there were no complications such as vessel injury. A high-flow-type microcatheter was used with a coaxial 1.6 or 1.9F microcatheter (Marvel; Tokai Medical Products, Aichi, Japan) in 12 procedures. A standard type was used in 4 procedures. SMs were used for selective catheterization and embolization in the shunted venous pouches in 14 procedures (**Fig. 2A**–**2F**), and it was used to cross the acute angle of the junction of the affected sinuses, including the torcular or jugular–sigmoid junction, in 2 procedures (**Fig. 3A**–**3F**). In the 2 cases using the standard-type SM, although SM was useful for successful navigation to the shunted pouch over the acute angle, microcatheter exchange to a coaxial system was required for further selective navigation to the shunted pouch.

In 26 of 27 target legions, successful selective catheterization was achieved, which included navigation into 24 of 25 shunted pouches and both affected sinuses with anatomical difficulty. One of the shunted pouches failed to undergo selective transvenous catheterization, and it was occluded by additional transarterial embolization with an n-butyl-2-cyanoacrylate–lipiodol mixture. Angiography immediately after embolization showed complete occlusion of the DAVFs in 10 patients and marked reduction in DAVFs without cortical venous reflux in 3 patients. There were no complications during endovascular procedures. One post-procedural complication of spontaneous sinus thrombosis with asymptomatic cerebral hemorrhage was observed a few days after sTVE in one patient. Among the 13 patients, two patients who obtained complete occlusion of DAVFs

Table 1 Result of endovascular treatment

Case	Age/ Sex	Locations	Symptoms	Type of SM	Purpose for using SM	Target lesions	Selected legions	Successful catheterization	Treatment	Immediate results	Complication	Follow-up results and periods (months)
1	68/F	CS	Hypermia	High flow	SC	3	3	Success	TVE	CO	No	CO MRI (48)
2	70/F	TSS	Pulsative tinnitus	Standard	SC	3	3	Success	TVE + TAE	MR	No	CO MRI (54)
				High flow	SC			Success	TVE	CO	No	
3	76/F	TSS	Headache	Standard	AI	1	1	Success	TVE	CO	No	CO MRI (11)
4	78/F	TSS	Pulsative tinnitus, dizziness	Standard	SC	2	2	Success	TVE + TAE	MR	No	Stable MRI (59)
				High flow	SC			Success	TVE + TAE	MR	No	
5	77/F	TSS	Pulsative tinnitus	Standard	SC	1	1	Success	TVE + TAE	MR	No	CO MRI (4)
6	58/F	SPS	Headache	High flow	SC	2	2	Success	TAE + TVE	MR	No	CO MRI (6)
7	73/F	TSS	Pulsative tinnitus	High flow	SC	3	3	Success	TAE + TVE	MR	Hemorrhage	CO MRI (55)
8	71/M	TSS	Pulsative tinnitus	High flow	SC	3	2	Success	TAE + TVE	MR	No	CO MRI (56)
				High flow	SC			Success	TVE + TAE	CO	No	
9	80/F	CS	Epilepsy	High flow	SC	1	1	Success	TVE	CO	No	CO MRI (50)
10	83/M	CS	Chemosis	High flow	SC	2	2	Success	TVE	CO	No	CO MRI (27)
11	49/M	TSS	Pulsative tinnitus	High flow	SC	2	2	Success	TAE + TVE	CO	No	CO MRI (60)
12	60/M	TSS	Pulsative tinnitus	High flow	SC	3	3	Success	TVE + TAE	MR	No	CO MRI (40)
13	70/M	TSS	Pulsative tinnitus	High flow	AI	1	1	Success	TVE + TAE	MR	No	CO MRI (62)

AI: approach into the isolated sinus; CO: complete occlusion; CS: cavernous sinus; MR: marked reduction; SC: selective catheterization; SM: steerable microcatheter; SPS: superior petrosal sinus; TAE: transarterial embolization; TSS: transverse sigmoid sinus; TVE: transvenous embolization

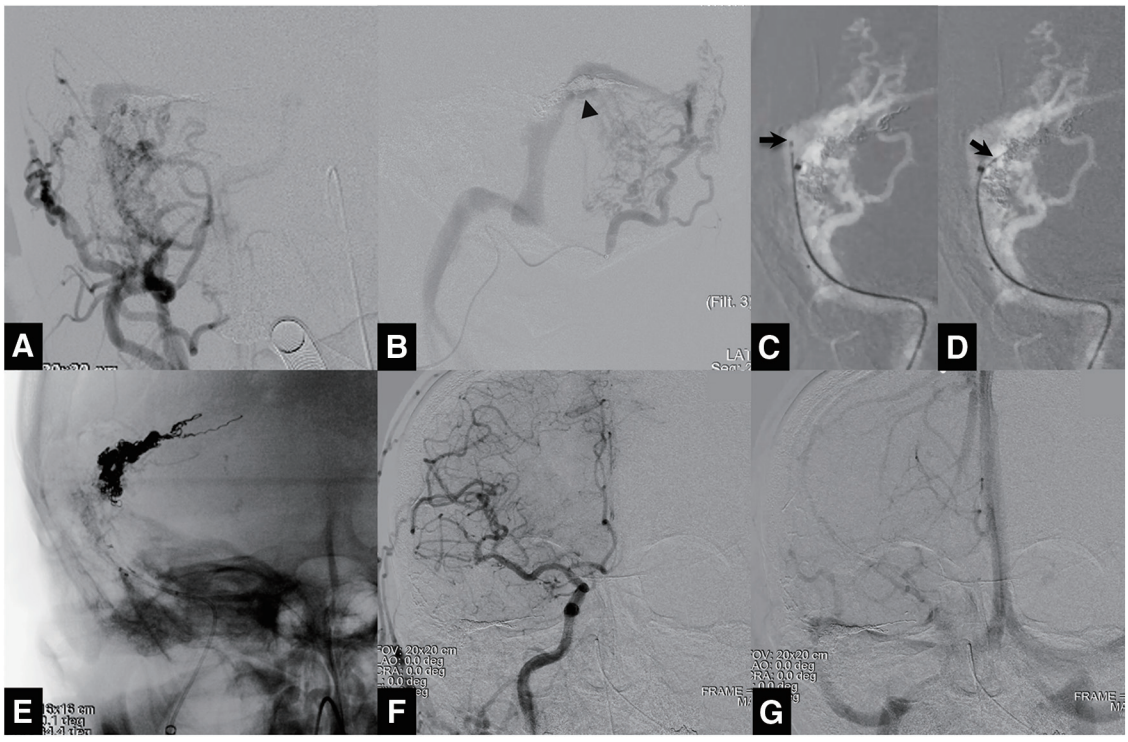

Fig. 2 A case of selective catheterization for shunted venous pouch with an SM. (**A**) Frontal view of an angiogram of the right external carotid arteriography shows right TSSDAVF. (**B**) Lateral view of an angiogram of the right occipital angiography shows shunted venous pouch near the coil mass (black arrowhead). (**C** and **D**) These images show the tip movement of the SM (black arrows). The SM is inserted to target shunted venous pouch. (**E**) Posttransvenous and arterial embolization. (**F** and **G**) Postprocedural right common carotid arteriography shows complete occlusion of TSSDAVF with preservation of the dural sinus. SM: steerable microcatheter; TSSDAVF: transverse–sigmoid sinus dural arteriovenous fistula

immediately after embolization were lost to follow-up. In the remaining 11 patients, complete occlusion was observed on follow-up angiography or MRA in 10 patients and a small stable remnant of DAVF was noted in one patient.

Illustrative case

Case 1 was a 76-year-old man who presented with right pulsatile tinnitus. Cerebral angiography revealed a Borden type 1 right transverse–sigmoid sinus dural arteriovenous fistula (TSSDAVF) (**Fig. 2A** and **2B**). Staged endovascular treatment was subsequently performed. In the first session, reduction of shunt flow was achieved by sTVE and transarterial embolization. In the second session, under general anesthesia, a 5F guiding sheath (Axcelguide; Medikit, Tokyo, Japan) was introduced from bilateral femoral veins into right internal jugular vein. A 4.2F distal access catheter (Fubuki; Asahi Intecc, Aichi, Japan) and the coaxial system of a 1.7F microcatheter (Headway17; Terumo, Tokyo, Japan) were inserted into the 5F guiding sheath of the right femoral vein. The high-flow-type SM and the coaxial system of a 1.9F microcatheter (Carnelian MARVEL; Tokai Medical Products) were inserted into the 5F guiding sheath of the left femoral vein. The target lesion was located near the coil mass; therefore, selective cannulation was difficult. However, manipulating the tip angle of the SM (**Fig. 2C** and **2D**) enabled catheterization into the target. Subsequently, transvenous embolization and transarterial embolization were performed. Finally, the right common carotid angiography after embolization confirmed the disappearance of the DAVF (**Fig. 2F** and **2G**).

Case 2 was a 70-year-old man who presented with right pulsatile tinnitus. The patient had undergone endovascular treatment for a Borden type 3 left TSSDAVF 6 years earlier, and a repeat treatment was planned for a recurrent lesion. Cerebral angiography revealed Borden type 3 left TSSDAVF with isolated sinus and cortical venous reflux (**Fig. 3A**). In the first procedure, coil packing the left transverse sinus had been performed. Therefore, the present treatment required an approach to the isolated sinus via torcular Herophili for sTVE. Under general anesthesia, a 5F guiding sheath (Axcelguide) was introduced from bilateral femoral veins into right internal jugular vein. A 4.2F distal access catheter (Fubuki) and the triple coaxial system of a 1.9F microcatheter (Carnelian MARVEL) through

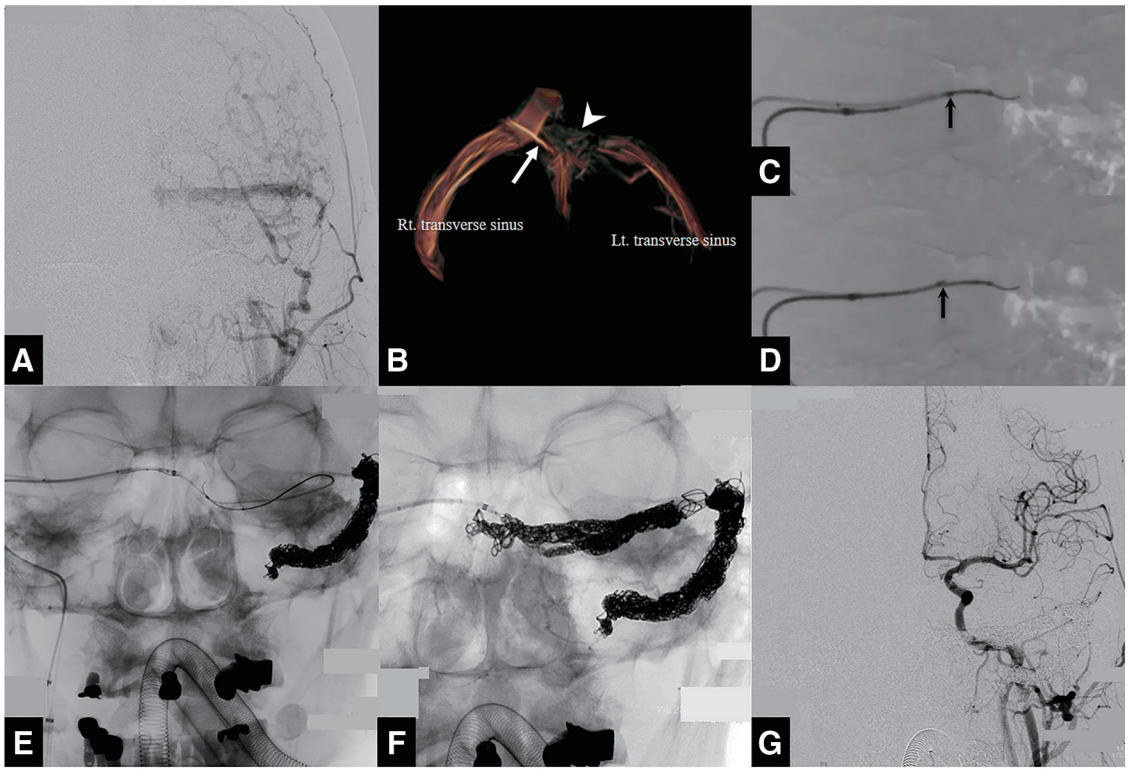

Fig. 3 A case of approach into the isolated sinus with the SM. (**A**) Frontal view of an angiogram of the left external carotid arteriography shows Borden type 3 TSDAVF. (**B**) 3D volume rendering (superior view) of the gadolinium-enhanced MR image shows the narrow access route from rt. TS to lt. TS (white arrow) and occlusion of the lt. TS due to thrombosis (white arrowhead). (**C** and **D**) These images show the tip movement of the SM (black arrows). (**E**) Intraoperative image shows that a 1.9F microcatheter is navigated to the isolated sinus. (**F**) Posttransvenous coil embolization. (**G**) Postprocedural left external carotid arteriography shows complete occlusion of TSDAVF. lt.: left; rt.: right; SM: steerable microcatheter; TS: transverse sinus; TSDAVF: transverse–sigmoid sinus dural arteriovenous fistula

the high-flow-type SM were inserted into the 5F guiding sheath of the right femoral vein. A 3.2F distal access catheter (TACTICS; Technocrat, Aichi, Japan) and a coaxial system of a 1.7F microcatheter (SL-10; Stryker, Kalamazoo, MI, USA) were inserted into the 5F guiding sheath of the right femoral vein. First, a 1.7F microcatheter was used to cannulate the isolated sinus via the sinus confluence, although it was difficult due to stenosis of access route. However, by adjusting the angle of the tip of the steering catheter, catheterization into the isolated sinus was achieved (**Fig. 3B** and **3C**). Subsequently, directly packing the isolated sinus using the turn-back embolization technique was performed (**Fig. 3D** and **3E**). Finally, complete occlusion of the TSSDAVF was achieved (**Fig. 3F**).

Discussion

The SM is the first commercially available catheter that can be used clinically. It was developed by Sumitomo Bakelite for effective performance of selective angiography, selective arterial infusion chemotherapy, and selective transarterial embolization.

In this study, there was no difficulty in using SM and there was no microcatheter-related complications. Inaba et al.[3] reported one case of failure of tip movement during a procedure due to breakage of the operating lines within the catheter wall. However, in their report, there were no severe complications of SM. They also reported that the mean success rate for insertion into target vessels was 99.2% per patient. In the present study, the success rate for selective catheterization into the target lesion was 96.3%, including 96% for shunted pouches and 100% for the affected sinuses. Regarding the field of neurointervention, Harmon et al.[4] reported a case of mechanical thrombectomy for acute ischemic stroke with SM. They used the SM to cross a thrombus within the middle cerebral artery without using a guidewire. In our study, there were two cases in which an SM was inserted into an isolated sinus with an acute angle at the junction with the affected sinuses. Therefore, we believe that the controllable tip of the SM is useful for transvenous

catheterization for some cases of DAVF with challenging anatomy characterizing the access route. Although some investigators reported[3–5] that the guidewireless technique is useful, all procedures in this study were performed with the guidewire technique because we do not feel that the guidewireless procedure is adequate for selective catheterization into the small shunted pouches from the large sinus lumen.

A high-flow SM has not been reported previously. In this study, in 12 of 16 procedures, a high-flow-type SM was used. A high-flow-type microcatheter has an advantage over a standard-type SM for sTVE. A 1.6F or 1.9F nontapered microcatheter can be inserted through the high-flow-type SM, which allowed us to navigate a 1.6 or 1.9F microcatheter more distally to the shunt point with a coaxial microcatheter system. It is important for effective embolization of DAVFs to navigate a microcatheter as distally to the shunt points as possible through a very narrow and tortuous vessel. In 2 procedures in our study, a standard-type SM was used for selective catheterization for shunted pouches, but in both cases, catheter exchange was required for further distal navigation of the microcatheter to the shunt point because the SM did not follow a microguidewire.

There are several limitations in this study. First, this study included a relatively small number of cases without random controls. Second, it is difficult to compare the procedure time with an SM and that with a standard catheter because the locations and number of target lesions strongly affecting the procedural time are different in each case.

Conclusion

The SM is a useful and safe device for selective catheterization into the target lesions in sTVE for DAVFs.

Disclosure Statement

The authors declare that they have no conflicts of interest.

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