A New Microcatheter System for Endovascular Treatment of Cerebral Arteriovenous Malformations

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A new microcatheter system was used for diagnostic and therapeutic purposes in three cases of arteriovenous malformation. This microcatheter is used with a steerable guidewire and provides high selectivity of the target vessels and greater catheter maneuverability than does balloon catheters. Tissue adhesive was safely injected for the therapeutic embolization in two of the cases. With this system, however, the utmost attention is necessary to prevent reflux of the tissue adhesive and to avoid lacerating the feeding vessels with the guidewire. This microcatheter system was found to be very useful for diagnostic and therapeutic procedures in endovascular treatment of cerebral arteriovenous malformations.

KEY WORDS: Arteriovenous malformation; Embolization; Microcatheter; Tissue adhesive

Introduction

With the recent advances in microcatheters and steerable guidewires, balloons and embolic materials, and digital subtraction angiography (DSA), as well as technical refinements in endovascular surgery, there has been a revolution in therapeutic strategies for cerebral arteriovenous malformations (AVMs). At the present time, management of cerebral AVMs is usually through surgical excision, endovascular embolization, or a combination of both. Within 2 months after this new microcatheter system became commercially available in Japan, we treated three cases of cerebral AVM. In this report we present these three cases and discuss the utility of this new microcatheter system.

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Materials and Methods

A new microcatheter system (Tracker-18 infusion catheter vascular access system, Target Therapeutics Inc., Los Angeles, CA) was used in three cases of cerebral AVM (one woman and two men). The AVMs in this series were located at the genu of the corpus callosum, in the right occipital lobe, and at the left basal ganglia. The microcatheter used (135 cm) has a graded shaft stiffness ranging from a flexible distal shaft (2.2 Fr., 12 cm) to a semi-rigid proximal shift (3.0 Fr., 123 cm) and has a highly visible radiopaque tip (2.7 Fr.). The microcatheter also has low surface friction, thus allowing easy passage of a torque guidewire. The steerable guidewire used (175 cm) has a strong proximal shift (0.016 in., 163 cm) and a shapeable, floppy atraumatic tip (0.013 in., 12 cm). The microcatheter was used coaxially through a 6.5 Fr. Headhunter catheter (Cook Inc., Bloomington, IN), which was selectively inserted into the appropriate internal carotid artery or vertebral artery through a transfemoral route under local anesthesia. The whole system between the microcatheter and the guidewire and between the guiding catheter and the microcatheter was continually flushed with heparinized saline using two Tuohy-Borst adaptors with pressure bags. Systemic heparinization was not performed because it might facilitate rebleeding from the AVM. Even without systemic heparinization, the possibility of thromboembolic complications associated with coaxial catheters and the guidewire was minimized by continuous flushing with heparinized saline. The microcatheter system was used for a number of purposes: (1) superselective angiography, (2) presurgical embolization, and (3) staged therapeutic embolization for a surgically inaccessible, deep seated AVM. The embolic material used was

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N-butyl-2-cyanoacrylate (NBCA, Histoacryl blue, B. Braun Melsungen AG, West Germany). Ethyl ester of iodinated poppy-seed oil fatty acids (Lipiodol Ultra-Fluide, Laboratoires Guerbet, France) was the oil contrast medium used for opacification of NBCA and for prolonging its polymerization time. Polymerization of NBCA was deliberately designed to occur at the nidus of the AVM rather than proximal or distal to the nidus, by changing the mixing ratio of NBCA and Lipiodol. The basic mixing ratio of 1 : 1 was occasionally modified in consideration of the transit time of the contrast medium through the AVM as demonstrated by DSA.

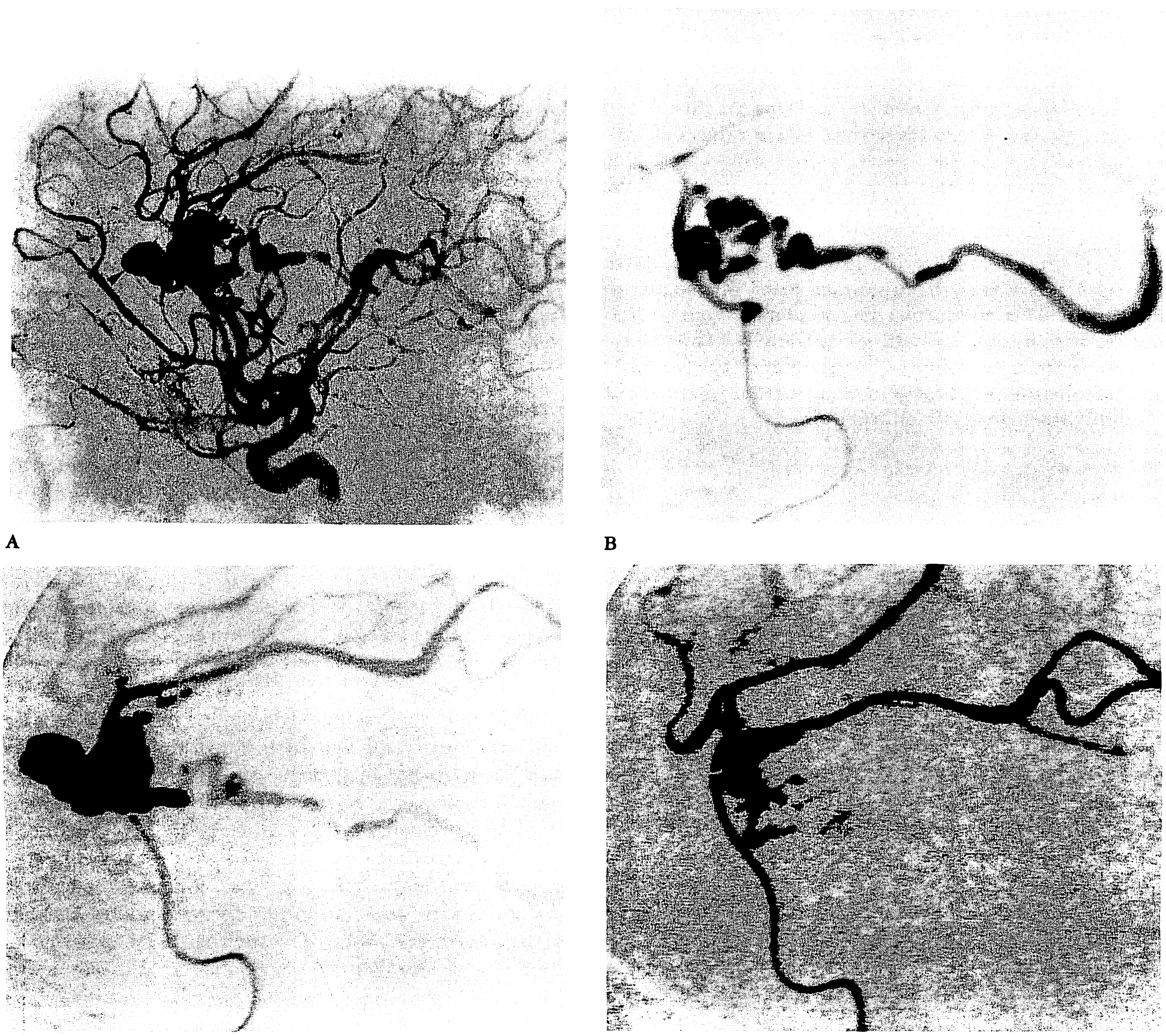
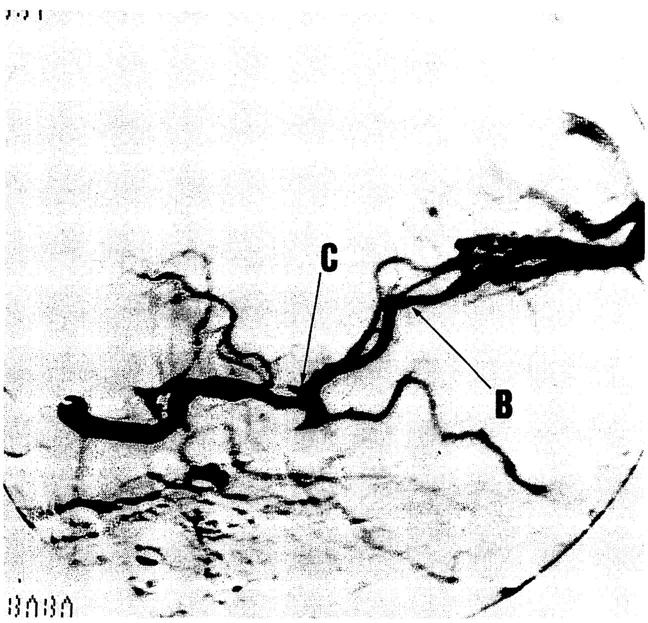


Figure 1. *A 42-year-old man with an AVM at the genu of the corpus callosum.* **(A)** *Left internal carotid artery angiogram. Even with subtracted stereoscopic films, it was impossible to depict each feeder and the neck of the aneurysm (arrowhead) and their relationship to each other. The small aneurysm (arrow) at the origin of the proximal feeder from the left anterior cerebral artery was missed during superselective angiography. The arrowhead indicates the large aneurysm, which originates from the left anterior cerebral artery.* **(B)** *The proximal feeder was catheterized. As it was impossible to navigate the catheter tip distally, embolization was not carried out for fear of reflux of the tissue adhesive to the anterior cerebral artery. There is a small aneurysm visible at the tip of the catheter. Drainage is to the internal cerebral vein and to the great vein of Galen.* **(C)** *The catheter tip is in the left anterior cerebral artery, immediately proximal to the neck of the large aneurysm. The nidus of the AVM is near the aneurysm.* **(D)** *The catheter tip is immediately distal to the neck of the large aneurysm. A small feeder to the nidus is visible.*



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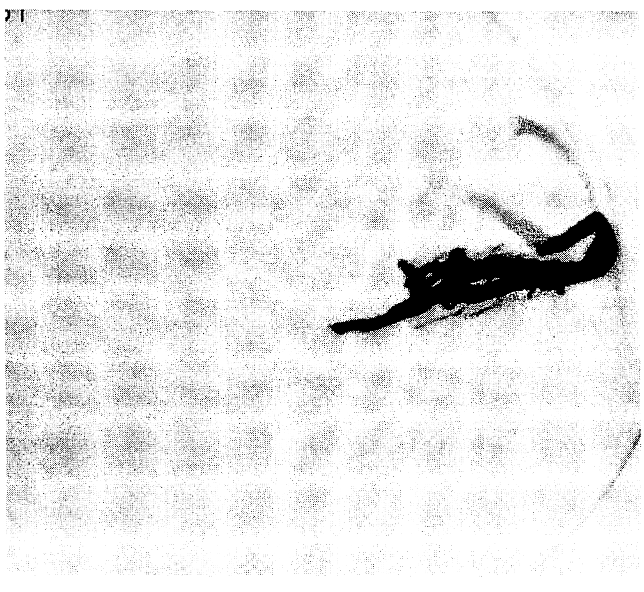

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Figure 2. *A 33-year-old man with a right occipital AVM.* **(A)** *The tip of the catheter is located in the P1 portion of the right posterior cerebral artery. The location of the tip of the catheters in* **B** *and* **C** *are marked as* B̲ *and* C̲, *respectively.* **(B)** *The catheter was advanced into the feeder of the AVM. At this location of the catheter tip, embolization with 0.1 and 0.05 ml of tissue adhesive (NBCA and Lipiodol mixture) was carried out.* **(C)** *This DSA shows the state immediately after embolization. The nidus has almost disappeared.*

Case Presentations

Case 1 (Figure 1)

A 42-year-old previously healthy man was brought to our clinic by ambulance after a sudden, severe headache and vomiting. On admission, he was almost alert and had no neurological deficit. Computed tomography (CT) revealed severe subarachnoid hemorrhage and a hematoma at the genu of the corpus callosum as well as ventricular hemorrhage. Immediately after CT examination, he suddenly became comatose with anisocoric pupils, and underwent controlled ventilation through endotracheal intubation. Cerebral angiography with superselective catheterization was subsequently performed. Angiography revealed an AVM at the corpus callosum, of which the three main feeders originated from the distal part of the left anterior cerebral artery, and there was a large aneurysm proximal to the origin of the callosomarginal artery. Since it was impossible to catheterize each feeder deep enough to inject the tissue adhesive without reflux, embolization was not performed. Bilateral ventricular drainage was carried out following angiography. The anatomical information obtained by superselective angiography was vital for operative planning. Thirteen days later, total removal of the AVM and clipping of the large aneurysm were successfully carried out.

During the operation, a small aneurysm that had been missed during superselective angiography was noted at the origin of the most proximal feeder; it also was clipped. There had been some chance that this small aneurysm could have been punctured by the 0.016-inch guidewire during selective catheterization of the feeder. The preoperative and postoperative neurological status was almost the same as a vegetative state, and there has been no improvement. Follow-up angiography showed complete disappearance of the AVM and successful clipping of the aneurysms.

Case 2 (Figure 2)

A 33-year-old previously healthy man was brought to our clinic by ambulance after a sudden headache. On admission, he was somnolent with isocoric reactive pupils but had no apparent motor weakness. The visual field could not be examined because of decreased consciousness. Computed tomography showed a large hematoma in the right occipital region measuring 4 × 5 × 5 cm, with ventricular hemorrhage.

Cerebral angiography was carried out immediately after CT examination and showed an AVM fed by the right posterior cerebral artery. A microcatheter was introduced into the proximal portion (P1) of the right posterior cerebral artery through the basilar artery, while a guiding catheter was placed in the left vertebral artery (Figure 2 *A*). The microcatheter was then further advanced distally. There was one main feeder from the distal portion of the posterior cerebral artery (Figure 2 *B*). Embolization was carried out with a 0.1- and 0.05-ml mixture of NBCA and Lipiodol. Postembolization DSA showed that the AVM had almost disappeared (Figure 2 *C*). The hematoma was so large that surgery was performed immediately after embolization. The hematoma and the AVM were completely removed. Intraoperatively, the draining veins on the occipital cortical surface were dark blue, not red in color or even very distended. This was probably due to diminished blood flow caused by embolization. One month later, the patient was alert and only left homonymous hemianopia remained. Follow-up cerebral angiography showed complete disappearance of the AVM.

Case 3 (Figure 3)

A 20-year-old woman without any notable past history experienced sudden right hemibody numbness. Computed tomography showed a hematoma measuring 2 × 3 × 3 cm at the left basal ganglia, and cerebral DSA revealed a left basal ganglia AVM. The patient was conservatively treated at another clinic and discharged without any neurological deficit. One month later, however, she suddenly developed disturbance of consciousness and right hemiparesis and was transferred to our clinic. On admission, she was comatose and her pupils were anisocoric (right < left) and not reactive to light. Computed tomography revealed a large hematoma measuring 4 × 5 × 5 cm at the left basal ganglia, extending to the midbrain. Rupture of the hematoma into the left lateral ventricle was also noted. Bilateral ventricular drainage was performed immediately after CT examination.

One week later, cerebral angiography was carried out, but the feeders could not be precisely depicted even on subtracted stereoscopic films (Figure 3 *A*). Superselective angiography was then performed, which revealed two main feeders originating from the distal portion of the left internal carotid artery (Figure 3 *B*).

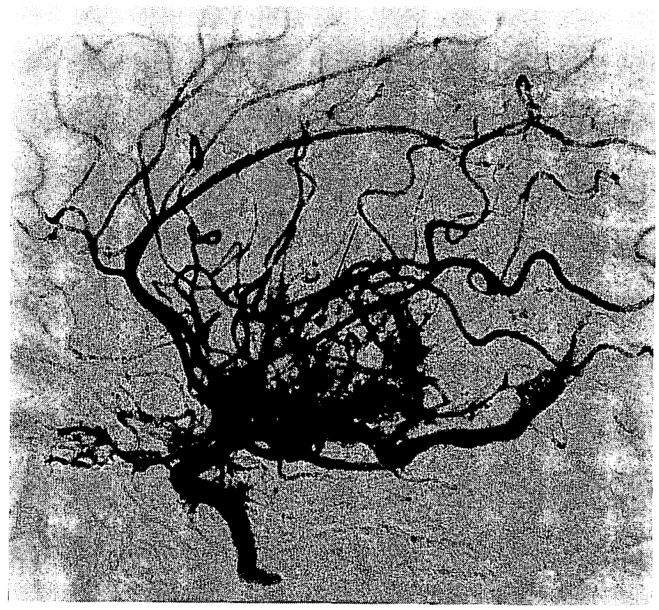

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Figure 3. *A 20-year-old woman with a left basal ganglia AVM.* **(A)** *Left internal carotid angiogram. It is almost impossible to depict the feeders to the AVM even with subtracted stereoscopic films. Drainage is to the left basal vein of Rosenthal. The arrow indicates a small aneurysm at the distal part of the perforating artery.* **(B)** *This proximal feeder originates from the distal portion of the internal carotid artery. The nidus shown here was completely embolized with 0.1 and 0.2 ml of tissue adhesive (NBCA and Lipiodol mixture) in the first embolization.* **(C)** *This distal feeder also originates from the distal portion of the internal carotid artery and is slightly distal to the feeder shown in* **B**. *At the second embolization, 1 week after the first embolization, this nidus was partially embolized with 0.15 ml of tissue adhesive.* **(D)** *Left internal carotid angiogram after the second embolization. The small aneurysm has disappeared, probably as a result of spontaneous thrombosis. The reduced blood flow in the drainage vein is faintly visualized (arrowheads).* **(E)** *Computed tomography scan after the second embolization. The high-density substance (arrowheads) mainly visible in the nidus is the tissue adhesive mixed with Lipiodol. The hematoma (H) at the left basal ganglia still has a moderately high density.*

First, the nidus fed by the distal feeder was embolized through the microcatheter with a 0.1- and 0.2-ml mixture of NBCA and Lipiodol. The tissue adhesive spread widely throughout the nidus and slightly to the left internal cerebral vein. Postembolization DSA showed that the nidus fed by this feeder had disappeared. One week after the first embolization, a second embolization was carried out. This time, DSA showed complete disappearance of the previously embolized nidus. Next, the nidus fed by the proximal feeder was partially embolized with 0.15 ml of the same tissue adhesive (Figure 3 *C*). Postembolization DSA showed decreased blood flow in the draining vein (Figure 3 *D*). Two months after admission, the patient was alert and ambulatory, showing mild right hemiparesis and left oculomotor palsy (Weber syndrome). One more embolization with the tissue adhesive or particulate emboli was scheduled for 6 months later.

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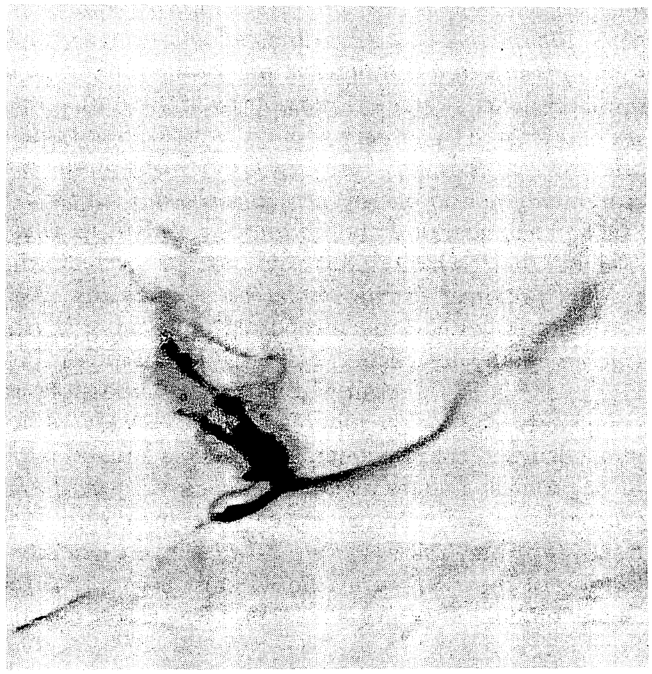

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Discussion

The information obtained from superselective angiography can be classified into (1) anatomical, (2) dynamic, and (3) functional information [7]. *Anatomical information* includes the contribution of the catheterized feeder to the AVM and the draining vein, the distance from the catheter tip to the nidus, and the normal branches distal to the catheter. *Dynamic information* is the transit time of the blood in the AVM, which is necessary for determining the appropriate polymerization time for the tissue adhesive. Reflux of the contrast medium into the parent artery is also important information. *Functional information* is usually obtained when amobarbital sodium is injected through the microcatheter and neurological deficits can be observed. Even for AVMs that are best treated by surgery without embolization, superselective angiography is useful for obtaining the aforementioned information to ensure safer surgery.

The ideal goal of embolization of AVMs is to safely occlude their whole nidus and not to occlude the feeders proximal to the nidus. To achieve this goal, tissue adhesives have been reported to be more advantageous than detachable balloons or particles [1]. However, it is frequently difficult or impossible to completely and safely embolize larger AVMs (those more than 2.0 cm in diameter). In such a situation, the most promising alternative is preoperative, partial embolization of the nidus, followed by complete surgical removal of the AVM [4]. We now believe that embolization of the AVM using liquid emboli and/or particulate emboli is principally a presurgical procedure, except for AVMs located in surgically inaccessible, critical sites, such as a basal ganglia or frontal motor area. Selection of the appropriate embolic materials is still open to discussion. We used only liquid emboli in this series since particulate emboli, such as polyvinyl alcohol (PVA) particles, were not available at that time. However, currently, we prefer PVA particles to liquid emboli since there is no chance for PVA particles to cause catheter gluing to the vessel wall, and particles are easier to handle than liquid emboli.

Superselective catheterization of feeders is possible by transvascular navigation of many different kinds of balloon catheters [2,3,5]. Thus far, however, only a calibrated leak balloon catheter can effectively deliver tissue adhesive into the nidus unless the feeder is cannulated directly at surgery.

This new microcatheter system is completely different from balloon catheters and gives the operator higher maneuverability and greater selectivity than do previously available catheter systems. A flow-guided catheter greatly depends on blood flow; this means that the direction of the catheter is decided mainly by preferential blood flow. If the destination of the catheter is an artery with low blood flow or there is a sharp angle to the proximal vessel, it is necessary to use a second balloon for occlusion of the other branch or to compress the contralateral carotid artery in the neck to change the flow pattern in order to navigate the balloon catheter to the target [5].

Although a calibrated leak balloon catheter prevents reflux of tissue adhesive to the proximal vessel, it is necessary to deflate the balloon completely when removing the catheter for fear of gluing its balloon to the vascular wall or embedding the balloon in the cast of the tissue adhesive. It takes a second or more to deflate the balloon completely, which increases the chance of gluing of the balloon. The new microcatheter can be removed more quickly than a balloon catheter. Since the inner diameter of this microcatheter is much larger than the hole of the calibrated leak balloon, it can deliver more contrast medium and tissue adhesive than the balloon catheter in the same time period. To carry out embolization using tissue adhesive, a small amount is injected several times. For repeated injection of tissue adhesive, it is desirable to keep the catheter tip in the same position near the target, which increases the chance of catheter gluing. This microcatheter can be kept in the same position under close observation with a DSA monitor, whereas the calibrated leak balloon is usually removed each time.

With this microcatheter, tissue adhesive and contrast medium as well as other emboli such as platinum microwires can be introduced into the target area [8]. This provides alternative options in interventional procedures, which is not the case with balloon catheters.

Although the total number of cases in which we have used this new microcatheter system, including other neoplastic cases, is rather limited, we have found that it can easily be inserted into the third or fourth branches of cerebral vessels, that is, the A3, M3, and P3 portions, and sometimes into even more distal portions. The anterior cerebral artery on the contralateral side can be approached through the ipsilateral anterior cerebral artery and anterior communicating artery. The posterior cerebral artery can be approached through the posterior communicating artery.

The more distal the tip of the microcatheter extends, the more friction occurs between the microcatheter and the guidewire. To reduce this friction, we use a continuous flush with heparinized saline between the microcatheter and the guidewire using a pressure bag. It is not advisable to use silicone oil to lubricate the microcatheter system because this usually increases friction. However, we do use silicone oil on the tip of the microcatheter to prevent the catheter from gluing to the vascular walls.

As shown in Case 1, there is some potential danger of puncturing the pathological vessel or an unexpected aneurysm with the guidewire. This possibility should always be kept in mind in order to prevent such a complication. The guidewire is very flexible in a direction perpendicular to its axis, but is not so flexible in the direction of its axis.

When a calibrated leak balloon is overdistended in the feeder of an AVM, there is danger of subarachnoid hemorrhage, followed by serious complications. With the new microcatheter system, there is no possibility of overdistention in the feeder.

Just as with a calibrated leak balloon catheter, a provocation test is easily performed with amobarbital sodium. This enables preembolization assessment of the critical regions, such as the frontal motor area, the speech area on the left side, the basal ganglia, and the internal capsule.

The DSA "road map" technique facilitates selective catheterization and a variety of interventional procedures, since it permits continuous observation of the catheter in relation to the intracranial vasculature [6]. Although we usually use a 6.5-Fr. torque-control guiding catheter, a catheter with a wider inner diameter such as a 7.0-Fr. thin-walled catheter is sometimes useful because contrast medium can be injected through the guiding catheter to make a "road map" while the microcatheter remains coaxially within the same guiding catheter.

In conclusion, the authors found this new microcatheter system to be very useful for the diagnostic and therapeutic procedures used for cerebral AVMs owing to the high maneuverability of the catheter system and high selectivity of the vascular architecture. With full understanding of the potential danger of reflux of the emboli and vascular laceration with the guidewire, this microcatheter system is likely to play an important role in the endovascular treatment of cerebral AVMs.

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