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Arteriovenous Malformation Nidus Catheterization with Hydrophilic Wire and Flow-Directed Catheter

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Summary: Arteriovenous malformation nidus catheterization with a flow-directed catheter at times can be difficult owing to tortuosity of the intracranial vasculature and distal location of the nidus. Since January 1995, hydrophilic wire has been used in conjunction with the 1.8F flow-directed microcatheter in over 150 vessel embolizations with cyanoacrylate glue for brain and spinal arteriovenous malformations at our institution. This technique has improved our success rate in achieving superselective catheterization of the nidus and has shortened the overall procedure time. To date, only one complication has occurred that was directly related to wire manipulation.

Index terms: Arteriovenous malformations, embolization; Catheters and catheterization, technique

Several techniques are used for embolization of arteriovenous malformations (AVMs), including solid polyvinyl alcohol (PVA) particles, alcohol, and liquid adhesives (1–14). Embolization with solid particles of PVA, either alone or in conjunction with alcohol or coils, is done extensively as a presurgical procedure (5, 11, 12, 14–16). Embolization of brain AVMs with cyanoacrylic glue has been performed for over a decade, but the technique has evolved tremendously as a result of the development of different glue formulations (17, 18) and advances in catheter and guidewire technologies (7, 8, 19–23).

All brain AVMs referred to our institution (including those that have not bled) are initially treated with *N*-butyl cyanoacrylate glue embolization (Histoacryl, Braun; Melsungen, Germany) with the final goal of treatment being permanent cure, with or without additional therapy, such as surgical resection or radiosurgery. The embolization procedure is performed under general anesthesia, with systemic heparinization if the AVM is less than 3 cm and hypotension (mean arterial pressure, 60 to 65 mm Hg) during cyanoacrylate glue injection. The flow-directed Balt (Montmorency, France) 1.8F Magic catheter (20) is the microcatheter most commonly used, and nidus embolization is performed with a 25% mixture of Histoacryl and ethiodized oil. A full-column flow-controlled injection technique is used, with injection times of up to 1 to 2 minutes.

Positioning of the microcatheter is crucial to the success of this embolization technique. Ideally, the tip of the Magic microcatheter is in a wedge position within the nidus of the AVM without proximal reflux of contrast material during the preembolization test injection. Difficulty in advancing the catheter frequently occurs as a result of tortuosity of the intracranial vasculature, a relatively small feeder, or decreased flow through the AVM caused by previous embolizations. Several maneuvers can be used to facilitate advancement of the flow-directed microcatheter in these situations, including augmentation of the blood pressure with Neo-Synephrine and intraarterial injection of papaverine through the microcatheter. However, in our experience, these methods have been used with only limited success.

Since January 1995 we have used the hydrophilic Terumo 0.010 wire (Terumo, Japan) in conjunction with the 1.8F Magic microcatheter for superselective catheterization of the AVM nidus in more than 150 separate feeders. This technique has improved our success rate in navigating distal tortuous feeding vessels and in selectively catheterizing the nidus of the AVM.

The purpose of this article is to describe in detail the technique of superselective catheterization of the nidus of brain AVMs with the Balt

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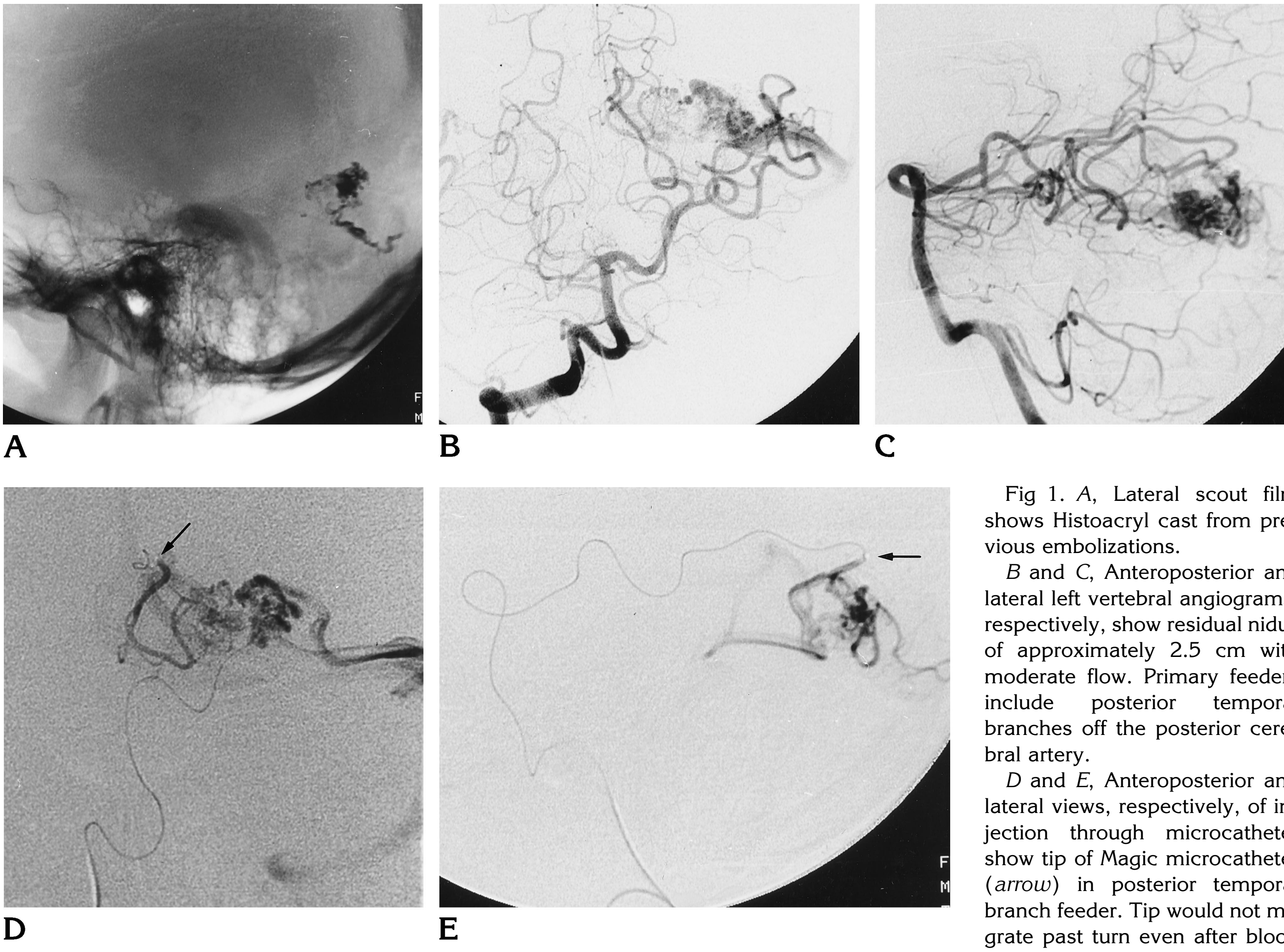


Fig 1. *A*, Lateral scout film shows Histoacryl cast from previous embolizations.

B and *C*, Anteroposterior and lateral left vertebral angiograms, respectively, show residual nidus of approximately 2.5 cm with moderate flow. Primary feeders include posterior temporal branches off the posterior cerebral artery.

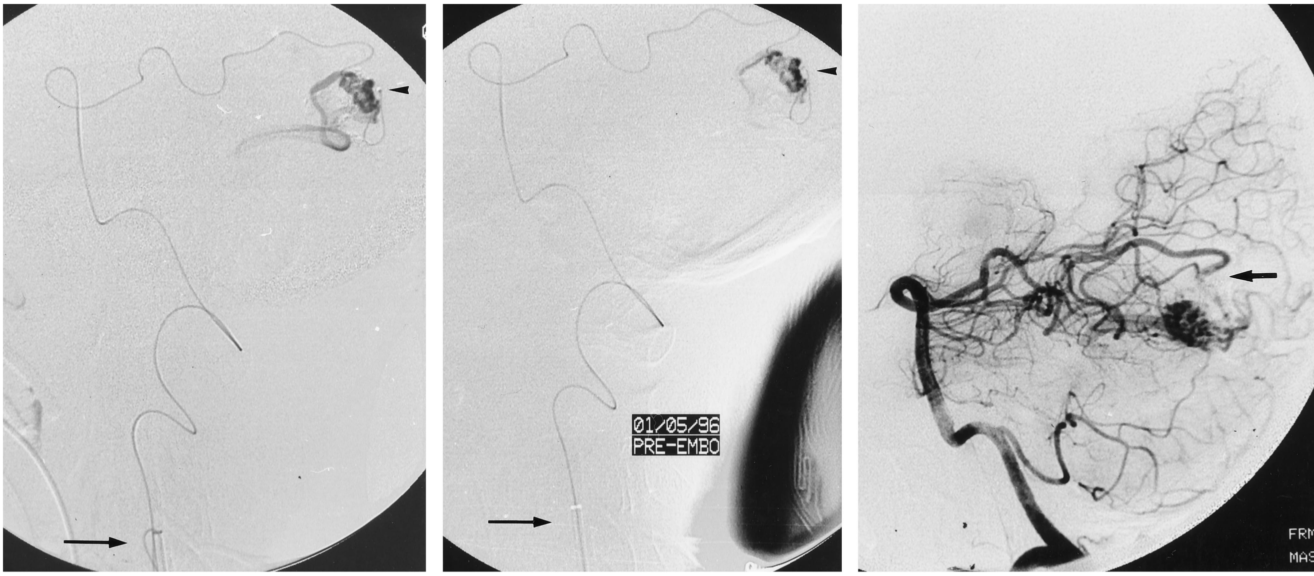
D and *E*, Anteroposterior and lateral views, respectively, of injection through microcatheter show tip of Magic microcatheter (*arrow*) in posterior temporal branch feeder. Tip would not migrate past turn even after blood pressure augmentation and infusion of papaverine through the microcatheter. *Figure continues.*

Magic microcatheter facilitated by the Terumo 0.010 guidewire.

Technique

The embolization procedure is performed with the patient under general anesthesia. To minimize potential complications from catheter-induced thrombotic emboli, we add systemic heparinization (a 5000-U bolus followed by 1000 U every hour) to the treatment protocol when the nidus of the AVM is less than 3 cm in diameter and has few relatively small feeders. Heparin, however, is not given when AVMs are larger than 3 cm or when multiple large feeders from two or three major intracranial vessels are present, since inadvertent emboli will most likely travel to the AVM in association with the high-flow shunt. Additionally, in cases in which hemorrhagic complications occur either because of normal pressure breakthrough phenomenon or unwanted venous occlusion, heparin may potentiate the severity of bleeding. All catheters used during the procedure including the guide catheter and microcatheter are continuously flushed with heparinized saline (2000 U/L).

A 90-cm 6F or 7F guide catheter that resists kinking and has a large inner diameter (Schneider/Cordis/Micro-interventional) is steam shaped to approximate the curve of the access vessel (internal carotid artery) and positioned as close as technically feasible to the skull base to facilitate advancement of the microcatheter. The microcatheter most commonly used at our institution is the flow-directed Balt 1.8F Magic. Use of a 1.8F Magic catheter as the initial microcatheter is important, as the hydrophilic Terumo 0.010 wire, if needed, will not pass into the distal 15 cm (white portion) of the 1.5F Magic, because of its smaller inner diameter. The tip of the Magic catheter is shaped into a small question mark with a curve diameter of approximately 0.5 mm, which provides some operator control in catheter migration of the distal cerebral vasculature. The Magic catheter is advanced into a feeder of the AVM by flow control, which is facilitated by cerebral blood flow augmentation with Neo-Synephrine, raising the mean



F G H

Fig 1, *continued.*

F, Lateral view of injection through microcatheter shows microcatheter tip (*arrowhead*) within the nidus of the AVM. A region of redundancy (*arrow*) developed in the microcatheter after use of the Terumo 0.010 wire. This redundancy must be removed before glue embolization is performed.

G, Lateral view of injection through microcatheter shows microcatheter tip (*arrowhead*) wedged within the nidus of the AVM. Previously noted microcatheter redundancy (Fig 1F) has been removed (*arrow*).

H, Lateral left vertebral angiogram obtained after embolization with Histoacryl shows the posterior aspect of the nidus has been occluded. The remaining nidus is compact and circular, amenable to radiosurgery. *Arrow* points to stasis in feeder.

arterial pressure to approximately 110 to 115 mm Hg, until the tip of the microcatheter reaches the nidus of the AVM. If the Magic catheter fails to progress to the nidus of the AVM or does not migrate through the tortuosity of the AVM feeder, the Terumo 0.010 wire is used.

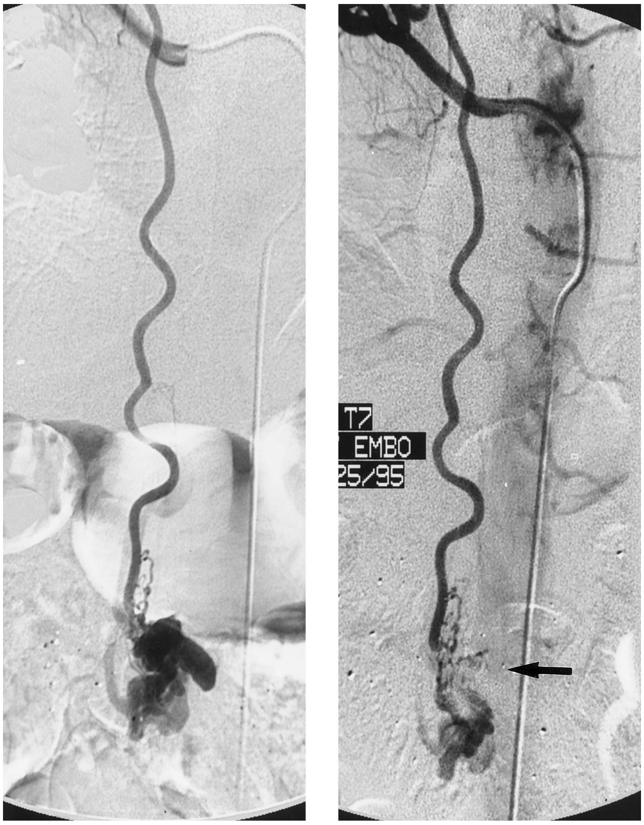
The Terumo wire has a hydrophilic coating along its entire length and is 175 cm long, with a tip angled 45°. It is packaged with a control device in a plastic holder that is uncoiled and flushed to extract the wire. Because of its hydrophilic coating, the wire must be kept moist, and we use a continuous flush system with a rotating hemostat valve as recommended for wire/microcatheter systems. The Terumo is then advanced into the Magic catheter until slight resistance is felt, at which point further advancement is done under fluoroscopic control. This resistance most commonly occurs at the pink–white junction in the microcatheter, unless redundancy is present in the microcatheter and/or multiple loops are present proximally. It is at this point in wire advancement that use of the Terumo 0.010 wire diverges from the standard microcatheter/wire technique.

Owing to the elasticity of the Magic microcatheter, the wire provides only proximal stiffness and increased "pushability." The Magic catheter does not "strip" off the wire as commonly seen in the standard microcatheter/wire systems and does not "direct" the microcatheter. Therefore, the wire does not need to extend beyond the tip of the catheter. The wire is advanced under simultaneous biplane fluoroscopic control, using oscillating rotation to aid in forward progression. Sharp turns or extreme tortuosity of the feeder vessel can be transversed by advancing the microcatheter and wire as a unit, taking extreme caution to ensure the wire and catheter are advancing together around the turn and the wire is progressing along the course of the vessel. As the wire advances, potential energy builds up within the distal microcatheter as a result of the inherent elasticity of the microcatheter and friction propelling the microcatheter tip forward. Once the wire is approximately 1 cm from the end of the microcatheter, it is then slowly withdrawn, frequently resulting in further advancement of the microcatheter tip as the flexibility of the Magic is restored. This technique can be safely repeated as needed to facilitate microcatheter migration into the nidus of the AVM.

Slack or redundancy in the microcatheter must be removed before advancing the wire. Because the wire is much stiffer than the catheter, the wire in a slack catheter will advance the elastic midshaft of the microcatheter as a loop without transmitting the forces to the catheter tip. This will increase the stress placed on vessel walls at turns or angulations and increase the risk of vessel perforation as well as create more loops and kinks through which the wire must transverse.

The tip of the Magic must be free to migrate for similar reasons, for if it is lodged or wedged (eg, at a vessel branch or in a small vessel), redundancy will develop in the shaft of the Magic.

Once the tip of the microcatheter is wedged within the nidus of the AVM, the wire is removed. Before embolization, a test injection must be performed, not only to con-



A **B**

Fig 2. *A*, Anteroposterior view of a right T-7 intercostal artery injection shows an enlarged artery of Adamkiewicz and anterior spinal artery feeding a fistula.

B, Anteroposterior view of T-7 intercostal artery after embolization shows reduction of flow to the superior aspect of the fistula (*arrow*). A second embolization followed by surgery produced complete cure of the fistula.

firm a wedge position in the AVM nidus but also to check for catheter redundancy that may have developed during use of the Terumo wire. At our institution, we use full-column flow-controlled injection of Histoacryl for AVM nidus embolization (24). If the microcatheter has redundant loops that are not removed before glue injection, the risk of having its tip glued in the AVM increases.

Representative Cases

Case 1

A 34-year-old man with a left posterior temporooccipital AVM returned for a fourth embolization procedure after seizures developed. He was neurologically intact after five previous feeder embolizations and has never bled (Fig 1A). Vertebral angiography showed a residual nidus with moderate flow, filling primarily by posterior temporal branches from the posterior cerebral artery (Fig 1B and C). A 1.8F Magic microcatheter was advanced by flow control into one of the posterior temporal branch feeders, but it became stuck at a turn approximately 4 cm from the nidus. No further advancement was obtained even with blood pressure augmentation with Neo-Synephrine to a mean arterial pressure of 110 mm Hg and infusion of papaverine (Fig 1D and E). A Terumo 0.010 wire was then used, and the catheter subsequently advanced into the nidus of the AVM (Fig 1F). Redundancy that developed in the microcatheter during wire manipulation was removed, and a preembolization test injection confirmed a wedge position of the microcatheter tip in the nidus of the AVM (Fig 1G). Successful embolization was performed with reduction in size of the residual nidus and stasis in the posterior temporal branch feeders (Fig 1H). No further embolization was done, and the patient underwent radiosurgery 1 month later.

Case 2

A 48-year-old man had had a known spinal vascular malformation since 1982. He was referred to our institution for further therapy. A diagnostic angiogram revealed a subpial fistula fed primarily from the right T-7 intercostal artery, involving the artery of Adamkiewicz and the anterior spinal artery (Fig 2A). Secondary feeders were derived from the right T-10 and middle sacral artery. Venous drainage was via enlarged perimedullary veins. Embolization was performed with a 1.8F Magic catheter from the right T-7 intercostal level, and required the use of a Terumo 0.010 wire to help advance the microcatheter along the extended distance of the anterior spinal artery feeder. The Magic was advanced to the level of the fistula, and embolization significantly reduced the flow of the fistula (Fig 2B). The patient subsequently underwent a second embolization procedure and surgery, resulting in cure of the fistula. Clinically, the patient has improved, with no further progression of his symptoms; however, he continues to have mild weakness of the lower extremities.

Case 3

A 53-year-old man had a 1-year history of increasing apneic episodes during sleep. Work-up, including cerebral angiography, revealed a right-sided superior cerebellar AVM fed by branches of the right superior cerebellar artery. Additionally, a flow-related aneurysm approximately 5 mm in diameter was present at the bifurcation of the main trunks of the two feeders (Fig 3A and B). The treatment plan developed for this patient was to include embolization with Histoacryl followed either by surgery or radiosurgery. Initial embolization of approximately 15% to 20% of the AVM nidus was successfully performed through the inferior feeder without incident (Fig 3C). A second embolization was then attempted. A Magic 1.8F microcatheter was advanced by flow control beyond the aneurysm and into the superior feeder approximately 1.5 cm, at which point the catheter failed to progress. A Terumo 0.010 wire was then employed. Advancement of the wire 2 cm proximal to the microcatheter tip resulted in a sudden change in orientation of the microcatheter, associated with an abrupt rise in the patient's blood pressure, indicating intracranial hem-

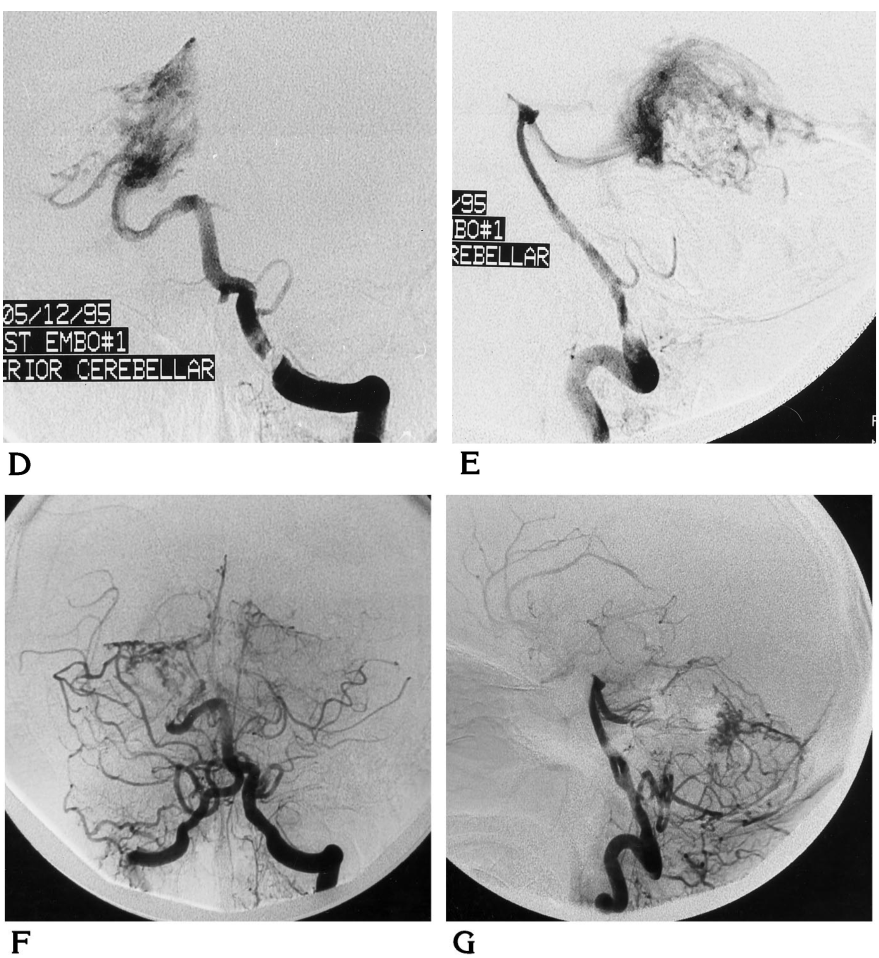


Fig 3. *A* and *B*, Anteroposterior and lateral left vertebral angiograms, respectively, show a left cerebellar AVM with primary feeders as two branches of the superior cerebellar artery. *Arrow* points to flow-related aneurysm near origins of the two branch feeders.

C, Lateral injection through microcatheter shows a wedge position of the microcatheter tip (*arrow*) before the first embolization.

D and *E*, Anteroposterior and lateral left vertebral angiograms, respectively, show contrast extravasation after rupture of the flow aneurysm.

F and *G*, Anteroposterior and lateral left vertebral angiograms, respectively, obtained after the left superior cerebellar artery proximal to the flow aneurysm and the feeders to the AVM were occluded with Histoacryl.

orrhage. A left vertebral angiogram showed contrast extravasation (Fig 3D and E), and the procedure was terminated immediately. Initially, we thought that the AVM nidus ruptured as a result of the altered hemodynamics from the first embolization; however, a subsequent computed tomographic (CT) scan showed only subarachnoid and intraventricular blood.

At our institution, videotaping of each neurointerventional case is done to allow a review of the procedure. In this case, the review enabled us to understand the true mechanism of the hemorrhage. While the wire was being advanced, it failed to follow the microcatheter into the proximal feeder. Instead, it buckled the midshaft of the microcatheter into the flow aneurysm, resulting in rupture. The change in orientation of the tip of the microcatheter seen fluoroscopically was in fact caused by the catheter entering the subarachnoid space. After the CT was done, the superior cerebellar artery was recannulated and occluded proximal to the flow aneurysm and AVM feeders (Fig 3F and G). However, the patient died the following day.

Discussion

Since January 1995, we have used the hydrophilic Terumo 0.010 wire in conjunction with the 1.8F Magic microcatheter for superselective catheterization of the nidus of AVMs in over 150 separate feeders. Use of this technique has consistently improved our success rate in navigating distal tortuous feeding vessels and in selectively catheterizing the nidus of the AVM. We are aware of the Quicksilver 10 microguidewire (Microinterventional Therapeutics), which is a hydrophilic-coated metallic wire recently used by other interventionalists in conjunction with the Magic microcatheter (Jacques Dion, personal communication, 1996). However, our experience with this wire is limited, and comparisons with the Terumo wire cannot be made.

This technique has inherent risks. Extending the Terumo wire beyond the tip of the Magic increases the risk of perforating the fragile intracerebral vessel. However, we have used the tip of the Terumo wire to help direct the Magic in extracerebral vessels with success where the risk of perforation is lower and subsequent sequelae from a perforation are not as devastating as those from an intracranial perforation. Perforation of a vessel may occur at vessel angulations or in associated aneurysms (either congenital aneurysms, flow-related feeder aneurysms, or intranidal aneurysms) as a result of the increased stiffness of the wire as compared with the microcatheter. The wire in these cases does not make the turn with the catheter and places increased lateral stress on the midshaft of the microcatheter and on the walls of the vessel or aneurysm. Continued advancement of the wire alone, and not as a unit with the microcatheter, could potentially result in a perforation. Only one such perforation occurred in our experience (case 3).

Conclusion

Since we started using the hydrophilic Terumo 0.010 wire, we have consistently improved our success rate in navigating distal tortuous vessels and in selectively catheterizing the nidus of AVMs. The Terumo 0.010 is a marvelous tool, but it carries the potential risk of causing vessel perforation in essentially two scenarios: in cases in which there is a sharp loop or angulation in the vessel and in cases in which there is an aneurysm on the feeder to the AVM. Of over 150 superselective catheterizations we performed with the Terumo wire in conjunction with the 1.8F Magic catheter, only one vessel perforation occurred. No other complications were observed. The technique requires advanced training and should only be performed by physicians completely familiar with microcatheter techniques, including flow-directed microcatheters. In the future, the Terumo 0.010 wire with different curves at its tip may aid in the navigation of tortuous vessels. Additionally, the development of a hydrophilic 0.007 wire that can be used in the 1.5F Magic catheter would allow superselective catheterization of smaller feeders that cannot be selected with the 1.8F Magic.

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