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ENDOVASCULAR TREATMENT OF RUPTURED ANEURYSMS OR PSEUDOANEURYSMS ON THE COLLATERAL VESSELS IN PATIENTS WITH MOYAMOYA DISEASE

OBJECTIVE: Ruptured aneurysms or pseudoaneurysms on the collateral vessels in patients with moyamoya disease have been known to be difficult to treat surgically because of their deep location and combined ischemic condition of the brain. For several years, we have treated these aneurysms by endovascular means. In this article, we describe the detailed techniques and outcomes.

METHODS: Eight patients with moyamoya disease who presented with intracerebral or intraventricular hemorrhage were treated by endovascular embolization. All had small aneurysmal lesions on distal collateral arteries (the distal part of the anterior and lateral posterior choroidal artery as periventricular collaterals in 7 patients and a small collateral branch from anterior communicating artery in 1 patient) that were located at corresponding area to the hemorrhage demonstrated on angiography. After superselecting the arteries as distally as possible, the aneurysms were occluded by n-butyl-cyanoacrylate injection.

RESULTS: Seven of 8 aneurysms were successfully and completely occluded without complication. One failed due to a small artery. Neither additional neurological deficit nor newly developed infarction was observed during the follow-up period. Clinically, 6 of the 8 patients demonstrated complete recovery. No further bleeding occurred during the follow-up period (mean, 24 months; range, 11–60 months).

CONCLUSION: Although further investigation is required to determine many aspects of this treatment, including indication, safety, and efficacy, the endovascular occlusion of aneurysms on the collateral vessels in moyamoya disease with glue could be an effective treatment option.

KEY WORDS: Cerebral hemorrhage, Endovascular treatment, Moyamoya disease

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Intracerebral or intraventricular hemorrhage is one of the major presentations of moyamoya disease (MMD), especially in adult patients (15). Although the natural history of MMD with bleeding has not been fully defined, several investigators have shown that rebleeding could occur in approximately 16% to 20% and that clinical outcome after the rebleeding is poor (4, 17). In terms of preventing rebleeding, no effective method has been found. Several authors have proposed that surgical revascularization might play a preven-

tive role in hemorrhage, but its efficiency remains in question (6, 7, 9, 12).

The exact causes of the hemorrhage are not known, but the fragile nature of collateral vessels has been considered as a major cause. Angiograms often fail to define the direct cause of the hemorrhage, but they occasionally show small aneurysmal lesions at the collateral moyamoya vessels. If these are located at the hemorrhage site, it is reasonable to assume that the aneurysm is the direct cause of the bleeding (true aneurysm) or a result of vessel rupture (pseudoaneurysm) (8, 18). Regardless of its character, it is very difficult, and often impossible, to access the lesion directly without additional brain damage because of its deep location and preexisting ischemic brain condition.

ABBREVIATIONS: MMD, moyamoya disease; nBCA, n-butyl-cyanoacrylate

For several years, we have treated these aneurysms with endovascular means by a direct approach. In this article, we describe detailed techniques and outcomes of the endovascular treatment of these lesions.

PATIENTS AND METHODS

We retrospectively reviewed 8 consecutive patients with MMD with hemorrhagic presentation who were treated by endovascular embolization in 3 cooperative hospitals from July 2003 to September 2007. On angiograms, all had aneurysmal lesions (true aneurysms or pseudoaneurysms) on the distal parts of collateral vessels. All of the patients underwent endovascular n-butyl-cyanoacrylate (nBCA) glue injection for the closure of the lesions. Pre- and postoperative computed tomography and/or magnetic resonance imaging were performed. Neurological status was also evaluated during the pre- and postoperative periods.

The typical embolization procedure was as follows: under local or general anesthesia, a femoral artery was punctured and 60-French arterial sheath (Radifocus Introducer; Terumo, Tokyo, Japan) and 6-French guiding catheter (Envoy; Cordis Neurovascular, Miami, FL) was placed at the corresponding vertebral or internal carotid artery. The parent artery that held the aneurysm was selected with a microcatheter (Prowler-10; Cordis Neurovascular, Inc., Miami, FL) using a microguidewire (Agility 10 soft; Cordis Neurovascular, Inc.). The microcatheter was advanced as far as possible. Selective angiography was performed by careful hand injection and analyzed for determining the relationship between the aneurysm and the connecting arterial network. If needed, the microcatheter was repositioned to minimize the length of arterial occlusion. A mixture of 33% nBCA and lipiodol was injected through the microcatheter until the glue reached and filled the aneurysm and/or reflux of the glue was found. Therefore, a short segment of the artery and the aneurysm were occluded together. After the injection, postembolization angiography was performed to verify closure of the aneurysm (Figs. 1 and 2). Neither heparin nor antiplatelet agent was given during or after the procedure.

RESULTS

Of 8 patients, 7 had MMD and 1 had probable MMD (unilateral MMD). The patients' mean age was 38.5 years (age range, 23–50 years); 4 of the patients were men and 4 were women. Three patients had intracerebral hemorrhage and intraventricular hemorrhage, 2 had intraventricular hemorrhage, 2 had intracerebral hemorrhage, and 1 had subarachnoid hemorrhage. On angiograms, small aneurysmal lesions on collateral vessels from the lateral posterior choroidal artery were found at the hemorrhage site in 6 patients, on the distal part of the anterior choroidal artery in 1 patient, and on a collateral artery from the anterior communicating artery in 1 patient (Table 1). Preoperatively, 5 patients had a neurological deficit, including altered mentality in 3. The other 3 patients had only headache due to the cerebral hemorrhage.

The aneurysms were successfully and completely occluded in 7 patients. In 1 patient, microcatheter navigation into the lateral posterior choroidal artery failed because the vessel was too small. There was neither additional neurological deficit nor newly developed ischemic lesion on follow-up magnetic resonance imaging studies. Six patients were fully recovered at the time of discharge, and 2 patients with poor initial condition

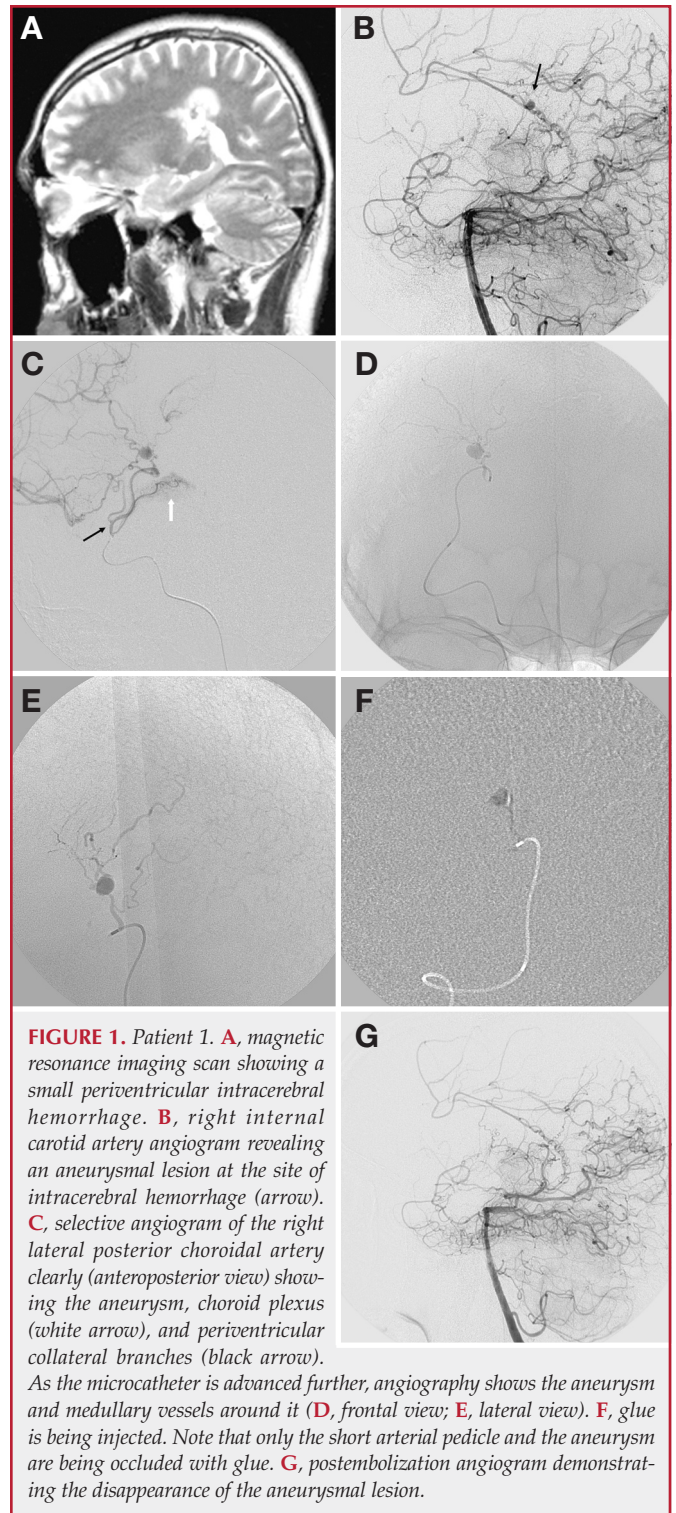


FIGURE 1. Patient 1. **A**, magnetic resonance imaging scan showing a small periventricular intracerebral hemorrhage. **B**, right internal carotid artery angiogram revealing an aneurysmal lesion at the site of intracerebral hemorrhage (arrow). **C**, selective angiogram of the right lateral posterior choroidal artery clearly (anteroposterior view) showing the aneurysm, choroid plexus (white arrow), and periventricular collateral branches (black arrow). As the microcatheter is advanced further, angiography shows the aneurysm and medullary vessels around it (**D**, frontal view; **E**, lateral view). **F**, glue is being injected. Note that only the short arterial pedicle and the aneurysm are being occluded with glue. **G**, postembolization angiogram demonstrating the disappearance of the aneurysmal lesion.

recovered partially and retained a neurological deficit (Figure 3). Follow-up radiological studies, including angiograms and magnetic resonance angiograms, were performed in all patients

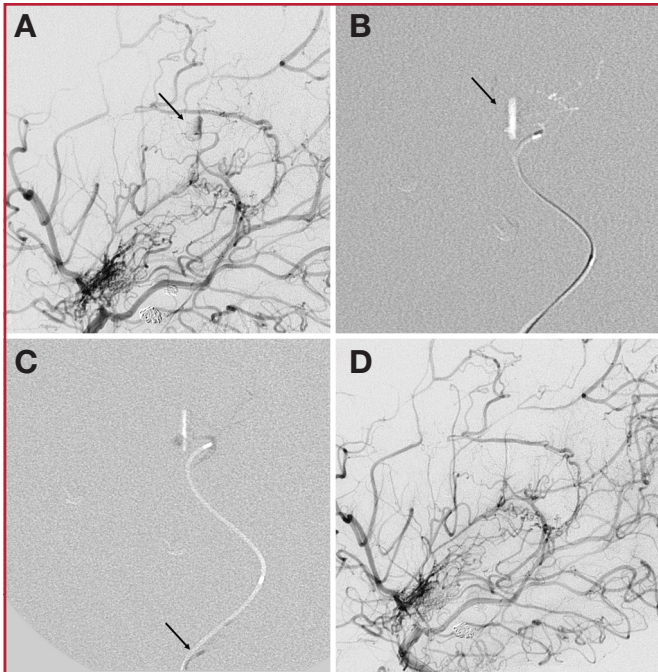


FIGURE 2. Patient 3. **A**, internal carotid artery angiogram showing a pseudoaneurysm-like lesion on the distal part of lateral posterior choroidal artery. This patient had repeated intraventricular and paraventricular hemorrhage. **B**, a microcatheter is advanced distally. Note the pseudoaneurysm on the roadmap image in white (arrow). **C**, glue is being injected into the aneurysm including proximal short segment of the parent artery. The microcatheter is withdrawn after glue injection (arrow). **D**, the aneurysm is no longer seen on the postembolization angiography.

(mean, 24 months; range, 11–60 months) and revealed no reappearance of the aneurysm lesion at the same site. No rebleeding occurred during the follow-up period.

DISCUSSION

Intracerebral or intraventricular hemorrhage is the second most common clinical presentation in patients with MMD. The precise pathophysiological mechanism of the hemorrhage in MMD is not fully elucidated, but considering the patterns of the hemorrhage, fragile characters of the collateral vessels which bear hemodynamic stress have been considered a responsible cause (1, 4). Although not commonly found on angiograms, aneurysmal lesion arising from the collateral artery at the hemorrhage site could, if seen, be considered a direct cause of the bleeding or the result of bleeding from a collateral vessel (i.e., a pseudoaneurysm). According to the pathological examination, collateral vessels in MMD have weakened media with segmentation of the internal elastic lamina and fibrosis. Attenuated arterial wall acquires a predisposition for microaneurysm formation or rupture under hemodynamic stress (16). In our series, small aneurysmal lesions were most commonly found at the distal paraventricular segment of the lateral posterior choroidal

artery, which explains the prevalent occurrence of intra- and paraventricular hemorrhage.

Although the natural history of the patients with hemorrhagic MMD has not been fully defined, many reports have shown an aggressive clinical course. Rebleeding occurred in ~28% to 35%, and mortality associated with the rebleeding was very high (14, 17). The rate of good outcome after a single episode of bleeding is 60%; however, after repeated bleeding, this rate decreases to 40% (14). Therefore, elimination of the bleeding source has been a critical issue in terms of the treatment of MMD patients with hemorrhagic presentation. This, however, remains controversial. Conservative management may be a treatment option. There have been several reports of spontaneous disappearance of small aneurysms of collateral vessels among the patients who did not exhibit repeated intracranial bleeding (3, 5, 8, 11). However, this does not always happen (5, 14, 17). Several authors have proposed surgical revascularization, which could reduce preexisting collateral vessels or hemodynamic stress on those vessels, and may have effect on reducing hemorrhagic risk (10). The efficiency remains in question (6, 7, 9, 13).

Direct surgical intervention for aneurysms, such as aneurysmectomy or clipping, could be a treatment option (2, 13) but carries a risk of additional brain damage, because aneurysms of collateral vessels are usually located deeply (i.e., the prevalent locations of hemorrhage in MMD are basal ganglia and periventricular white matter). In addition, because collateral circulation is important in patients with MMD, surgical injury of these vessels can produce additional ischemic brain damage (10).

Endovascular treatment has advantages with respect to its less invasive nature. As the cases in this study show, direct access to the distal lesion with microcatheters could be relatively easy, feasible, and safe. Unlike cisternal or ventricular locations, periventricular collateral branches connecting the anterior or posterior choroidal artery to cortical vessels via medullary arteries run through the subependymal course, which is relatively straight and stable because it is covered by ependymal lining. We believe that this subependymal location of the target artery allowed us to advance the microcatheter with ease once we selected the orifice of the corresponding choroidal artery. This also allows the safe withdrawal of the microcatheter after nBCA injection. This subependymal course seems to provide some protection to small vessels from the whiplash injury that could occur with catheter withdrawal.

From a practical point of view, access to the collateral moyamoya vessels from the anterior cerebral or middle cerebral arteries is often impossible because the supraclinoid internal carotid artery is very small. We observed one exceptional case of an aneurysm on the basal moyamoya vessel from the anterior communicating artery treated by endovascular nBCA injection. We were able to select the aneurysm through the left internal carotid artery because this case was unilateral MMD in which only the right internal carotid artery was involved (Fig. 2).

In spite of the potential risk of adjacent collateral vessel occlusion, we used nBCA for aneurysm obliteration rather than platinum coils for several practical reasons. First, the artery size is small for accepting detachable platinum coils. Forceful advance-

TABLE 1. Patient summary^a

Patient no.	Age (y)/sex	Symptom	Hemorrhage location	Aneurysm location	Cannulation	Embolization	Outcome
1	23/M	Dysarthria	R PVWM, R thalamus	R LPCA	VA/PCA	Complete	Excellent
2	43/F	Stupor	Whole ventricle	L anterior choroidal artery	ICA	Complete	Stationary
3	34/F	Stupor	R PVWM, R lateral ventricle	R LPCA	Pcom/PCA	Complete	Excellent
4	26/F	Headache	R lateral ventricle	R LPCA	VA/PCA	Complete	Excellent
5	46/M	Headache	L PVWM, L lateral ventricle	L LPCA	VA/PCA	Complete	Excellent
6	50/M	Headache	SAH	Acom	Contralateral ICA/ACA	Complete	Excellent
7	45/F	Hemiparesis, dysarthria	R PVWM, R thalamus	R LPCA	VA/PCA	Complete	Excellent
8	41/M	Stupor	R PVWM, R lateral ventricle	R LPCA	VA/PCA	Failed	Stationary

^a R, right; PVWM, periventricular white matter; LPCA, lateral posterior choroidal artery; VA, vertebral artery; PCA, posterior cerebral artery; ICA, internal cerebral artery; Pcom, posterior communicating artery; SAH, subarachnoid hemorrhage; Acom, anterior communicating artery; ACA, anterior cerebral artery.

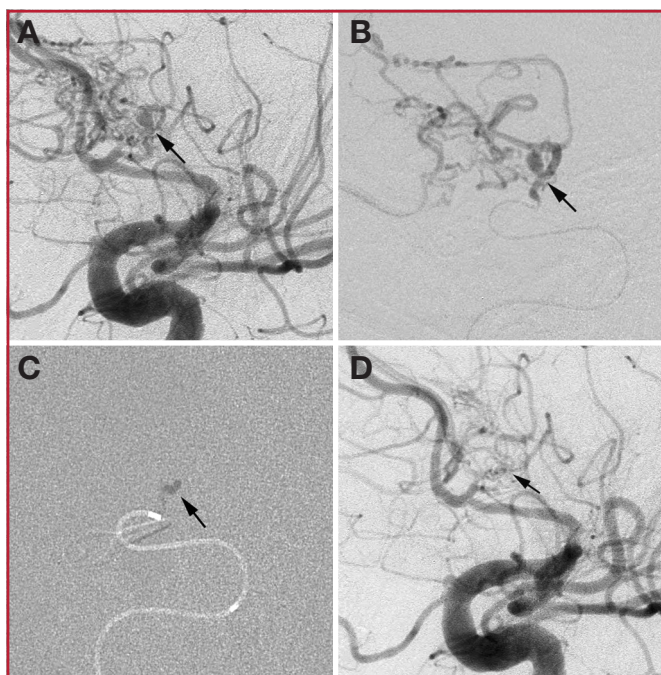


FIGURE 3. Patient 6. **A**, internal carotid artery angiogram showing an aneurysm on the fine vascular network adjacent to the anterior communicating artery. **B**, selective angiogram showing the aneurysm and adjacent collateral vessels more clearly. **C**, glue is being injected into the aneurysm (arrow). **D**, the aneurysm is no longer seen on the post-embolization angiography (arrow).

ment of the coil may cause dangerous straightening or rupture of the fragile vessels. Secondly, the aneurysms are also too small to allow coiling. Third, the aneurysms at collateral vessels could be pseudoaneurysms (8, 18).

One of the practical issues is how far the microcatheter should be advanced in terms of avoiding occlusion of collateral network and whether it is safe to occlude the parent artery of the aneurysm and its branches. In this study, the microcatheter was positioned several millimeters to centimeters proximally to the aneurysm, and there were several branches from the segment between the microcatheter tip and the aneurysm. In addition, this arterial segment (between the microcatheter tip and the aneurysm) had to be occluded along with the aneurysm because we used liquid embolic material. However, the patients show neither additional neurological deficit nor new infarct on magnetic resonance imaging after the embolization. There may be several explanations for this. First, we advanced the microcatheter as far as possible. Branches of relatively large size were all passed. Only small collateral branches remained between the microcatheter tip and the aneurysm. Second, the direction of blood flow was reversed in the territory of the parent vessel of the aneurysm after the selection of the parent vessel because the parent vessel was usually wedged by the catheter. We performed selective angiography and fluoroscopic test injection several times with changing injection strength, speed, and contrast volume, with careful review. We tried to perform controlled injection, i.e., sending embolic agent from the microcatheter tip just to the aneurysm but not to collateral network beyond the lesion. Because the parent vessel of the aneurysm was wedged, fine

control of the glue was relatively easy. The collateral vessels are well developed in MMD. The occluded arterial part could be taken for a short segment of conduit located in ventricular wall, not whole collateral channels at that area. Rich collateral network nearby could compensate the one conduit blockage so no infarction may occur. If any ischemia is produced, it might be trivial.

We showed successful endovascular treatment in 7 of 8 cases of MMD with ruptured aneurysms at collateral vessels but have questions about indications for and safety of this relatively aggressive treatment. Further investigation, including the natural history of these specific aneurysms in patients with MMD, is needed to determine the risks and benefits of this treatment.

CONCLUSION

Although further investigations are required to elucidate the safety and effectiveness of this treatment, the endovascular occlusion of aneurysms on the collateral vessel in MMD with nBCA might be an effective treatment option.

Disclosure

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COMMENTS

Kim et al. have done an excellent job in presenting the endovascular treatment of ruptured aneurysms and pseudoaneurysms of the collateral vessels in patients with moyamoya disease. The insight provided on the devices used and routes taken is of critical importance in helping others who might choose this method of treatment. As the authors point out, open surgery would be much too invasive. Furthermore, on the basis of limited available data, the natural course after rupture seems much too risky. Given the authors' success rate, the benefits of embolization appear to outweigh the risks and should absolutely be considered when a lesion can be identified.

In awake patients, challenge testing (e.g., with amobarbital) might be beneficial in some cases, but the results would have to be interpreted with caution. Embolization with other agents (e.g., Onyx; Micro Therapeutics, Inc., Irvine, CA) might also be possible if one is very close to the aneurysm. The key to success is extremely careful flow control, as described in this article.

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