Multimodal Treatment for Complex Intracranial Aneurysms: Clinical Research

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INTRODUCTION

Recent advances in endovascular treatment have increased safety and efficacy for treating patients with aneurysms, but neither this modality alone nor microsurgical clipping alone is sufficient for patients with complex aneurysm such as giant or dissecting aneurysms. A neurovascular, multimodal, team approach is necessary to select the optimal management strategy for patients with complex aneurysms. In this study, we describe here our experiences from using a multimodal approach in patients with complex aneurysms. Our goals were to identify the types of complex aneurysms for which such an approach is recommended and to evaluate efficacy and outcome of these multimodal approaches.

MATERIALS AND METHODS

A review of our medical records identified fifteen patients who underwent multimodal treatment for complex aneurysms between January 1995 and June 2007. Patients undergoing clip treatment for the recurrence of a previously treated aneurysm with a coil or coil occlusion with bypass surgery were included. Location of aneurysm, types of endovascular and surgical treatment, types of bypass surgery, follow-up results, and treatment-associated complications were evaluated.

Patients characteristics

Among fifteen patients, six were male and nine were female with mean age of 48.7 years (range from 17 to 76 years) (Table 1). Nine patients had unruptured aneurysms and 6 had ruptured aneurysms. Of the nine patients with
unruptured aneurysms, eight presented with symptoms related to mass effects of aneurysm, and one patient who had multiple traumatic dissecting aneurysms of the ICA showed distal anterior cerebral artery (ACA) territory infarction. Of the six patients with ruptured aneurysms, five presented with subarachnoid hemorrhage (SAH), 4 with dorsal wall aneurysms of the internal cerebral artery (ICA), and 1 with dissection of the posterior inferior cerebellar artery (PICA). One patient had massive nasal bleeding because of a pseudoaneurysm of the cavernous ICA.

Characteristics of the complex aneurysms

Of fifteen aneurysms, thirteen aneurysms were located in the anterior circulation and two were located in the posterior circulation. In the anterior circulation, four lesions involved dorsal wall of ICA, four lesions involved terminal ICA, one lesion involved paracclinoid ICA, two lesions involved cavernous ICA, and two lesions were located in middle cerebral artery (MCA). In the posterior circulation, one involved posterior cerebral artery (PCA) P2 portion, and one involved in peripheral PICA. Six types of the lesion complexity in our study were the following: 1) giant aneurysm (n=6), 2) ICA dorsal wall aneurysm (n=5), 3) pseudoaneurysm (n=1), 4) large calcified aneurysm (n=1), 5) serpentine thromosed giant aneurysm (n=1), and 6) dissecting aneurysm (n=1).

Indications for bypass

The balloon occlusion test (BTO) represents the main criteria for choosing an appropriate bypass conduit. During

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Table 1. Clinical summary of 15 patients with aneurysms who underwent combined treatment approaches

| Patient No | Age (yrs), sex | Indication for Op | Location of lesion | Complicating factor | Complication | Neurological sequelae |
|------------|---------------|------------------|--------------------|--------------------|--------------|----------------------|
| 1          | 61, F         | Headache, nausea, vomiting | Rt cavernous ICA | Giant | Balloon distal | None |
| 2          | 56, F         | Altered mentality | Lt dorsal wall | Ruptured, blister like | Lt MCA infarction | Rt hemiparesis |
| 3          | 76, M         | Epistaxis | Lt cavernous ICA | Pseudoaneurysm | None | None |
| 4          | 64, F         | Headache | Rt distal ICA | Large calcified | None | None |
| 5          | 67, F         | Headache | Rt distal ICA | Giant | Rt MCA infarction | Lt side weakness |
| 6          | 50, M         | Headache | Lt M1 | Giant | None | None |
| 7          | 37, F         | Headache | Lt distal ICA | Giant | Lt MCA infarction | None |
| 8          | 36, M         | Headache | Lt dorsal wall | Ruptured, blister like | Lt MCA infarction | Rt hemiparesis, global aphasia |
| 9          | 47, F         | Diplopia | Rt paracclinoid | Giant | None | None |
| 10         | 65, F         | Pt facial palsy | Lt proximal P2 | Large thrombosed | None | None |
| 11         | 43, F         | Headache | Rt MCA | Giant | None | None |
| 12         | 54, F         | Headache | Rt ICA dorsal wall | Rt ICA occlusion | None | Rt optic disc atrophy, blindness |
| 13         | 27, M         | Trauma, nystagmus | Lt distal ICA | Ruptured | None | None |
| 14         | 14, M         | TA, Lt eye blindness | Lt ICA dorsal wall | None | None | None |
| 15         | 33, M         | Headache | Lt peripheral PICA | Dissecting | None | None |

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Table 2. Locations of lesions, treatments, and outcomes in 15 patients with complex aneurysms

| Location of lesion | Treatment | Outcome |
|--------------------|-----------|---------|
| Cavous ICA         | ECA–M2 (radial artery graft) bypass, ICA coil occlusion, balloon occlusion, STA–M4 direct, ICA clip trapping | Excellent (79.9%), Good (13.4%), Fair (6.7%), Poor (0%), Dead (0%) |
| Distal ICA         | ECA–M2 (radial artery graft), ICA coil occlusion | Excellent (79.9%), Good (13.4%), Fair (6.7%), Poor (0%), Dead (0%) |
| ICA dorsal wall    | ECA–M2 (radial artery graft), ICA coil occlusion | Excellent (79.9%), Good (13.4%), Fair (6.7%), Poor (0%), Dead (0%) |
| Paracclinoid       | ECA–M2 (radial artery graft), ICA coil occlusion | Excellent (79.9%), Good (13.4%), Fair (6.7%), Poor (0%), Dead (0%) |
| MCA                | ECA–M2 (saphenous vein), MCA clip trapping | Excellent (79.9%), Good (13.4%), Fair (6.7%), Poor (0%), Dead (0%) |
| PCA                | STA–Aneurysm, distal, PCA clipping | Excellent (79.9%), Good (13.4%), Fair (6.7%), Poor (0%), Dead (0%) |
| PICA               | OA–PICA (direct), PICA clipping | Excellent (79.9%), Good (13.4%), Fair (6.7%), Poor (0%), Dead (0%) |
the study, three different conditions were evaluated: 1) good clinical tolerance during the occlusion test, no sign of hypoperfusion at Diamox single positron emission computed tomography (SPECT); 2) good clinical tolerance, appearance of hypoperfusion at SPECT; 3) poor clinical tolerance. The ICA can easily be occluded without bypass in the first condition. It is a routine to perform STA-MCA bypass with low flow in the second condition. It is general to perform saphenous vein graft (ECA-SVG-MCA) or radial artery graft (ECA-RAG-MCA) is generally performed in the third condition.

**Treatment modalities**

Treatment decisions were made after review by a neurovascular team composed of two cerebrovascular surgeons (B.K., J.A.) and one endovascular neurosurgeon (D.K.). Bypass surgery included low flow bypass such as superficial temporal artery to middle cerebral artery (STA-MCA) direct anastomosis in six patients and high flow bypass such as external carotid artery-radial artery graft-middle cerebral artery (ECA-RAG-MCA) bypass grafting in six patients and external carotid artery-saphenous vein graft-middle cerebral artery (ECA-SVG-MCA) bypass grafting in one patient (Table 2). Two patients had posterior circulation aneurysms. These patients were treated with occipital artery-posterior inferior cerebellar artery (OA-PICA) and STA-P2 anastomosis. Parent artery occlusion was performed with a clip in nine patients, with a coil in four, with a balloon plus coil in one patient. Distal ICA aneurysm, which may be caused by trauma, was planned for ICA trapping with clip and was performed by direct neck clipping due to aneurysm morphology based on microscopic view.

**RESULTS**

The mean follow-up period for surviving patients was 30.3 months (range, 7 to 55 months). All aneurysms were excluded from the blood flow of their respective parent arteries. Twelve patients had excellent outcomes, three patients had complications, and there was no mortality. Postoperative angiography showed that 10 out of 11 patients had good patency of anastomotic site and peripheral flow. The remaining one patient had post-surgical neurologic deficits resulting from occlusion of the bypass graft. Perfusion computed tomography (CT) showed that six of nine patients had good patency of distal blood flow, whereas three patients showed insufficiency. All 3 patients with insufficient flow on perfusion CT suffered strokes, resulting from occlusion of the bypass graft in one patient and from insufficient bypass blood flow in two patients, presented with hemiparesis with or without aphasia.

**Illustrative cases**

**Case 1**

This 61-year-old woman had a history of headache and ocular pain. Magnetic resonance imaging and magnetic resonance angiography revealed a mesial temporal lobe mass and a bony erosion, and four-vessel angiography demonstrated a bilobular giant cavernous aneurysm.

Follow-up angiography after a right STA-MCA bypass with radial artery interposition graft showed good patency. Six days after surgery, a right ICA occlusion was performed with a balloon. External carotid angiography demonstrated excellent filling of the distal MCA branches through the bypass graft. Three years later, the patient reported resolution of her symptoms. CT angiography confirmed obliteration of the aneurysm and good patency of the bypass graft (Fig. 1).

**Case 14**

This 14-year-old boy had a left facial bone injury and left eye blindness resulting from a traffic accident. Brain MRI showed a small mass-like lesion with hemorrhage at the left frontal base. Three months after the head injury, he complained about right leg weakness (Fig. 2). An MRI showed a new infarction of the left distal ACA territory. CTA and transfemoral cerebral angiography (TFCA) showed a traumatic aneurysm of the left ICA dorsal wall, multiple aneurysms of the left ophthalmic artery, and cavernous ICA arising from multiple vessel wall injury.

Direct ICA occlusion was not recommended because of his relative young age and due to the perfusion defect revea-
led during a Diamox SPECT study. STA-M4 anastomosis was performed; seven days later, left ICA occlusion was performed with a coil. During ICA occlusion, the posterior communicating artery was saved since it was a major supplier for distal ICA flow.

The patient's postoperative outcome was good, and he was discharged without any new deficit.

DISCUSSION

The intracranial giant aneurysms (< 2.5 cm) involving the ICA such as paraclinoid aneurysm, cavernous ICA aneurysm, and MCA aneurysm present several treatment difficulties. Direct surgical approach or endovascular techniques is incapable for these giant aneurysms due to an artheroma or a calcification at the base of the aneurysm, retraction injury, and occlusion of the parent artery or adjacent perforators. The aneurysm size, the width of the neck, the outflow arteries incorporated into the aneurysm base, the blister-like aneurysm, the fusiform and dolichoectatic morphology of the sac, and the poor radiological visualization of the aneurysm and its adjacent branches are the causes of failure for both the microsurgical and endovascular treatments. Symptomatic traumatic internal carotid artery dissection or the traumatic damage of the intrapetrous ICA is impossible to be treated by direct surgical clipping or endovascular coiling. These multimodal treatments have been found to significantly alter the natural course of these complex lesions.

We found that multimodal treatment was both safe and effective in all fifteen patients with complex aneurysms. Multimodal treatment may be divided into four categories: 1) endovascular or surgical treatment after prior unsuccessful surgical or endovascular treatment, 2) endovascular treatment of a remote second aneurysm, 3) endovascular proximal parent artery control during surgery for clip occlusion/decompression, and 4) combination of surgical and endovascular treatment for complex intracranial aneurysms. All our patients fell within the last category. Our treatment modality was composed of booster bypass surgery and parent artery occlusion with clip or coil, and each procedure was performed by different neurosurgeons.

The first multimodal techniques used were within the third category and consisted of temporary ICA occlusion with a balloon during aneurysm dissection or during clip application with suction decompression. Temporary balloon occlusion of the ICA before dissection of the unruptured aneurysm allowed proximal artery control without requiring neck dissection for proximal control of the ICA. This procedure, however, carries particular associated risks and is difficult to perform simultaneously during microsurgical clip application. Cerebral revascularization, an adjunctive method used to treat complex aneurysms.
and cranial base tumors, has also been used to treat complex aneurysms, together with microsurgical clipping and endovascular coiling for parent artery occlusion. Patients with giant intracranial aneurysms, in whom parent artery occlusion with clipping alone was associated with high complication rates, have also been treated by this method.

Several trials have described the multimodal treatment of large numbers of patients with the combination of endovascular and surgical methods for the initial treatment plan. These patients may be categorized into three subgroups. The first subgroup consists of patients with aneurysms involving the petrous, cavernous, or paraclinoid ICA aneurysms that were not amenable to direct surgical clip occlusion and that required a STA-MCA bypass or a saphenous vein interposition graft followed by parent-vessel occlusion. The second subgroup consists of patients with aneurysms in the posterior circulation requiring an STA-PICA bypass followed by parent artery occlusion. The third subgroup is composed of patients with complex aneurysms that may be categorized from the circulation and that require flow-redirection techniques.

In our cases, the most common aneurysms requiring a combined technique included ruptured dorsal wall aneurysms of the ICA and giant or large cavernous ICA aneurysms. All MCA and PCA aneurysms were symptomatic giant aneurysms. One ruptured PICA dissecting aneurysm was treated by OA-to-PICA anastomosis with simultaneous parent artery occlusion with clipping.

Dorsal wall aneurysms of the ICA with subarachnoid hemorrhages were difficult to be dissected and almost impossible to be clipped. In these patients, bypass surgery was performed first, followed by parent artery occlusion with a clip or coil. This methodology was also used in patients with giant aneurysms of the PCA and giant serpentine aneurysms of the MCA in our series.

BTOs were used to evaluate the necessity for bypass surgery in four patients with ICA aneurysms. Three of these patients showed normal clinical status and good cross-flow, but decreased perfusion reservoir by Diamox single positron emission computed tomography (SPECT).

Among four patients who underwent booster bypass surgery followed by parent artery occlusion in the same day, two patients developed complications, suggesting that parent artery occlusion should be performed after several days of primary bypass surgery, even in patients with subarachnoid hemorrhages.

CONCLUSION

Complex aneurysms in our study, those that were difficult to be treated simply by direct neck clipping or endovascular coiling, included giant aneurysms, ICA dorsal wall aneurysms, dissecting aneurysm, pseudoaneurysm, serpentine thrombosed aneurysm, and large calcified aneurysm. Combination of bypass surgery plus parent artery occlusion with a clip or coil may be recommended for these complex aneurysms.

Although these multimodal treatments are associated with complications, the high-risk nature of these complex aneurysms mandates an aggressive approach. The risks of multimodal treatment methods are likely lower than those associated with the natural progression of this subset of aneurysms.

References

1. Anson JA : Epidemiology and natural history of giant aneurysms, in Awad IA, Barrow DL (eds) : Giant Intracranial Aneurysms. Park Ridge : AANS, 1995, pp 23-34
2. Arnautovic KI, Al-Mefty O, Anguaco E : A combined microsurgical skull-base and endovascular approach to giant and large paraclinoid aneurysms. Surg Neurol 50 : 504-518; discussion 518-520, 1998
3. Barnett DW, Barrow DL, Joseph GJ : Combined extra- and intracranial bypass and intraoperative balloon occlusion for the treatment of intracavernous and proximal carotid artery aneurysms. Neurosurgery 35 : 92-97; discussion 97-98, 1994
4. Barrow DL, Alleyn C : Natural history of giant intracranial aneurysms and indications for intervention. Clin Neurol Surg 42 : 214-244, 1995
5. Butjer HH, Samson DS : Retrograde suction decompression of giant paraclinoidal aneurysms. Technical note. J Neurosurg 73 : 305-306, 1990
6. Drake CG : Giant intracranial aneurysms: experience with surgical treatment in 174 patients. Clin Neurol Surg 26 : 12-95, 1979
7. Eckard DA, Purdy PD, Bonte FJ : Temporary balloon occlusion of the carotid artery combined with brain blood flow imaging as a test to predict tolerance prior to permanent carotid sacrifice. AJNR Am J Neuroradiol 13 : 1565-1569, 1992
8. Ferguson GG, Peerless SJ, Drake CG : Natural history of intracranial aneurysms. N Engl J Med 305 : 99, 1981
9. Gelber BR, Sundt TM Jr : Treatment of intracavernous and giant carotid aneurysms by combined internal carotid ligation and extra-intracranial bypass. J Neurosurg 52 : 1-10, 1980
10. Hacein-Bey L, Connolly ES Jr, Mayer SA, Young WL, Pile-Spellman J, Solomon RA : Complex intracranial aneurysms : combined operative and endovascular approaches. Neurosurgery 43 : 1304-1312; discussion 1312-1313, 1998
11. Heros RC, Ameri AM : Rupture of a giant basilar aneurysm after saphenous vein interposition graft to the posterior cerebral artery. Case report. J Neurosurg 61 : 387-390, 1984
12. Heros RC, Nelson PB, Ojemann RG, Crowell RM, DeBrunner G : Large and giant paraclinoid aneurysms : surgical techniques, complications, and results. Neurosurgery 12 : 153-163, 1983
13. Hoh BL, Carter BS, Budzik RF, Putman CM, Ogilvy CS : Results after surgical and endovascular treatment of paraclinoid aneurysms by a combined neurovascular team. Neurosurgery 48 : 78-89; discussion 87-90, 2001
14. Hoh BL, Putman CM, Budzik RF, Carter BS, Ogilvy CS : Combined surgical and endovascular techniques of flow alteration to treat fusiform and complex wide-necked intracranial aneurysms that are unsuitable for clipping or coil embolization. J Neurosurg 95 : 24-35, 2001
15. Jafar JJ, Russell SM, Woo HH : Treatment of giant intracranial aneurysms with saphenous vein extracranial-to-intracranial bypass
grafting: indications, operative technique, and results in 29 patients. Neurosurgery 51: 138-144; discussion 144-146, 2002.
16. Mathis JM, Barr JD, Jungreis CA, Tumas H, Sekhar LN, Vincent D, et al: Temporary balloon test occlusion of the internal carotid artery: experience in 500 cases. AJNR Am J Neuroradiol 16: 749-754, 1995.
17. Mizoi K, Takahashi A, Yoshimoto T, Fujiwara S, Koshu K: Combined endovascular and neurosurgical approach for paraclinoid internal carotid artery aneurysms. Neurosurgery 33: 986-992, 1993.
18. Ponce FA, Albuquerque FC, McDougall CG, Han PP, Zabramski JM, Spetzler RF: Combined endovascular and microsurgical management of giant and complex unruptured aneurysms. Neurosurg Focus 17: E11, 2004.
19. Serbinenko FA, Filatov JM, Spallone A, Tchurilov MV, Lazarev VA: Management of giant intracranial ICA aneurysms with combined extracranial-intracranial anastomosis and endovascular occlusion. J Neurosurg 73: 57-63, 1990.