# Advances in Endovascular Neurosurgery Techniques: Toyama Hospital Experience

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Abstract: Advance developing technologies of neurosurgery field in the world especially endovascular treatment and vascular surgery. Endovascular treatment has new technique in internal carotid stenosis, basilar tip aneurysm, and carotid cavernous aneurysm. Effectiveness and safety of endovascular treatment not inferior compare to open surgery and for some cases more superior. The only management for moyamoya disease is surgical revascularization by direct bypass, indirect bypass, and combined bypass. Most of the previous procedures were aimed on MCA territory so EDMAPS was developed to revascularize ACA territory by using frontal pericranial flap for additional indirect bypass through medial frontal craniotomy. Studies demonstrates STA-MCA anastomosis and EDMAPS is safe and effective to improve long term prognosis in moyamoya disease.

## 1 INTRODUCTION

Vascular neurosurgery has remarkable of neurosurgical advances that require decision making, critical care support, microsurgical skill, and advanced technology. This field has evolved for this past several decades and changed the nature of this subspecialty of neurosurgery. In 1937 the first aneurysm clipping procedure was performed by Walter Dandy and evolved progression of devices and techniques. Aneurysm sac obliteration by endovascular insertion of silver wire was reported in 1941. Evolution of endovascular treatment was continue by development of detachable device, balloon and stent-assisted coiling, and recently flow diverter. Vascular neurosurgery should be a field oriented on disease and not procedure. At present, vascular neurosurgery requires extraluminal and endoluminal approach. The extraluminal approach is an open cranial microsurgical technique involves clipping, cortical mapping, and anastomosis. The endoluminal approach is a technique requires microcatheter, coils, balloon systems, embolic materials, and stent technology (Tjoumakaris et al, 2011; Crocker, 2007).

## 2 ENDOVASCULAR NEUROSURGERY

### 2.1 Internal Carotid Artery Stenosis

Many clinical trials have been done to compare carotid endarterectomy with carotid artery stenting (CAS) in regard to their effectiveness and safety. Most studies show that CAS is not inferior compare to carotid endarterectomy. Currently there are three types of cerebral embolic protection devices (EPD): Flow preservation devices with distal filters, distal occlusion devices, and proximal protection device by flow stasis or flow reversal. Neurosurgery department of Toyama University hospital has policy that asymptomatic carotid artery >80% treat by CAS (Gahremanpour, 2012).

Carotid stenosis cases will be analyzed by magnetic resonance imaging (MRI) and diagnostic digital subtraction angiography (DSA). DSA will be performed with addition of three-dimensional rotational angiography and 3D shaded surface displays (SSDs). Two imaging modalities will improve accuracy of the diagnosis and plan for treatment. DSA can evaluate the entire carotid artery system about tandem atherosclerotic disease, plaque morphology, collateral circulation, and lesion associated with atherosclerotic disease can be done



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by DSA. MRI was used to evaluate consistency of the plaque by T1 and TOF (Adla, 2015).

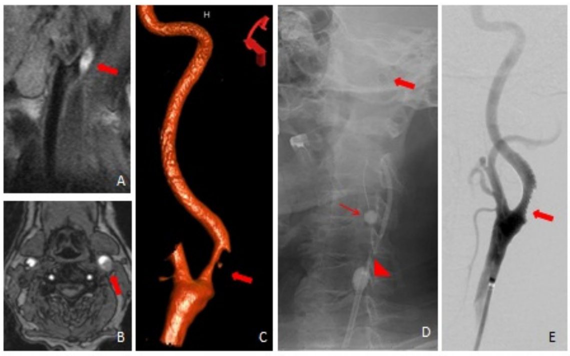


Figure 1: A. Plaque in T1 sagittal MRI image (arrow). B. Plaque in TOF axial MRI image (arrow). C. ICA stenosis showed by 3D angiography (arrow). D. Lateral unsbtracted angiographic view during angioplasty using du protection with flow reversal: CCA (arrowhead) and ECA (small arrow) occluded with balloon and distal filter (big arrow). E. CCA angiography after stenting.

Carotid stenosis with large and soft plaque (unstable plaque) was treated using dual protection device (simultaneous flow reversal and distal filter) and blood aspiration. Using EPD with only distal filter or proximal balloon protection by flow stagnant or flow reversal might not be sufficient to prevent debris migrating to intracranial artery because potential distal embolization by large and soft plaques is high. Dual protection during CAS can cause debris floating between the distal filter and the proximal end of the stent so blood aspiration was performed after post-dilation stent (Sakamoto, 2015).

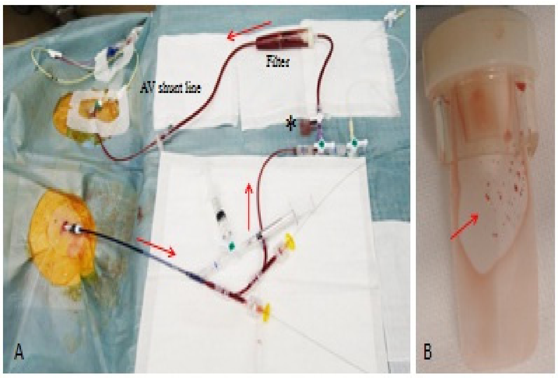


Figure 2: A. A 9 Fr occlusion balloon-guiding catheter in femoral artery connected to 4 Fr sheath in femoral vein via filter and line for manual blood aspiration (asterisk). B. Visible debris captured by the filter from AV shunt line. (Image used with permission from Akioka N. (2016). Textbook of JSNET educational seminar, Kobe).

All CAS procedures were performed under local anesthesia and using heparin to maintain activated clotting time between 250-300 seconds. Purpose of using local anesthesia is to enable neurologic examination during procedure. A 4 Fr sheath was placed into the left femoral vein and 9 Fr occlusion balloon-guiding catheter (OPTIMO; Tokai Medical Products, Aichi, Japan) was introduced into the common carotid artery (CCA) via right femoral artery. An external arteriovenous (AV) shunt line was created by connecting 9 Fr occlusion balloon-guiding catheter with 4 Fr sheath via the blood filter to capture debris. The line from AV shunt line was made for manual blood aspiration. The balloon wire system (GuardWire; Medtronic, Minneapolis, MN, USA) was introduced into the external carotid artery (ECA) and continuously inflated during procedure. Blood flowed to venous circulation through AV shunt line was confirmed after occlusion in the CCA and ECA because of difference pressure of arterial and venous (flow reversal). Distal filter using FilterWire EZ (Boston Scientific, Natick, MA, USA) passed through stenotic lesion and deployed into distal internal carotid artery (ICA). After dual protection was created with simultaneous flow reversal, stenotic lesion was pre-dilated then performed blood aspiration manually through AV shunt line about 30 cc using 50 cc syringe. Balloon in CCA was deflated after aspiration to reduce duration of brain ischemia. After inflation of CCA balloon, self-expanding stent (Carotid Wallstent; Boston Scientific or PRECISE; Johnson & Johnson, Miami Lakes, FL, USA) was deployed from distal stenotic lesion to the CCA and post-dilatation was performed. Manual blood aspiration through AV shunt line about 30 cc using 50 cc syringe was performed repeatedly until absence of debris from aspirated blood then CCA and ECA balloon deflated. EC balloon and distal filter was retrieved and the CAS procedure was completed.

## 2.2 Basilar Tip Aneurysm

Aneurysms in posterior circulation are considered as the most hazardous location and also been long considered as the most difficult lesion to treat by surgery. Treatment of posterior circulation aneurysms has shifted from microsurgery to endovascular during past decade. Microsurgical clipping in this region need aggressive cranial base resection and has high risk of perforator infarction and cranial nerves neuropathy. While endovascular treatments using coils with stent or balloon assistance are considered easier and more benign. Microsurgical clipping is considered as secondary alternative when endovascular treatment is not possible especially for both ruptured and unruptured aneurysms at basilar trunk, proximal anterior inferior cerebellar artery, or vertebrobasilar junction region (Sanai, 2008).

Important issue for endovascular treatment is aneurysm recanalization, with approximately 20% recanalized and 10% need retreatment. Quality of aneurysm occlusion was mostly depended on the neck size. Wide-neck aneurysm was treated with stent assisted coiling and study show significantly decrease need to retreatment and increase long-term anatomical stability. For recent years, wide-necked aneurysm on bifurcation artery like basilar tip was treated using Y-stenting technique. Y-stenting technique is Y-configuration double stent using combination of open-open, open-closed, or closed-closed stent with preserving parent artery circulation. This technique shown good outcomes with low complications but it's technically complex and has various challenges. Invention of braided stent with compliant and flexible closed-cell design enable to perform single stent assisted coiling at the wide-neck bifurcation aneurysm (Alghamdi, 2016; Du, 2016).

At neurosurgery department of Toyama University hospital**,** unruptured basilar tip aneurysms are treated with single stent assisted-coil jailed-catheter technique using Low-profile Visualized Intraluminal Support Junior device (LVIS Jr; MicroVention-Terumo, Tustin, California, USA) that are dedicated for small parent artery from 2 to 3.5 mm. Single stent assisted coiling using LVIS Jr can be obtained by placing from one of the branch arteries to the parent artery with pull and push technique. All procedure was performed in general anesthesia and by using heparin to maintain activated clotting time between 250-300 seconds. Procedures were using standard 6 Fr guiding catheter from one or both femoral arteries depend on the vertebral artery diameter, for small size vertebral artery both femoral artery will be used.

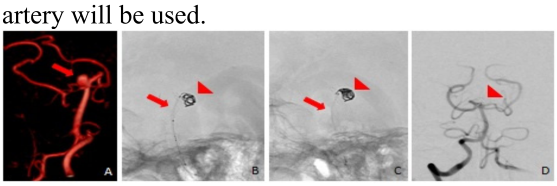

Figure 3: A. Wide-necked basilar tip aneurysm showed by 3D angiography (arrow). B. Coil (arrowhead) was partially inserted to the sac and stent (arrow) was deployed use 'push and pull' technique until cover all the neck. C. Stent (arrow) was fully deployed and embolizing with coils (arrowhead). D. Complete occlusion of Aneurysm (arrowhead).

Headway 21 microcatheter (Microvention-Terumo) will be used for LVIS Jr stent. First, Headway 21 microcatheter will be accessed to one of distal arteries. After that, other microcatheter that used to coil will be place in the aneurysm sac. Once both microcatheters were placed, the coil was partially inserted to aneurysm sac and stent was deployed three quarters until cover all aneurysm orifice. Unsheathing first centimeter of the stent by withdraw the microcatheter. After that, deployment of stent was by pushing on the pusher wire of the stent and pulling the microcatheter. The stent deployed 1 mm at a time and continued until the stent pooch at the neck of aneurysm and form a shape like shelf. After the stent was considered shape satisfactory, the rest of the stent was deployed three quarters using standard technique. Then by using dyna-CT, the stent was checked for the opening and absence of twisting. Now, the microcatheter containing coil was constrained between deployed stent and parent artery wall. Coils continued to deploy until aneurysm sac was completely packed, then stent can also be deployed completely. After aneurysm sac was completely occluded, microcatheter for coil was pulled slowly with microguidewire. Packed coils have been encaged between the aneurysm sac and stent to prevent migration out of the sac.

## 2.3 Carotid Cavernous Aneurysm

Natural history of aneurysms from cavernous segment was thought to be more benign and low tendency to rupture than other vascular territories. Due to dysplastic nature and anatomical morphology, treatment options including surgical clipping, parent artery occlusion with or without bypass, and endovascular coiling was difficult to achieve complete occlusion and have varying risk of morbidity and mortality. Treatment was only indicated for carotid cavernous aneurysm (CCA) that symptomatic (opthalmoplegia or intractable retro-orbital neuralgia), large size, and evidence of growth. Because of endovascular technology advances, new treatment option by using endoluminal device was offered with a promising clinical outcome and also low morbidity and mortality (Tanweer, 2014).

Endoluminal device or flow diversion is use to exclude aneurysm segment of the parent artery by implanting a metal scaffolding of low porosity (small pore size) across the aneurysm neck. The idea of flow diversion is to reduce intra-aneurysmal flow by redirect blood flow along the parent artery. Reduction of inflow jet velocity and level of shear stress on aneurysm wall will initiate thrombosis in the aneurysm sac. Ultimately, endothelization process will begin with neointima and endothelium overgrowth of the stent that covered the aneurysm neck. Adjacent branch vessel with uninterrupted perfusion will not be affected. Thrombus in aneurysm sac will be resorbed gradually via scavenger-cell-mediated process and aneurysm mass will collapse. This process begins immediate after stent deployment and evolves over weeks to months. Currently, flow diversion that approved by FDA is Pipeline Embolization Device (PED; ev3-Covidien, Irvine, CA) (Krishna, 2014).

PED is cylindrically shaped, self-expanding, and made of 75% cobalt chromium alloy and 25% platinum filament to impart greater radiopacity. PED has low porosity (65-70%) and available in 10-35 mm lengths and 2.5-5 mm diameters. Multiple PEDs can be telescoped within each other to increase length or to augment stent porosity over the aneurysm neck. PEDs are supplied loaded within a removable sheath an mounted on delivery microwire. The PED is delivered through 0.027inch inner diameter microcatheters so PED can be reconstructed to any location that can be accessed with a 0.027inch inner diameter microcatheter. Microcatheter can be advanced to either capture delivery wire or relocated distally for additional of PED deployment in a telescoping fashion (Krishna, 2014).

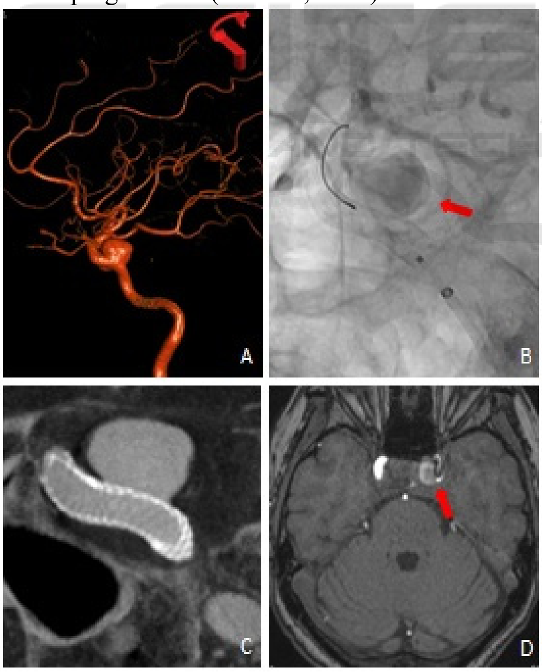


Figure 4: A. Cavernous carotid aneurysm showed by 3D angiography. B. Immediate angiography post flow diverter placement showed stasis of contrast within aneurysm sac. C. CT showed good position of device. D. Axial TOF MRI after oneweek treatment showed trombosis in aneurysm sac.

## 3 COMPARISON APPROACH

Endovascular therapy in 3 months at Toyama hospital was 33 cases compare to vascular surgery only 12 cases. For vascular lesion, there are great swift from vascular surgeries to endovascular therapies. So, endovascular therapies 2.75 times more than vascular surgeries. This is caused by improvement in endovascular technology that made endovascular therapies were effective and safe. Endovascular therapies need a lot of cost depend on how complicated the case and device that needed. Sometimes endovascular therapies more expensive than vascular surgeries.

Table 1: Approach list for vascular lesion.

| Procedure | Sum | Type |
|---|---|---|
| Carotid angioplasty Stenting | 14 | Endovascular |
| Coiling | 12 | Endovascular |
| Embolization | 7 | Endovascular |
| Clipping | 8 | Vascular |
| Vascular Anstomosis | 4 | Vascular |

## 4 CONCLUSION

Training with a different work culture at Toyama University Hospital was an excellent experience. It gave a broad perspective of different ways of to approach similar conditions. This training also made me more familiar with state-of-the-art neurosurgical equipment and procedures in endovascular and vascular neurosurgery.

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