Stent-Assisted Clip Placement for Complex Internal Carotid Artery Intracranial Aneurysms

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Abstract

Background—We report two procedures using a stent-assisted microsurgical clip placement to treat complex intracranial aneurysms originating from supraclinoid segment of the internal carotid artery.

Case Descriptions—In both procedures, primary clip placement was considered technically difficult due to either complex morphology or inferior protrusion of aneurysm fundus within the interclinoid space. A nitinol self-expanding stent was placed across the neck of the aneurysm either preoperatively or intraoperatively. Obliteration of aneurysm and patency of the artery was confirmed by angiography after clip placement.

Conclusion—Description of an integrated open microsurgical and endovascular approach and review of literature pertaining to considerations for treatment approach are discussed.

Keywords
Aneurysm; internal carotid artery aneurysm; microsurgery; stent placement; surgical clip

Introduction

Both surgical and endovascular treatment options provide unique advantages for treatment of intracranial aneurysms[21]. Craniotomy followed by clip placement has been infrequently used in the event of rupture related to coil placement in patients with intracranial aneurysms [2,11,23,24,26]. Such combined procedures may require removal of coils during surgery [23]. Planned combined procedures have been reported which include aneurysm exploration followed by endovascular treatment, partial aneurysm obliteration by clip placement followed by coil embolization, and extracranial-to-intracranial bypass followed by endovascular parent artery occlusion[10]. We report two cases of a novel approach, which consists of intravascular stent placement across the neck of the aneurysm followed by clip placement to obliterate the aneurysm.

Summary of Cases

Case 1

History and Presentation

A 75-year-old woman was driving when she developed sudden onset severe headache. She described her headache as a global throbbing headache and categorized it as the worst headache of her life. She was subsequently transferred to our hospital and on initial assessment, a Hunt and Hess grade 2 was assigned.

Imaging

Computed tomographic scan demonstrated diffuse subarachnoid hemorrhage, (Fischer grade III). Computed tomographic angiography demonstrated that there is no evidence of an aneurysm. On day one, she underwent digitally subtracted diagnostic cerebral angiography. A small conical broad-based aneurysm was detected at the junction of the left internal carotid artery and the posterior communicating artery (Fig. 1A). The aneurysm measured 2.5 mm × 3.7 mm with a 3.3 mm neck.
Operation

On day one, she underwent digitally subtracted diagnostic cerebral angiography. Under fluoroscopic guidance using roadmap, the catheter was advanced in the left internal carotid artery and digital subtraction angiographic images were obtained in anterior–posterior and lateral projections. This demonstrated focal protrusion and prominence of the left internal carotid artery at the level of the posterior communicating artery. Due to the small size and anatomical characteristics, it was decided to place an intravascular stent across the ostium of the aneurysm prior to attempting clip placement.

On day two, postsubarachnoid hemorrhage, the patient underwent stent placement and was already intubated and given general anesthesia. She did not receive aspirin or clopidogrel prior to the procedure. The catheters were infused continuously using 0.9% sodium chloride with heparin 200units/1000 ml. A six French MPD Envoy guide catheter (Codman Neurovascular, Wokingham, Berkshire, England) was advanced into the left common carotid artery over a 125 Simmons-2 catheter (Codman Neurovascular, Raynham, MA). The guide catheter was subsequently advanced into the internal carotid artery under fluoroscopic guidance over a 0.035-inch guide wire. A Prowler Select Plus microcatheter (Codman Neurovascular) was advanced through the cervical, petrous, cavernous and clinoid regions and then across the aneurysm over a Synchro II microwire (Boston Scientific, Natick, Massachusetts). The microcatheter was placed into the left inferior branch of middle cerebral artery. An exchange length microwire (Transend, Stryker) was advanced into the M2 segment and used to exchange existing microcatheter for a XT-15 microcatheter (Stryker Neurovascular, Fremont, California). After removing the microwire, A 4 × 22 mm Enterprise stent (Codman Neurovascular, Raynham, MA, USA) was advanced through the microcatheter under fluoroscopic guidance until it reached the distal end of the XT-15 microcatheter. The distal end of the stent was deployed at the origin of the M1 segment by retracting the XT-15 microcatheter while applying forward pressure. Initial attempt to deploy the distal end of the stent in the distal most internal carotid artery were not successful due to proximal displacement. The main body and proximal end of the stent were deployed in the internal carotid artery across the aneurysm neck with sufficient coverage both proximal and distal to the aneurysm. A postprocedure angiogram (Fig. 1B) demonstrated patency of the stent with adequate flow into the distal segments of anterior and middle cerebral arteries.

On day three, postsubarachnoid hemorrhage, the patient underwent a left pterional craniotomy for placement of aneurysm clips under general anesthesia. A 4-mm cutting bur was employed under operating microscope to access the dura and AM-8 bits were used to carry the dissection down along the sphenoid wing/ridge with minimal osteotomy for better access. After identifying the Sylvian fissure and anterior frontal lobe, dissection was performed until the optical carotid complex was identified. The inferior laterally pointing aneurysm was visualized at the supraclinoid level. The broad-based neck of the aneurysm was identified and the struts of the stent within the internal carotid artery could be visualized (Fig. 1C) A straight Yasargil clip (Aesculap, Inc. Center Valley, Philadelphia) was placed across the neck of the aneurysm. An initial migration of the clip was noticed and a second Yasargil semicurved clip (Aesculap, Inc.) was placed parallel and medial to the first clip on first attempt. A manual pressure on the arterial segment with stent from opposite direction confirmed the stability of the second clip. Intraoperative angiogram with left internal carotid artery catheterization demonstrated obliteration of the aneurysm and patency of the normal artery adjacent to the aneurysm (Fig. 1D).

Postoperative Course

The postoperative course was uncomplicated. Besides mild encephalopathic symptoms due to her underlying subarachnoid hemorrhage, she had no focal deficits. Aspirin 325 mg daily was started and daily transcranial Doppler studies showed no evidence of vasospasm. By postoperative day five, her encephalopathic symptoms had completely resolved. On postoperative day seven, she was discharged home with no neurological deficits. At one-month follow-up, she did not complain of any new symptoms.

Case 2

History

A 43-year-old woman presented to the emergency department with left facial droop, slurred speech, and left upper extremity weakness. She reports her symptoms began the night before with progressive worsening over the last five hours.

Imaging

The initial computed tomographic scan was normal. The patient subsequently underwent a head magnetic resonance imaging and magnetic resonance angiography that demonstrated a distal left internal carotid aneurysm at
the upper cavernous/postcavernous location measuring 8 mm with a broad neck. The magnetic resonance imaging demonstrated an acute infarct in the right corona radiata adjacent to the thalamus on diffusion-weighted sequences. The patient was started on aspirin (325 mg daily). The following day, she had an elective catheter angiogram to further characterize the unruptured intracranial aneurysm that was detected on magnetic resonance angiogram. The images acquired from injection following selective left internal carotid artery catheterization demonstrated aneurysm measuring 6.1 mm × 9.1 mm in dimension with 4.9 mm neck originating from left internal carotid artery. The aneurysm originated from the clinoid segment of internal carotid artery adjacent to origin of posterior communicating artery and projected inferiorly and medially toward the cavernous sinus in the

Figure 1. A: a small conical broad-based aneurysm was detected at the junction of the left internal carotid artery and the posterior communicating artery (arrow). B: Poststent placement angiogram demonstrated patency of the stent with adequate flow into the distal segments of anterior and middle cerebral arteries C: the struts of the stent are visualized within internal carotid artery and aneurysm is visualized (arrow), D: Intraoperative angiogram demonstrating obliteration of aneurysm after clip placements (arrow).
interclinoid space (Fig. 2A). She underwent rehabilitative treatments until day 7 when she had resolution of her presenting symptoms. She was scheduled for elective surgical aneurysm treatment.

**Operation**

A month after occurrence of acute ischemic stroke, she underwent a left pterional craniotomy for aneurysm clip placement under general anesthesia and continued on aspirin. After obtaining pterional access under operating microscope, dissection was performed until optical carotid complex was visualized. The anteroinferiorly pointing large internal carotid artery aneurysm was visible at the supraclinoid level. However, the aneurysm fundus projected within the inter clinoid space parallel to the internal carotid artery. The 4-mm diamond bit and high-speed drill was used to perform osteotomy of the overlying clinoid process. Despite further exposure using a combination of the drill and 1.0 mm Kerrison rongeur,
the inferior end of the aneurysm and separation from parent artery was not well visualized. Microangiography with indocyanine green (Akron Inc, Lake Forest, Illinois) IV contrast video angiography was performed to identify the borders of aneurysm and the study confirmed the aneurysm fundus descending within the clinoid/carotid foramen. To ensure stability and patency of the parent artery, an intraoperative angiogram was performed and a decision to place a stent across the aneurysm made in conjunction with the family. The decision to place a stent prior to clip placement was based on the need to provide internal support and alignment of the internal carotid artery. Using road map guidance from C-arm equipment (Toshiba medical systems corporation), a six French MPD Envoy guide catheter (Codman Neurovascular) was advanced into the left internal carotid artery. The XT-15 microcatheter (Stryker Neurovascular, Fremont, California) was advanced over a Synchro II microwire (Boston Scientific) through the cervical, petrous, cavernous, and clinoid segments of the internal carotid artery across the aneurysm the microcatheter was placed into the left inferior branch of middle cerebral artery. A 4 × 22mm Enterprise stent (Codman, Neurovascular) was advanced through the microcatheter under fluoroscopic guidance until it reached the distal end of the XT-15 microcatheter. The distal end of the stent was deployed at the distal most segment of the internal carotid artery by retracting the XT-15 while applying forward pressure on the stent delivery wire. The main body and proximal end of the stent were deployed in the internal carotid artery across the aneurysm neck with sufficient coverage both proximal and distal to the aneurysm. An intraoperative angiogram (Fig. 2B) demonstrated patency of the stent with adequate flow into the distal segments of anterior and middle cerebral arteries.

The neck of the aneurysm was identified under operative microscope and a left angled clip Yasargil clip (Aesculap, Inc. Center Valley, Philadelphia) was placed across the neck. A small remnant of the aneurysm was seen medial and outside the first clip. A second small straight clip Yasargil clip (Aesculap, Inc. Center Valley, Philadelphia) was placed alongside to obliterate the remaining small remnant (Fig. 2C). Both clips were placed on first attempts. Intraoperative angiogram with left internal carotid artery catheterization demonstrated obliteration of the aneurysm and patency of the normal artery adjacent to the aneurysm (Fig. 2D).

**Postoperative Course**

The patient’s postoperative course was uncomplicated and she had no residual neurologic symptoms or focal neurological deficits in the postoperative period. The patient was started on aspirin 325 mg daily. The patient experienced local swelling and ecchymosis in the over the left orbital region. A postoperative computed tomographic scan demonstrated the previous infarct and the two clips in the vicinity of the skull base. The patient was discharged four days later. She was asymptomatic at follow-up two months later. She was also found to be a heterozygous carrier for factor V mutation.

**Discussion**

We report the results of clip placement in two patients with intracranial aneurysm after stabilization of parent artery by intravascular stent placement. We used intravascular stent placement for the visual and tactile identification of parent artery and aneurysm junction. The intravascular stent also limited the compressibility and prevented inadvertent clip placement across the parent artery. The concept of parent artery protection from coil protrusion by stent placement has been used in endovascular treatment of intracranial aneurysm [1,4,13,25]. The stent has been placed either prior to coil embolization or after protrusion of coils to reconstruct the parent artery lumen. The first patient that was treated had a ruptured conical broad-based aneurysm that was pointing posteriorly and medialy. Such aneurysms similar to blister aneurysms are difficult to treat by surgical or endovascular treatments and have a relatively high risk of intra procedural rupture and parent artery compromise [7,9,16]. The aneurysm was successfully obliterated after placement of two clips. In the second patient, the close proximity of the downward projecting aneurysm fundus and parent artery in the interclinoid space prevented adequate exposure for clip placement intraoperatively. Extradural anterior clinoidectomy to increase exposure and better visualization was another option [19,20]. The current approach was preferred to avoid the risks of direct power-drilling mechanical and thermal injury to adjacent mucous membranes of sinuses, caroticoclinoid foramen, and interclinoid osseous bridge and the risks of ultrasound-associated cranial neuropathies [3,19].

Certain changes occur within the arterial wall and aneurysm hemodynamics after stent placement. Straightening of parent artery, increase in angle at bifurcation, and flow reductions into aneurysm have been seen after stent placement. Stent placement straightened the parent artery by a mean (±standard deviation) of 12.9 ± 13.1 when analyzed by computational flow dynamic studies [14]. Straightening of vessels reduced flow velocity by 9.6% ± 12.6%. The struts of the stent had considerably greater flow velocity reduction and the combination of
stent struts and straightening reduced flow velocity by 32.6% ± 12.2%. In patients with bifurcation intracranial aneurysms, [6], stent placement increased the bifurcation angle with significant straightening immediately after treatment. Stent-induced angular remodeling blunted apical pressure in aneurysm as assessed by computational flow dynamic studies. We used the Enterprise nitinol-based self-expanding stent with a nominal diameter of 4.5 mm and is indicated for placement in arteries with diameters ranging from 2.5 mm to 4 mm. The Enterprise stent is retractable after partial deployment. The radial force of a stent corresponds to the force that the stents exert on the vessel wall and is available to support the wall under external compression [15]. The radial force of Enterprise stent under 50% compression was 0.0082 N/mm and chronic outward force was 0.010 N/mm. In comparison, the radial force of Wingspan stent under 50% compression was 0.0116 N/mm and chronic outward force was >0.020 N/mm. The stent is coated with Parylene C and has therefore a very smooth surface in addition to low radial force [15]. Spontaneous stent displacement has been observed after Enterprise stent deployment [5, 15, 17, 18]. We did not observe any stent movement during or after clip placement in the two cases because external compression was limited to the central part of the stent.

There are some important considerations regarding the currently described technique. It is a common practice to use a combination of aspirin and clopidogrel to prevent stent thrombosis in patients after stent placement [12, 22]. Unlike stent placement for atherosclerotic lesions, stent thrombosis is infrequent when used for aneurysmal disease [8]. Because of necessity of follow-up craniotomy in such an approach, aspirin alone may be more preferable to combination treatment. However, increased vulnerability to stent thrombosis must be recognized. The second potential limitation is secondary to alteration in physical properties (limited focal compressibility) that may impede a stable clip placement. In the first patient, difficulty in clip placement was evident. Temporary or permanent occlusion of the parent artery in the event of intraoperative aneurysm ruptures maybe difficult in the presence of an intravascular stent.

Our reports present the initial experience with a novel combination of endovascular and neurosurgical techniques to treat complex internal carotid artery aneurysms.

References


