

Clinical Article

Experiences of Neuroform Stent Applications for Ruptured Anterior Communicating Artery Aneurysms with Small Parent Vessel

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Objective : The purpose of this study was to review the safety and durability of aneurysms treated with stent-assisted coiling of ruptured anterior communicating artery aneurysms with small parent vessels (< 2.0 mm).

Methods : Retrospective review of all ruptured aneurysm treated with stent assisted endovascular coiling between March 2005 and March 2009 at our institution was conducted. We report 11 cases of the Neuroform stent placement into cerebral vessels measuring less than 2.0 mm in diameter (range, 1.3-1.9 mm) in anterior cerebral artery. Clinical follow-up ranged from 3 to 12 months and imaging follow-up was performed with cerebral angiography at 6 months and 12 months after discharge.

Results : Complete occlusion was achieved in 10 patients, and a remnant neck was evident in one. No stent displacement or no dislodgement occurred during stent placement. There was no evidence of thromboembolic complication, arterial dissection and spasm during procedure. We performed follow-up angiography in all patients at 6 months and/or 12 months from the first procedure. The follow-up angiographic data showed successfully results except one in-stent stenosis case. All patients improved clinical performances except one patient with severe vasospasm who showed poor clinical condition initially.

Conclusion : We have safely and successfully treated 11 vessels smaller than 2.0 mm in diameter with self-expanding stents with good short and intermediate term results. More clinical data with longer follow-ups are needed to establish the role of stent-assisted coiling in ruptured aneurysms with small parent vessels.

KEY WORDS : Neuroform stent · Small parent vessel.

INTRODUCTION

Endovascular embolization of intracranial aneurysms with detachable coils is associated with lower morbidity and mortality rates compared with traditional microsurgical clipping^{11,12}. However, despite advances in devices and techniques, endovascular treatment of wide-necked aneurysms remains one the technical challenges. If the neck of the aneurysm is not narrow enough to contain the coils, the coil can be herniated into the parent vessel.

Various tools and techniques have been introduced to over-

come these limitations including three-dimensional (3D) coils, multiple microcatheter, and remodeling techniques^{10,13,17}. Neuroform stent (Boston Scientific/Target Therapeutics, Fremont, CA, USA) is a specifically designed for use in cerebral vessels and is increasingly being used in the embolization of wide-necked aneurysms.

An increasing number of publications has reported on the use of the Neuroform stent in the embolization of wide-necked aneurysms^{1,6,7}. Stent-assisted coiling has also been proposed as an alternative to achieve endovascular reconstruction of complex aneurysms. However, the published data on stent-assisted coiling consist mostly of results in unruptured aneurysms, and the safety of the procedure during ruptured aneurysms is still open to dispute. In particular, its use for wide-necked aneurysms with small parent vessel is limited. In this article, we describe our experience in 11 patients with ruptured wide-necked aneurysms with small

• Received : May 4, 2010 • Revised : June 15, 2010
• Accepted : June 29, 2010
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parent vessel treated by stent-assisted coiling.

MATERIALS AND METHODS

Patient population

Between March 2005 and March 2009, a total of 123 aneurysms (94 ruptured; 29 unruptured) were treated using the stent assisted coiling at our institution. Among these aneurysms, 11 cases with a ruptured anterior communicating artery (ACoA) aneurysm with small parent vessel have been selected for this study. Patient selection for treatment with intracranial stenting and coiling was based on only on the angioarchitectural characteristics of each aneurysm. Only broad ACoA aneurysms with small parent vessels (< 2.0 mm) were considered for this treatment. The definition of broad neck in this series was a complex wide-necked aneurysm (neck > 4.0 mm) or an aneurysm with a neck diameter smaller than 4 mm in which the dome/neck ratio less than 1.5.

The detailed information, including the patient's age and sex, aneurysm location, clinical manifestations (Hunt and Hess grade, Fisher grade), aneurysm morphology (dome and neck, parent vessel size), and endovascular treatment strategy (used stent size) was carefully reviewed. Initial and follow-up angiographic results were recorded at points of periprocedural stenosis or coil migration, stent displacement etc.

Overall, clinical follow-up ranged from 3 to 12 months, with mean of 7.5 months, and angiographic follow up was performed at 6 months and 12 months after discharge from the hospital. Clinical modified Rankin Scale (mRS) scores were recorded at 24 hours, 2 weeks, 6 months, and 12 months (last follow-up period) post-procedure.

After the procedure, angiographic results were classified by the following : 1) class 1 as complete obliteration. 2) class 2 denoted a residual neck that was defined as the persistence of any portion of the original defect of the arterial wall as seen on any single projection but without opacification of the aneurysmal sac. 3) class 3 was defined any opacification of the sac that was classified as residual aneurysm and considered a failure of treatment.

Timing of endovascular treatment

Ideally, this type of ruptured aneurysm should be treated on an emergency basis to avoid a second and mostly fatal rebleeding. Note that 100% of patients were treated within 24 hours of subarachnoid hemorrhage (SAH) except for delayed referral patients from other hospital.

Process

All procedures were performed under intravenous sedation by using Propofol and Alfentanil. Patients were not pretreat-

ed with clopidogrel and aspirin. Both conventional and rotational digital subtraction angiographies (DSA) were performed for 3D reconstruction in all patients. Following cerebral angiography and the discovery of an aneurysm considered to be adequate for direct coiling. If it was decided for application of stent, a bolus of 3,000 to 5,000 IU of heparin was administered after insertion of a 6 French guiding catheter in internal carotid artery followed by 1,000 IU/hour of heparin and intravenous aspirin lysine[®] (aspirin 900 mg) during the endovascular procedure. During the procedure an activated clotting time was maintained between 250 and 300 seconds.

Stents were prepared by attaching the stent delivery catheter and stabilizer to heparinized saline flushed, and advancing the stabilizer into the delivery catheter proximal to the stent. At the appropriate location for sufficient coverage of the aneurysm base, the stent was gently deployed and the delivery catheter was subsequently retrieved. After successful stent placement, coil embolization was performed with detachable coils through a microcatheter (Excelsior SL-10; Bostone Scientific/Target Therapeutics) placed in the aneurysm through the interstices of the stent. Eventually, we deployed stent first, then we advanced a microcatheter into aneurysm sac and packed coils in all our patients.

After the procedures, patients were transferred to the intensive care unit, and fluid balance, neurological status, blood pressure were carefully monitored. All patients were maintained on clopidogrel (75 mg per day) for a 2 weeks and aspirin (100 mg per day) for 4 weeks.

RESULTS

Angiographic results

Eleven patients (five men and six women) were treated with conventional Neuroform stent-assisted coiling. The age ranged from 38 to 74 years with a mean age 55. According to the Hunt and Hess (H-H) grade, 1 patient was classified as grade I, 6 patients as grade II, 2 patients as grade III; and 2 patients as grade IV (Table 1).

Selective embolization was successfully performed in all patients and resulted in excellent clinical outcomes. In 11 cases, the microcatheter was easily navigated and positioned with a micro-guidewire past the aneurysm neck. Stent deployments were technically successful in all eleven patients. Parent vessel diameter ranged from 1.3 to 1.9 mm with a mean 1.6 mm as measure on cerebral angiography with 3D reconstruction. Complete occlusion was achieved in 10 patients, and a remnant neck was evident in one. No stent displacement or no dislodgement occurred during stent placement. There was no evidence of thromboembolic complication, arterial dissection and spasm during procedure.

We performed follow-up angiography in all patients at 6 months and/or 12 months from the first procedure. In one of these 11 patients, follow-up angiogram 6 months after procedure showed stenosis of the parent vessel that was not evidence at the immediate post-procedural angiographic images. This patient with in-stent stenosis of the parent artery remained asymptomatic and takes a medication by aspirin alone.

Clinical outcomes

Clinical evaluation was performed in all patients before their discharge from the hospital and clinical mRS scores were recorded at 24 hours post-procedure and 2 weeks, 6 months, and last follow-up period.

One patient with a poor pre-procedural condition died as a consequence of severe vasospasm within 12 days after the embolization procedure. Each patient presented mRS score 0 in 5, score 1 in 1, score 2 in 3, score 3 in 0, score 4 in 1 and score 6 in one (Table 1).

Complications

There were no major complications during procedure and peri-procedure, including infarction, in stent stenosis, aneurysm rupture, and vessel dissection in treated lesion.

In one aneurysm case, delayed in-stent stenosis occurred in a patient follow-up angiogram 6 months after procedure. And, one patient underwent external ventricular drainage for acute hydrocephalus at immediate post-procedure period. This patient was fully recovered without neurologic deficits (Table 1).

Illustrative cases

Case 3

A 66-year-old woman presented with a 3.2×4.0 mm sized ACoA with a wide neck and grade 3 of H-H grade (Fig. 1A). The left A1 and A2 segments of anterior cerebral artery (ACA) were selectively navigated with a 0.14-microguide wire (Transend soft; Boston Scientific/Target, Fremont, CA,

Table 1. Characteristics of 11 ruptured aneurysms treated with stent-assisted coiling

Case	Age	Sex	Location	H-H grade	Fisher grade	Dome size (mm)	Neck size (mm)	Parent artery size (mm)	Stent size (mm)	Angiographic results		mRS last	Cx. last
										Initial	F/U		
1	50	F	ACoA	2	3	3.2	3.0	1.7	2.5 × 20	Class 1	Class 1	0	None
2	49	M	ACoA	4	4	5.0	4.0	1.9	2.5 × 20	Class 2	Class 2	4	None
3	66	F	ACoA	3	4	3.2	4.0	1.5	2.5 × 20	Class 1	Class 1	2	None
4	74	M	ACoA	2	2	4.2	4.4	1.5	2.5 × 20	Class 1	Class 1	2	None
5	38	M	ACoA	4	4	12.0	5.0	1.7	2.5 × 20	Class 1	-	6	Dies
6	70	F	ACoA	3	3	6.2	5.2	1.8	2.5 × 20	Class 1	Class 1	0	None
7	60	F	ACoA	2	3	4.8	4.4	1.8	2.5 × 20	Class 1	Class 1	0	None
8	67	F	ACoA	1	2	3.5	3.3	1.3	2.5 × 20	Class 1	Class 1	1	None
9	50	F	ACoA	2	2	6.0	3.6	1.8	2.5 × 20	Class 1	Class 1	0	None
10	48	M	ACoA	2	3	5.8	3.2	1.9	2.5 × 20	Class 1	Class 1	2	None
11	48	M	ACoA	2	2	4.6	3.2	1.9	2.5 × 20	Class 1	Class 1	0	None

Class 1 : complete occlusion. Class 2 : remnant neck (nearly complete occlusion). H-H grade : Hunt and Hess grade, mRS : modified Rankin Scale, Cx. : complication, ACoA : anterior communicating artery



Fig. 1. 3D reconstruction image in left internal carotid artery (ICA) angiography presented with a 3.2×4.0 mm sized anterior communicating aneurysm (ACoA) with a wide neck. A : 3D angiogram shows anterior communicating artery aneurysm on left ICA before the procedure. B : Immediately post-treatment, left ICA angiography demonstrating no contrast dye filling in the aneurysm. C : Follow-up 6 months angiographic image, there are no definite internal change with coil and stent.

USA). A 2.5 × 20 mm Neuroform stent was deployed from the left A2 segment into the right A1 segment to restrain the coils within the aneurysm because of broad neck (Fig. 1B). Following stent placement, the aneurysm was embolized with multiple variable sized coils and follow-up angiography was obtained 6 months later (Fig. 1C).

Case 6

A 70-year-old woman was admitted with sudden onset of severe headache relating to a ruptured aneurysm at the left dominant ACoA aneurysm and H-H grade 3. The aneurysm measured a 6.2 × 5.2 mm had a broad neck and irregular shape with 1.8 mm parent vessel (Fig. 2A). A 2.5 × 20 mm sized Neuroform stent was deployed from left A2 segment to ipsilateral A1 segment. Following placement of the stent, the aneurysm was embolized with multiple sized coils (Fig. 2B). No complications during procedure, including aneurysm rupture, in-stent stenosis, infarction, vessel dissection in procedural lesion, occurred. At procedure 12 months later, follow-up angiography was performed and there were no definite interval change (Fig. 2C).



Fig. 2. Left ICA angiography and 3D reconstruction image presented with a 6.2 × 5.2 mm sized ACoA with a wide neck. A : The left ICA angiogram shows a wide-neck aneurysm at ACoA segment before treatment. B : Immediately after the treatment, left ICA angiography no contrast dye filling in the aneurysm. C : At follow-up angiography after 12 months, coil and stent application was good position without stenosis.



Fig. 3. Left ICA angiography and 3D reconstruction image presented with pre and post-embolization view, then follow-up image showed in-stent stenosis. A : The left ICA angiogram 3D reconstruction image showing a 4.6 × 3.2 mm sized broad neck ACoA with 1.9 mm parent vessel before embolization. B : Immediately post-treatment, oblique view left ICA angiogram demonstrating an optimal stent position and no filling in aneurysm. C : Follow-up cerebral angiography after 6 months, angiogram revealed in-stent stenosis at left anterior cerebral artery (A1) segment.

Case 11

A 48-year-old man was admitted with sudden onset severe headache and decreased mentality. Clinical manifestation was the H-H grade 2. Angiographic image showed a 4.6 × 3.2 mm sized broad neck ACoA aneurysm with 1.9 mm parent vessel (Fig. 3A). A 2.5 × 20 mm sized Neuroform stent deployed from left A2 segment to ipsilateral A1 segment. Stent was deployed over the neck of the aneurysm in satisfactory position. After successful stent placement, coiling was performed with multiple sized coils (Fig. 3B).

The patient was discharge after procedure 14 days without any neurologic deficit. Then follow-up angiogram 6 months after treatment showed stenosis in parent vessel at left anterior cerebral artery (A1) vessel that was stent placement (Fig. 3C). But patient was no neurologic change relation in-stent stenosis. Until now, the patient is observed clinically and angiographic aspect, remained without neurologic deficit.

DISCUSSION

The development of a flexible and self-expandable intra-

cranial stents has increased the options for treatment of wide-necked aneurysms. In associated with coiling, the deployment of a stent within the parent vessel has some advantages^{2,7,15}. It enables dense packing in aneurysm, it induces significant intra-aneurysmal flow modification that may lead to spontaneous thrombosis, and it may provide a framework for endothelial growth resulting in permanent separation of the aneurysm from parent vessel lumen. Up to now, several authors have demonstrated the technical feasibility and efficacy of treating complicated intracranial aneurysms^{5,6}.

The stents may produce flow redirection and disruption of the aneurysm inflow and outflow zones resulting in hemodynamic uncoupling of the parent vessel-aneurysm complex^{6,7}. This hemodynamic advantage may help to reduce flow in the region of the inflow zone and prevent subsequent growth of the aneurysm and promote the endothelium.

However, the use of the Neuroform stent can lead to complications as reported in some articles. The stent may also cause vessel trauma and vessel caliber can decrease by stent deployment, especially in small parent vessels. Fiorella et al.⁴ reported on a case of delayed stent stenosis after the use of the Neuroform stent in the coil embolization of a wide-necked aneurysm. And, intimal hyperplasia, the main cause of early restenosis, follows a fairly predictable time course. The greatest smooth muscle proliferation in humans with serial angiographic studies was demonstrated between 1 and 3 months after the procedure; only a small number of stents exhibited narrowing between 6 and 12 months⁸. But, the incidence of in-stent stenosis after stent deployment will be unclear.

In this way, most published data on stent-assisted coiling consist of results in patients with unruptured aneurysms, and the safety of the procedure in ruptured aneurysm is still open to dispute. Additionally, there is limited knowledge of effects of self-expandable stent on the ruptured aneurysms with small parent vessels. Zhang et al.¹⁸ described 12 patients who had safely and successfully undergone stent treatment in small parent vessel < 2.5 mm with good short and intermediate-term results, including 9 ruptured aneurysms. Turk et al.¹⁶ have safely and successfully treated 8 vessels smaller than 2.0 mm in diameter with newer self-expanding stents in distal small cerebral vessels with good intermediate-term results. However, there are few reports in the literature describing the feasibility, use a safety of the Neuroform stent in ruptured aneurysms with small parent vessel.

Stent-assisted coiling is considered to be thrombogenic until the stent is covered by endothelialization and the normal intrinsic fibrinolytic activity of the endothelium is renewed. Most authors report that the premedication of antiplatelet drugs have been strongly recommended to prevent the thromboembolic events enhanced by stent positioning^{4,5,9}.

But, in the cases of ruptured aneurysms, the procedures should be performed as early as possible with the recommended premedications of antiplatelet drug for 2 or 3 days in most cases. Katsaridis et al.⁹ reported a series of 44 patients treated with stent and coiling for ruptured intracranial aneurysms who were not pretreated with antiplatelet agents. Satisfactory aneurysm occlusion was achieved in 94.4% of cases, whereas there was no aneurysm bleeding, and no aneurysm recanalization or thromboembolic events have been reported. Ries et al.¹⁴ presented peri-operative infusion of acetylsalicylic acid has been shown to decrease the rate of thromboembolic events without an increase in the intra-operative bleeding rate and is advocated in the endovascular treatment of aneurysms, including ruptured aneurysm. The optimal antiplatelet medication during acute-phase treatment has yet to be determined, and a longer follow-up series is needed to evaluate the safety and efficacy of stent-assisted coiling in acute ruptured aneurysms.

The stent size should be chosen to match the diameter of the pertinent vessel and correspond to the length of the aneurysm neck. However, acute phase of ruptured aneurysms, there will be moderate or severe vasospasm. At this time, stent should not be undersized due to an inadequate measurement of vessel, which leads to the incorrect stent choice. Consequently, the authors usually oversize the diameter of stents used in cases presented here.

In our opinions, there are couple of cautious factors in ruptured aneurysm with small sized parent artery. In these cases, there is a possibility of insufficient expansion of stent because Neuroform stent has a lower radial force (10 mmHg), so that there would be small size of stent strut. It makes interventionists to place a microcatheter safely into the aneurysm and consequently, manipulation of the microcatheter can produce thrombus formation. This risk would be higher in cases closed cell design stents. Therefore, we need to be more careful in manipulation during procedure. In addition, first coil plays an important thing that provide to prevent coil migration or protrusion to parent vessels from aneurysm sac in shape formation after stent deployment in small sized aneurysm³.

The current report has some limitations. There were relatively short term clinical and angiographic follow-up periods and cases were limited in numbers (eleven cases). Therefore, further follow-up and more experience are necessary to determine long-term results.

CONCLUSION

Our preliminary findings suggest that Neuroform stent-assisted coiling for ruptured wide-necked anterior communicating artery aneurysms with small parent vessel (< 2.0 mm)

is technically feasible and effective. Follow-up angiographic data showed successful results with no severe imaging abnormalities except one in-stent stenosis case. A clinical result also was good without severe neurologic deficit except one severe vasospasm case.

Careful stent deployment seems to be important for ensuring good stent conformity within the arteries, particularly in significantly small parent vessels. More clinical data with long follow-up are needed to help establish the role of stent-assisted coiling in ruptured ACoA with small parent vessel.

• Acknowledgements

The present research was conducted using the research fund of Dankook University in 2008.

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