Early Experiences of Neuroform Stent-Assisted Coiling in Ruptured Intracranial Aneurysms

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Summary

Endovascular treatment of ruptured intracranial aneurysms with detachable coils has proven a favorable alternative to surgical clipping. However, coiling has limitations in the treatment of complex or broad neck aneurysms because of possible coil prolapse or coil migration into the parent vessel and long-term angiographic recurrences. To achieve reconstruction of intracranial vessels with preservation of the parent artery, the use of stents has the greatest potential for assisted coil embolization. Three-dimensional coils and reconstructive techniques such as balloon-assisted remodeling may overcome these problems. But these methods had some drawbacks.

The Neuroform stent is the most recently developed endovascular stent with self-expandable and micro-delivery properties that are specially designed for the treatment of unruptured intracranial broad neck aneurysms.

Aim of the following working is to report a single center experience of stent-assisted coiling on ruptured intracranial aneurysms with assessment of its efficacy and safety, and follow-up findings.

Introduction

The endovascular treatment of intracranial aneurysms with detachable coils has developed into a widely used and successful technique¹⁻⁴. Despite rapid technological advances in en-

dovascular technology and development of coil engineering, complex aneurysms have remained difficult because of their unfavorable geometry, which reduces the possibility of complete elimination of aneurysm from the parent artery¹.

The Neuroform stent (Boston Scientific/Target Therapeutics, Inc., Natick, MA) is the microcatheter delivered self-expandable stent designed specifically for the treatment of unruptured intracranial aneurysms⁵⁻⁷. So the premedication of antiplatelet drugs has been strongly recommended to prevent thromboembolic events during and after the procedure. But, in the case of ruptured aneurysms this procedure might have some limitations due to concern over premedication with these antiplatelet drugs.

The stent provides durable parent vessel protection during the coiling of complex aneurysms, and improving the density of coil packing to obtain a better angiographic result, and enabling final endovascular reconstruction of the arterial wall. Several authors already reported the use of a self-expanding stent for the treatment of broad neck aneurysms and showed the effectiveness of this technique⁵⁻⁷. But little clinical analysis has focused on ruptured aneurysms.

This study reports a single institution experience of Neuroform stent-assisted coiling for the treatment of ruptured complex intracranial aneurysms.

Clinical Material and Method

Patients Population

Between October 2003 and June 2006, 46 patients with ruptured intracranial aneurysms were 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 aneurysms were considered for this treatment. The definition of broad neck in this series was a complex wide-necked aneurysm (neck > 4 mm) or an aneurysm with a neck diameter smaller than 4 mm in which the dome/neck ratio was less than 1.5.

The routine follow-up angiographic studies were scheduled to be performed at a minimum of three months. Further clinical follow-up data were collected during hospitalization for follow-up angiography or by telephone interviews. The total number of months of clinical follow-up for each patient was recorded. The mean $\pm$ SD clinical follow-up was 12 ± 8.32 months.

Timing of Treatment

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

Procedure

Patients were not pretreated with the antiplatelet drugs Clopidogrel or Aspirin because the aneurysms in this study were all ruptured and coilings were performed on an emergency basis. The procedures were performed under intravenous sedation using Propofol and Alfentanil, which is the general anesthetic method for endovascular aneurysm coiling in this institute. The aneurysms were considered adequate for stent-assisted coiling and a bolus of 3,000 to 5,000 IU of heparin was administered after insertion of a 6 French introducer sheath followed by 1000 IU/hour of heparin and were started on the intravenous Aspirin lysine® (Aspirin 900 mg) at the beginning of the procedure. The activated clotting time was maintained between 250 and 300 seconds as usual.

All Neuroform self-expandable stents (Boston Scientific/Target Therapeutics, Inc., Natick, MA) were oversized by 0.5 mm compared with

the parent artery. The appropriately sized stent was selected (available sizes include 3.0 to 4.5 mm nominal diameters with 15 to 30 mm nominal lengths). 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. The stents were deployed over the neck of the aneurysm in a satisfactory position. After successful stent placement, coil embolization was performed with detachable coils through a microcatheter (Excelsior SL-10; Boston Scientific/Target Therapeutics) placed in the aneurysm through the interstices of the stent.

Three different therapeutic strategies were chosen: 1) initial stent implantation followed by coil placement; 2) placement of coils followed by stent implantation in the case of coil prolapse to the parent artery, and 3) stent alone. After the procedure, patients were transferred to the intensive care unit, and hemostasis was achieved by use of an arterial closure device. Heparin was not reversed at the end of the procedure.

Angiographic Findings

Angiographic findings were recorded immediately post coiling for all patients. The angiographic obliteration results were classified into three groups: 1) complete occlusion if no entry of contrast agent into the aneurysm sac was observed; 2) remnant neck (nearly complete occlusion) if entry of contrast agent was evidenced at neck without dome opacification; and 3) subtotal or incomplete occlusion if opacity due to the contrast agent was seen at the dome or among the coil interstices.

Follow-up

The first angiographic follow-up examination was scheduled after a minimum of three months. Clinical status was graded according to Glasgow Outcome Scale (GOS) at discharge or telephone interview.

Results

Patients

Forty-six patients with 48 aneurysms were treated with stent-assisted coiling during the study period. Nine were male, and thirty-seven were female. Patients ranged from 29 to 85 years of age (mean age 60.2 yrs). In this series

Figure 1 A) Lateral view of the right internal carotid artery (ICA) angiogram showing the aneurysm at the posterior communicating artery during coiling, but coil loop protruded toward parent artery. B) Lateral view of the right ICA angiogram showing the aneurysm at the posterior communicating artery after stent-assisted coiling because the herniated coil loop may be put again into aneurysm in consideration of the complication like parent artery obstruction caused by coil loop.

two patients presented with multiple aneurysms. In 38 of the 46 patients, neurological status was good (Hunt and Hess Scale Scores I-III) whereas in the other patients neurological condition was poor (Hunt and Hess Scale Scores IV or V) (Table 1).

A total of 49 Neuroform self-expanding stents were implanted. In three cases the stent in stent technique was conducted for the treatment of internal carotid artery dissection aneurysms (cases 4, 32, 40). In one case a Y-shaped reconstruction was performed for the treatment of a basilar tip aneurysm (case 17). One patient of stent navigation failure was excluded from the trial. Angiographic follow-up ranging from three to 24 months was available (Table 1).

Aneurysm Characteristics

All aneurysms considered for this treatment had broad necks (Table 1). Anatomically, 37 lesions were located in the anterior circulation (carotid artery-ophthalmic artery, three patients; posterior communicating artery, 30 patients; choroidal artery, one patient; middle cerebral artery, one patient; anterior communicating artery, one patient) and nine aneurysms were located in the posterior circulation (vertebral artery, two patients; posterior inferior cerebellar artery, one patient; superior cerebellar artery, one patient; basilar tip, five patients). The majority of aneurysms were smaller than 10 mm with a dome/neck ratio less than 1.5.

The average neck size was 5.7 mm (range, 2.0-13 mm). The average dome size was 9.1 mm (range, 2-25 mm).

Angiographic Results and Clinical Outcomes

The angiographic results for each case are summarized in Table 1. The complete occlusion rate was 76.1% (35 patients), each remnant neck and incomplete occlusion were 10.8% (five patients) and 13.1% (six patients). Two patients died from pneumonia and sepsis in the hospitalization period, four patients were lost to follow-up. Seven patients refused the angiographic follow-up, so only the clinical outcome assessment of Glasgow Outcome Scale by telephone interview could be done. So the angiographic follow-up examinations were performed in 33 patients (71.7%) after a mean time of six months (range 3-24 months). Follow-up angiograms demonstrated a stable appearance after treatment except for two cases (one coil compaction and one coil migration) (Table 1).

Clinical outcome was estimated by using Glasgow Outcome Scale (GOS) with "good outcome" compromising Grades 4 to 5 and "poor outcome with severe neurological deficit" comprising Grades 2 to 3 at discharge. Grade 5 was noted in twenty-eight patients (60.9%), Grade 4 in eleven (23.9%), Grade 3 in two (4.3%), Grade 2 in three (6.5%) and Grade 1 in two (4.3%). In the group of patients with good presentation Hunt and Hess grade (I-III) outcomes were good for 37 patients

Figure 2 A) Frontal view of the left vertebral angiogram showing the small aneurysm at the basilar artery bifurcation before stent-assisted coiling. B) Immediately posttreatment, frontal view of left vertebral angiogram angiography demonstrating an optimal stents position and filling in aneurysm. C) Follow-up angiography at six months, frontal view unsubtracted left vertebral angiography demonstrating an optimal stents position and no contrast dye filling in aneurysm.

(97.3%), poor for one patient (2.7%), no fatal outcome. Poor outcomes were due to vasospasm induced multiple cerebral ischemic changes. In the poor presentation Hunt and Hess grade (IV-V) patient group, the outcomes were good in two patients (25%), poor in four patients (50%), and fatal in two patients. Poor outcomes were attributed to severe initial neurological states in all four patients. Two patients died from pneumonia and sepsis.

Complications

Initial and delayed technical and clinical events were encountered in eight patients. In three patients, stent deployment was difficult due to anatomical arterial tortuosity (kinking, lack of flexibility in the delivery system). Among the one incomplete occlusion patient coil migration occurred ten months after treatment without any neurological events, and one patient (giant aneurysm) had coil compaction. One of them was related to suboptimal placement of the stent.

One patient was excluded from the trial due to failure of stent navigation of the parent vessel beyond the aneurysm. Lastly, one patient presented delayed transient dysarthria caused by focal infarction in the ipsilateral cerebral hemisphere related to the thrombogenicity of the stent (Table 2).

Illustrative Cases

Case 1 (salvage technique)

A 41-year-old woman presented with acute SAH. Brain CT scan revealed diffuse SAH in the basal cisterns. Cerebral angiography demonstrated a right posterior saccular communicating artery aneurysm (PCoA) 4 x 6 mm in size. Direct coiling without stent seemed to be possible, but the first coil loop protruded toward the parent artery during the second coil deployment.

A stent (4.5 x 15 mm) was installed so that the herniated coil loop could be bailed out against the parent arterial wall (figure 1). There was no untoward event during or after the procedures. Systemic heparinization was continued for three days and the oral antiplatelet drugs Clopidogrel (75 mg) with Aspirin (100 mg) were started immediately through gastric tube after the coiling procedures and maintained for three months. Follow-up angiography six months after treatment revealed complete oc-

clusion of the aneurysm without any PCA flow obliteration.

Case 7 (one stent with coil on basilar tip small broad neck aneurysm)

This 64-year-old man was transferred from a local hospital due to symptoms of decreased consciousness after the development of severe headache. Brain CT scan revealed a subarachnoid hemorrhage (SAH) with blood clot in the prepontine cistern. The clinical condition at presentation was equivalent to Hunt and Hess grade III. On the first day in the hospital, diagnostic cerebral angiography revealed a basilar tip aneurysm, measuring approximately 2 x 3 mm in size. Subsequently, we elected to proceed with basilar artery to right posterior cerebral artery (PCA) stent placement to reconstruct the basilar artery apex not to make any hemodynamic flow interruption by the coils once placed in the aneurysm sac. Y-configured two stent-assisted coiling already reported by our group could be applied for this aneurysm⁹, but the PCA angle to basilar artery looked available for coiling with a single stent.

Following placement of 3.0 x 20 mm Neuroform stents (Boston Scientific/Target Therapeutics, Inc., Natick, MA), the aneurysm was embolized with one Ultra-soft coil (2 mm x 3 cm). Cerebral angiography just after coiling demonstrated incomplete embolization. The antiplatelet drugs regimen was the same as the other stent-assisted coiling procedures (figure 2).

Case 14 (stent in AcomA with direct neck puncture)

A 70-year-old woman presented with headache relating to a ruptured aneurysm at the left dominant anterior communicating artery (AComA). The aneurysm measured 7 x 9 mm and had a very large neck. And the right distal anterior cerebral artery (ACA) flowed through the right A1 so we decided to maintain the left distal ACA flow through the left A1 and AcomA using stent-assisted coiling. First, a 6F guiding catheter was positioned in the left internal carotid artery through the right femoral artery puncture, but the proximal artery from the abdomen and the extracranial ICA were too tortuous to perform with this route, so the catheterization procedure was changed to the direct neck puncture to run the guiding ca-

Figure 3 A) Frontal view of the three-dimensional computed tomogram (3D-CT) angiogram shows anterior communicating artery aneurysm on left internal carotid artery (ICA). B) Oblique view of the left ICA shows a broad neck anterior communicating artery (AComA) aneurysm. Microwire navigation was difficult because of anatomical arterial tortuosity between A1 and A2 portion of anterior cerebral artery (ACA). C) Immediately post treatment, frontal view left ICA angiography demonstrating an optimal stents position and contrast dye filling aneurysm.

theter into the left ICA. 3.0 x 20 mm stent could be navigated without difficulties into the AComA from left distal A1 to proximal A2. Following placement of the stent, the aneurysm was embolized with coils (figure 3).

After the procedure, the puncture site of the neck was compressed by carotid artery pulsation for more than 15 minutes, and the patient was carefully monitored at ICU for the prevention of neck hematoma formation. The systemic heparinization was not reversed and the antiplatelet regimen was same as the others.

Case 27 (stent in MCA case)

A 53-year-old woman with headache showed SAH on brain CT scan. Cerebral angiography was performed revealing a 5 mm aneurysm with a 6 mm neck in the left middle cerebral artery (MCA). A 3.5 x 15 mm stent was posi-

tioned across the aneurysm neck, and coils were delivered, achieving complete occlusion (figure 4).

This patient presented delayed transient dysarthria, but improved after three weeks with hypertensive, hypervolemic therapy.

Case 40 (only stent in stent technique without coiling on ICA fusiform dissecting aneurysm)

A 43-year-old man was admitted with sudden onset of severe headache. On admission he was alert and had moderate neck stiffness. Brain CT scan revealed SAH in the basal cistern dominant to left side. CT angiography and catheter based cerebral angiography demonstrated a fusiform vessel dilatation with a small bleed considered the bleeding point arising from the left internal carotid artery (ICA). A 6F guiding catheter was positioned into the

Figure 4 A) Oblique view of the left internal carotid artery (ICA) angiography showing the aneurysm at the middle cerebral artery bifurcation. B) Immediately posttreatment, oblique view left ICA angiography demonstrating an optimal stents position and no filling in aneurysm. C) Immediately posttreatment, oblique view unsubtracted left ICA angiography demonstrating an optimal stents position and no filling in aneurysm. D) Postprocedure axial diffusion weighted MRI shows focal hyperintense signal change in left frontal lobe. E) Follow-up angiography at ten months, oblique view of left ICA angiography demonstrating an optimal stents position and no contrast dye filling in aneurysm. F) Follow-up angiography at 10 months, oblique view unsubtracted left ICA angiography demonstrating an optimal stents position and no contrast dye filling in aneurysm.

petrous portion of the left ICA, then the first stent (4.0 x 20 mm) was initially deployed to cover the dilated vessel segment. To decrease the stent porosity and laminar flow of the dissecting portion, an attempt was made to position an overlapping stent (4.0 x 20 mm) into the first one (stent in stent), but it was deployed a little proximal to the first one. Follow-up angiography six months following treatment revealed no contrast dye filling in the aneurysmal bleb and vessel dissection was controlled. The anterior choroidal artery originating from the dissecting portion was also seen and no flow obliteration occurred by the two stents overlapping (figure 5).

Discussion

The treatment of intracranial aneurysms with endovascular coils has become an important

and well known alternative to microsurgical clip placement^{1,8}. If possible, direct coiling without stent will be the first choice method in endovascular treatment for intracranial aneurysm.

Although this treatment does represent a useful option for the treatment of certain types of complicated aneurysms, wide-necked or broad-based complex aneurysms are still complicated to be completely coiled because of the risk of coil migration or coil protrusion into the parent vessel which might cause distal flow obliteration^{4,7,10}.

Complete isolation of the aneurysm from the normal intracranial circulation is the obvious goal without flow obliteration in both surgical and endovascular treatment. In various aneurysm coiling series, complete occlusion rates between 21% and 84% were reported using detachable coils¹⁰⁻¹², the relatively broad range being explained by differences in aneurysm size

and morphological composition, and the difference of individual application of the completeness. In analyzing factors that might influence the long-term stability of the angiographic result, Fernandez Zubillaga et Al⁸ found a positive correlation between angiographic result and aneurysm neck size. They observed that narrow-necked aneurysms could be obliterated completely in 85% of cases, whereas in wide-neck aneurysms complete occlusion was accomplished in only 15% as also reported by others^{10,12}.

In particular, the complete occlusion rate in large and giant aneurysms treated with Guglielmi detachable coils (GDC) ranged from 25 to 50%^{8,10,11,12}. Mizoi et Al¹³ reported histological findings in giant aneurysms incompletely packed with GDCs. These aneurysms showed no evidence of formation of neo-intima and neo-endothelium at the neck of the aneurysm up to six months. The authors believed that the use of GDCs in large and giant aneurysms should be restricted to patients with poor clinical grades or with surgically inaccessible lesions. These patients required strict follow-up angiography studies and, not infrequently, further embolizations.

The self-expanding stent delivered through a microcatheter offers several substantial advantages over the preexisting balloon expandable coronary stents. This is primarily related to the increased flexibility of the stent and delivery system, allowing safe navigation and deployment within even the most tortuous segments of the cerebrovasculature and high porosity and low radial force (10 mm Hg) which may prevent internal hyperplasia but limit its support capacity when used together with coils to prevent herniation into the parent artery^{9,13}. However, Fiorella et Al reported a case of delayed in stent stenosis after the use of the stent in the coil embolization of a broad neck aneurysm.

In early experience, specifically when we were using the Neuroform 2 stent, stent placement was not feasible in one case because vascular tortuosity made it impossible to reach the target. The stents come in a variety of diameters and lengths, ranging from 2.5 to 4.5 mm and 10 to 30 mm, respectively. The ultrathin property of the stent struts makes the stent essentially not visible on fluoroscopy, and this is offset by four radiopaque platinum marker bands at each end⁶⁻⁸.

Stent-assisted coiling provides important technical and theoretical advantages^{6-9,14}. By providing secure and durable protection of the parent vessel, a broad-necked aneurysm could be more completely packed with coils with less risk of rupturing, coil migration and parent artery obstruction. The stent itself may produce flow redirection and disruption of the aneurysm inflow and outflow zones resulting in hemodynamic uncoupling of the parent vessel-aneurysm complex. We experienced endothelial remodeling of a fusiform dissecting aneurysm by the stent in stent technique (case 40). This hemodynamic advantage may help to reduce coil compaction in the region of the inflow zone and prevent subsequent growth of the aneurysm.

In addition, the stent provides a physical matrix for endothelial growth and allows remodeling of the parent vessel along the aneurysm neck⁷. With these stent advantages, the application of an endovascular stent as an adjunctive technique to coil embolization has evolved rapidly in recent years^{5,7,9}. However, using of Neuroform stent can lead to complications such as dislodgment of the stent, movement of the stent or delayed in-stent stenosis⁵⁻⁹.

Otherwise, some authors reported^{15,16} the successful treatment of broad neck aneurysm using the "balloon remodeling technique." However, this technique may fail to retain coils within the sac in a very large neck, and is associated with a higher rate of thromboembolic events because of parent artery occlusion. We agree with these effects of stents, but the Neuroform stent also has some limitations. The stent manufacturer recommends that a minimum 4 or 5 mm margin be maintained between the stent and each side of the aneurysm neck along the parent vessel to avoid vessel damage or stent migration. As the maximum stent length is 20 mm in the Neuroform 2 previous version, the stent was not designed for use in the treatment of aneurysms with a neck diameter greater than 10 or 12 mm. Broadbent et Al¹⁷ suggested that the combination of two stents can be used to solve this problem, and we also used such a technique, but now we use the 30 mm long and longer stents from another company.

Stents inserted in arteries with important perforating branches can also elicit ischemic complications related to the untoward occlusion of some of these perforating arteries by

Table 1 Clinical presentation and characteristics of aneurysms treated with stent assisted coiling.

Case	Age	Sex	Location	H-H grade	Fisher grade	Dome size (mm)	Neck size (mm)	Stent size	Angiographic results	Follow-up angiography	G.O.S at discharge	Therapeutic strategy
1	41	F	PCoMA	3	3	8	5	4.5 x 15	CO	NS	5	Coil/Stent
2	85	F	PCoMA	1	2	11	5	3.5 x 20	CO	NS	4	Stent/Coil
3	69	M	ICA	2	2	2	2	4.5 x 15	CO	Coil migration	5	Stent/Coil
4	85	F	ICA	4	2	8	12	4.0 x 20 4.5 X 20	IC	–	3	Stent/Coil
5	75	F	PCoMA	2	2	21	8	4.5 x 20	CO	NS	5	Stent/Coil
6	56	F	PCoMA	2	3	9	5	4.0 x 20	CO	–	5	Stent/Coil
7	66	M	Basilar tip	3	3	6	4	3.0 x 20	IC	CO	5	Stent/Coil
8	61	F	PCoMA	3	2	10	5	3.5 x 15	CO	–	5	Stent/Coil
9	68	F	PCoMA	1	3	12	6	4.0 x 20	CO	NS	4	Stent/Coil
10	40	F	PCoMA	1	3	8	5	3.5 x 20	CO	NS	5	Stent/Coil
11	38	F	PCoMA	3	3	5	5	4.0 x 20	CO	NS	5	Stent/Coil
12	73	F	PCoMA	4	4	11	6	4.0 x 20	RN	–	2	Stent/Coil
13	48	F	PICA	2	4	9	5	3.5 x 20	CO	–	3	Stent/Coil
14	70	F	ACoMA	2	3	9	7	3.0 x 20	IC	–	5	Stent/Coil
15	66	M	ICA	2	3	3	6	4.5 x 15	CO	NS	4	Stent/Coil
16	81	F	PCoMA	2	4	5	5	3.5 x 15	CO	–	5	Stent/Coil
17	58	F	Basilar tip	3	2	2	2	3.5 x 15 3.5 x 20	CO	NS	5	Stent/Coil
18	63	F	MCA	3	3	17	13		IC	–	4	Fail
19	78	F	PCoMA	2	2	25	10	4.0 x 20	RN	Compaction	5	Stent/Coil
20	63	F	PCoMA	3	4	15	8	4.5 x 20	CO	–	4	Stent/Coil
21	63	F	PCoMA	1	2	16	10	4.0 x 20	CO	NS	5	Stent/Coil
22	61	M	PCoMA	2	2	7	5	4.5 x 15	CO	NS	5	Stent/Coil
23	63	M	Basilar tip	3	2	5	4	3.5 x 20	CO	NS	5	Stent/Coil
24	66	F	PCoMA	2	3	7	4	4.0 x 20	RN	NS	5	Coil/Stent

the stent struts^{5,7,18}. Although its occurrence is unpredictable, this technical complication appears to be very rare.

In addition, some authors and the manufacturer reported that the premedication of oral antiplatelet drugs was strongly recommended

to prevent the thromboembolic events enhanced by stent positioning. However, in the case of ruptured aneurysms, the procedures should be performed as early as possible and the recommended premedications of oral antiplatelet drugs for two to three days could not

Case	Age	Sex	Location	H-H grade	Fisher grade	Dome size (mm)	Neck size (mm)	Stent size	Angiographic results	Follow-up angiography	G.O.S at discharge	Therapeutic strategy
25	82	F	PComA	4	4	8	5	4.5 x 15	CO	–	2	Stent/Coil
26	43	F	PComA	2	4	9	5	4.0 x 20	CO	NS	4	Stent/Coil
27	53	F	MCA	2	2	6	5	3.5 x 15	CO	NS	5	Stent/Coil
28	63	F	PComA	2	4	25	12	4.5 x 20	IC	NS	5	Stent/Coil
29	66	F	PComA	2	3	7	4	4.5 x 20	RN	NS	5	Stent/Coil
30	79	F	Basilar tip	2	4	6	4	3.0 x 20	CO	–	4	Stent/Coil
31	67	M	PComA	2	3	8	5	4.0x 20	CO	NS	4	Coil/Stent
32	46	F	PComA	5	4	7	4	4.5 x 15 4.5 x 20	IC	–	1	Stent alone
33	52	F	Basilar tip	3	2	5	4	3.0 x 20	CO	NS	5	Stent/Coil
34	80	F	PComA	4	4	9	5	4.0 x 20	CO		4	Stent/Coil
35	52	F	PComA	2	3	11	5	4.5 x 20	CO	NS	5	Stent/Coil
36	53	F	PComA	1	3	4	4	4.5 x 15	CO	NS	5	Stent/Coil
37	57	F	SCA	2	3	6	4	3.5 x 15	RN	NS	5	Stent/Coil
38	46	M	V.A	5	4	5	5	4.0 x 20	CO	–	1	Stent/Coil
39	55	F	PComA	2	4	8	5	4.0 x 20	CO	NS	5	Stent/Coil
40	43	M	PComA	2	2	6	11	4.0 x 20 4.0 x 20	IC	Healing	5	Stent alone
41	34	M	PComA	2	3	9	5	4.5 x 20	CO	NS	5	Coil/Stent
42	65	F	PComA	3	4	16	10	4.5 x 20	CO	NS	4	Stent/Coil
43	78	F	ICA	2	3	5	4	3.5 x 20	CO	NS	5	Stent/Coil
44	65	F	PComA	3	3	8	5	4.0 x 20	CO	NS	5	Stent/Coil
45	63	F	V.A	4	4	4	4	4.0 x 20	CO	NS	4	Stent/Coil
46	74	F	PComA	4	4	9	6	4.5 x 20	CO	–	2	Stent/Coil
– : Not check, AComA: Anterior communicating artery, CO : Complete obliteration, IC: Incomplete obliteration ICA : Internal carotid artery, MCA: Middle cerebral artery, PComA: Posterior communicating artery, RN: Residual neck, SCA: Superior cerebellar artery, V.A: Vertebra artery												

be applied in all cases. Katsaridis et Al¹⁹ reported a series of 44 patients treated with stent-assisted coiling for ruptured intracranial aneurysms which were not pretreated with oral antiplatelet agents. Satisfactory aneurysm occlusion was achieved in 94.4% of their cases,

whereas there was no aneurysm bleeding and no aneurysm recanalization or thromboembolic events were reported.

In this series, we experienced no severe complications using intravenous aspirin, apart from one case with minor delayed thrombo-

Table 2 Periprocedural and delayed complications.

Case	Periprocedural complications	Cause	Treatment	Clinical outcome
4	Suboptimal displacement	Extreme vessel curvature	Observation	Asymptomatic
18	Stent deployment failure	Extreme vessel curvature	Coil embolization	Asymptomatic
5	Stent deploy difficulty	Extreme vessel curvature		Asymptomatic
6	Stent deploy difficulty	Extreme vessel curvature		Asymptomatic
28	Stent deploy difficulty Delayed complications	Extreme vessel curvature		Asymptomatic
3	Coil migration		Observation	Asymptomatic
19	Coil compaction			Asymptomatic
27	Transient dysarthria	Thrombogenicity	Antiplatelet	Asymptomatic

genicity, and no in-stent stenosis was encountered. This low rate of periprocedural thromboembolic events was achieved with no pretreatment of patients with oral antiplatelets in the ruptured intracranial aneurysms. Pretreatment with oral antiplatelets did not seem necessary in this series with a very low thrombogenic complication rate.

This article has some limitations. In particular, the results were mostly based on immediately angiographic results and a long-term analysis cannot be sufficiently performed. The reports on the cases of incomplete occlusion or remnant neck show that rebleeding accounts for between 3.5-28%, and that regrowth accounts for between 3.5-15%^{4-6,15}. The long-term clinical outcomes and angiographic results should be derived concerning stent-assisted coiling²⁰. The long-term clinical outcomes and angiographic results should be derived concerning stent-assisted coiling. Even though this is a small series with limited clinical and angiographic follow-up, the lack of permanent complications indicated that the stent is a useful tool for the minimally invasive treatment of selected patients with ruptured broad neck aneurysms.

Although short-term follow-up identified intact parent arteries and stable occlusion rates in the majority of cases, the long-term effect of the stent on the vessel wall and the rate of aneurysm recanalization and delayed in-stent stenosis remain to be studied.

Conclusions

Self expanding stents like the Neuroform stent are important additions to the devices used in the endovascular treatment of ruptured broad aneurysms. Difficulty of navigation may be the main drawbacks of the system and the difficulty of antiplatelet drug premedication might limit stent-assisted coiling in cases of early ruptured aneurysm. Two to three days pretreatment with oral antiplatelet drugs did not seem necessary to prevent thromboembolic events in this series.

We suggest that endovascular treatment of broad neck aneurysms using the stent is safe and effective. However, the long-term durability and safety of the occlusion of aneurysms with stents remains unsettled. More clinical data with long-term follow-up are needed to help establish the role of stent-assisted coiling for ruptured broad neck aneurysm and pretreatment antiplatelet therapy.

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EDITORIAL COMMENT

The number of reports on stent assisted coiling in the treatment of wide-necked and complex aneurysms is steadily increasing. The majority of these studies are performed on patients with non-ruptured aneurysms and the results are acceptable in terms of peri-procedural complications. There are a few studies including also ruptured aneurysms and the peri-procedural complication rates are then in the range of 25-31% adverse events, 8-9% permanent neurological morbidity and 2-4.5% mortality (Akpek S et Al (2005) Am J Neuroradiol 26: 1223-1231; Fiorella D et Al (2004) Neurosurgery 54: 6-16; Lylyk P et Al (2005) J Neurosurg 102: 235-241). The present article display extraordinary results with only 2.2% thromboembolic complications, 0% permanent neurological morbidity and 0% mortality, especially if one considers that all 46 aneurysms were ruptured.

Since most centers report relatively high complication rates, one must question whether stents are required in the acute setting. Several reports have now demonstrated very low peri-procedural morbidity and very low long-term complication and rebleed rates when using only coils, or coils together with balloon remodelling in this patient group. Could the patients in this article have been successfully managed without the aim of obliterating the aneurysm neck completely, especially in the acute setting? An alternative strategy would have been to treat less aggressively in the acute phase and if the neck remnant turned out to be unstable in the follow-up, perform additional coiling, possibly combined with stent placement. Indeed, there are ruptured complex aneurysms for which stent-assisted coiling will improve the management considerably. The challenge will be to identify and aggressively treat only those rare aneurysms, to avoid adding extra risks to a large number of patients. The cost aspect should also be considered when choosing strategy; additional stent costs should be similar to the cost for re-treatment in a subgroup of patients with unstable treatment results following simple coiling.

In the present study, the mean clinical follow-up is 12 months and the mean angiographical follow-up six months. It will be highly interesting to see the long-term clinical and angiographical results in this patient group.

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