Enterprise Stent-Assisted Coiling of Wide-Necked Intracranial Aneurysms: Clinical and Angiographic Follow-up

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Summary

We evaluate and report our clinical and angiographic outcomes associated with stent-assisted coil embolization of wide-necked intracranial aneurysms using the Enterprise stent.

One hundred sixty-nine patients diagnosed with 182 wide-necked intracranial aneurysms underwent placement of the Enterprise stent between April 2009 and October 2011. Demographic information, procedural data, procedure-related complications, angiographic results, and clinical outcomes were reviewed and evaluated.

Stent deployment was successful in 166 out of 169 procedures (98.2%). Four patients had acute procedure-related complications, including th romboembolism in three patients and aneurysm perforation resulting in the death of one patient. Immediate angiographic results showed complete occlusion in 101 aneurysms (56.4%) and near-complete occlusion in 55 aneurysms (30.7%). Follow-up angiography was performed in 108 patients with 119 aneurysms at a mean of 8.1 months: complete occlusion was observed in 95 aneurysms (79.8%) and near-complete occlusion was found in 12 aneurysms (10.1%). Delayed intra-stent thromboses were observed in two patients, and asymptomatic in-stent stenosis was observed in one patient. Ten aneurysms (8.4%, 10/119) demonstrated recanalization, all of which were subsequently recoiled successfully. Clinical follow-up was obtained for 132 patients at a mean of 11.4 months, out of which 118 (89.4%) had favorable clinical outcomes as determined using a modified Rankin Scale (mRS) ≤1. The rates of procedure-related mortality and permanent morbidity were 0.6% (1/169) and 2.3%(3/132), respectively.

This study adds to the current body of evidence supporting the Enterprise stent as an effective and safe tool for the treatment of wide-necked intracranial aneurysms because it results in more complete occlusion and lower complication rates.

Introduction

Stent-assisted coiling for the treatment of wide-necked intracranial aneurysms has grown in popularity. Stents provide mechanical, hemodynamic, and biological benefits by preventing coil protrusion into the parent artery, reducing intra-aneurysmal blood flow, and promoting vessel wall healing [1,2]. The Enterprise stent (Cordis Neurovascular, Miami, FL, USA) is a new, highly flexible nitinol stent designed for use in the endovascular treatment of intracranial wide-necked aneurysms. Our department began using this stent in 2009. This study evaluates and reports the results and complications associated with stent-assisted coil embolization (SACE) of intracranial aneurysms using the Enterprise stent.

Materials and Methods

Patients and aneurysms

From April 2009 to October 2011, 604 consecutive patients with a total of 670 cerebral aneurysms underwent endovascular coil em-

bolization procedure at our institution. Of these, 169 patients (182 wide-necked aneurysms) underwent an attempted SACE procedure. A wide-necked aneurysm was defined as having an angiographically measured dome-neck ratio of <1.5 mm or a neck that was ≥4 mm. Three of the 182 aneurysms were not stented (3/182, 1.6%) due to technical difficulties. Ultimately, 166 patients with 179 cerebral aneurysms were treated with the placement of the Enterprise stent. We reviewed the medical records, radiographic studies and endovascular procedure reports for each case. Information such as sex, age distribution, and the clinical manifestations and characteristics of aneurysms treated by SACE is summarized in Tables 1 and 2.

Table 1 **Summary of patient demographics and clinical presentations.**

	No. of patients
Average age (range) in years	53.1 (17-77)
Female	118
Male	48
Ruptured aneurysms	31
Unruptured aneurysms	135
Headache	37
Incidental	37
Dizziness	22
Neurological deficits	11
TIA	4
Recurrence after coiling	3

TIA: transient ischemic attack

Table 2 **Locations and sizes of aneurysms.**

	No. of cases
Anterior circulation	161
ICA-posterior communicating	55
ICA-ophthalmic	81
ICA-cavernous	16
ICA-carotid terminus	9
Posterior circulation	18
Vertebral artery	8
Vertebrobasilar junction	2
Basilar trunk	5
Basilar tip	3
Posterior cerebral artery	1
Aneurysm size, mm	
Small (<10 mm)	147
Large (10-25 mm)	31
Giant (≥25 mm)	1

ICA: internal carotid artery

Endovascular procedures

All endovascular procedures were performed on a biplane angiography unit with 3D rotational angiography under general anesthesia. Patients with unruptured aneurysms were premedicated for three days prior to the procedure with dual-antiplatelet therapy consisting of aspirin (100 mg/d) and clopidogrel (75 mg/d). Patients with acutely ruptured aneurysms were loaded with 300 mg of clopidogrel before the procedure. A 6F or 8F sheath was introduced into the right femoral artery following a standard Seldinger puncture. A 6F or 8F Envoy guiding catheter (Johnson & Johnson, New Brunswick, NJ, USA) was then placed into either the cervical internal carotid artery (ICA) or the vertebral artery, depending on the location of the aneurysm. Delivery and deployment of the Enterprise stent were performed using the same techniques as described previously [3]. During the procedure, a heparin bolus of 4000 IU followed by a heparin drip of 1000 IU/h was administered. The microcatheters used included the Prowler series (Johnson & Johnson), Excelsior SL-10/18 (Boston Scientific/Target Therapeutics, Natick, MA, USA), and Echelon-10/14 (ev3, Irvine, California, USA). Coiling was performed using Matrix coils (Boston Scientific), Guglielmi detachable coils (Boston Scientific), HydroCoils (MicroVention, Aliso Viejo, California), or a combination thereof. Aneurysms were coiled until there was no further evidence of angiographic contrast filling of the aneurysm or until the microcatheter was pushed out by the coil mass. After the procedure, systemic heparinization was continued for 24 h in all patients. Clopidogrel (75 mg/d) was given orally for an additional month and aspirin (100 mg/d) for an additional six months post-procedure.

Angiographic and clinical outcomes

Post-procedure aneurysm occlusion and follow-up were assessed by two senior independent reviewers according to the 3-point RS [4] (i.e., RS 1: complete obliteration of aneurysm and neck; RS 2: neck remnant without contrast filling the aneurysm sac; RS 3: contrast filling the aneurysm sac). In our institution, the digital subtraction angiography and computed tomographic angiography consisted of the follow-up images. For all patients, six-month, one-year, three-year, and five-year follow-up angiograms were recommended. At follow-up, an aneurysm was considered recanalized if a totally occluded aneurysm had a partial recurrence of the neck and/or the sac or if a subtotally occluded aneurysm had an increasing neck remnant or residual aneurysm. The post-procedure clinical outcomes at discharge and follow-up were evaluated with the modified Rankin score (mRS). Complications recorded included intraprocedural rupture, thromboembolism, and parent vessel stenosis.

Statistical analysis

Initial treatment status and aneurysm sac size were tested as potential risk factors for recurrence by using the Fisher exact test. A p value $<.05$ was considered to indicate significant difference. Statistical analysis was performed using the SPSS 18.0 software.

Results

Demographic data

In total, 166 patients (48 males and 118 females) with 179 wide-necked cerebral aneurysms underwent 166 attempted Enterprise stent deployments. The mean age of all patients was 53.1 years. Among these cases, the following presentations were observed: 31 with acute subarachnoid hemorrhage, 37 with headache, 22 with dizziness, 11 with neurologic deficits, four with TIA, three with coil compaction with aneurysm recanalization, and 37 were found incidentally. The locations of the aneurysms included the ICA (n=161), basilar artery (n = 8), vertebral artery (n = 8) and posterior cerebral artery (n = 1). The mean size of the 179 treated aneurysms was 6.7 ± 3.4 mm. The aneurysms were categorized into three different groups: small (<10 mm: 147 cases, 82.1%), large (10-25 mm: 31 cases, 17.3%), and giant (>25 mm: 1 case, 0.6%).

Failure of the endovascular treatment

An Enterprise stent was successfully deployed in 166 out of 169 patients. In three cases, failure to deploy the stent was due to the inability to cross the aneurysm neck with the Prowler Select Plus microcatheter (Johnson & Johnson, Miami Lakes, FL, USA).

Clinical outcomes

One patient with an unruptured aneurysm died of a procedure-related complication. Of the 132 patients with clinical follow-up from one to 33 months (mean 11.4 months), 118 patients (89.4%) had favorable clinical outcomes, as measured by the modified Rankin Scale (mRS) ≤1. No aneurysm was ruptured or reruptured during the follow-up period. Thirty-three patients were lost to follow-up, as they could not be located.

Angiographic outcomes

Endovascular treatment resulted in complete occlusion in 101 aneurysms (59.4%), near-complete occlusion in 55 aneurysms (30.7%), and incomplete occlusion in 23 aneurysms (12.9%). Fifty-seven patients did not undergo angiographic follow-up, 33 patients could not be located, and 24 patients refused follow-up due to old age, financial issues, or other medical conditions. Out of a total of 119 aneurysms (66.5%) with angiographic follow-up ranging from one to 24 months (mean 8.1 months), complete occlusion was observed in 105 aneurysms (80.8%), near-complete occlusion in 18 (13.8%), and incomplete occlusion in seven (5.4%). Ten aneurysms (8.4%) had recanalized, all of which were successfully recoiled.

Complications

There were seven cases of procedure-related complications in this study (Table 3). One patient with an unruptured aneurysm in the ICA-posterior communication segment died due to aneurysmal dome perforation by a microguidewire, which resulted in massive intracranial hemorrhage. There were three cases of clot formation near the neck of the aneurysm after stent deployment during aneurysm coiling. These patients were managed with intravenous administration of 8 ml of 5% tirofiban with good angiographic results, except for one patient who had a moderate deficit (mRS 3). During follow-up, two patients developed an ischemic stroke. One patient was treated for a posterior communicating artery aneurysm and

Table 3 **Summary of complications associated with the Enterprise stent.**

Age/Sex	Presentations	Location	Size	Complications
62/F	SAH	R-Pcom	3 mm	In-stent thrombosis
30/M	Headache	Basilar trunk	18 mm	In-stent thrombosis
59/F	TIA	L-Ophthalmic	6 mm	In-stent thrombosis
		L- Pcom	3 mm	
66/F	CN palsy	R-Pcom	4 mm	In-stent thrombosis
		L-Vertebral	11 mm	
40/F	CN palsy	L-Ophthalmic	7 mm	In-stent thrombosis
71/M	TIA	R-Pcom	3 mm	Asymptomatic stenosis
60/F	Headache	L-Ophthalmic	4 mm	Aneurysm perforation

Pcom: posterior communicating artery; L: left; R: right.

Table 4 **Aneurysm recurrence analysis at midterm.**

Characteristic	No Recurrence (n=109)	Recurrence (n=10)	P Value
Aneurysm size			
<10 mm	96	4	0.001
≥10 mm	13	6	
Initial treatment status			
Complete	80	1	0.001
Incomplete	29	9	

the other for a basilar trunk aneurysm. The delayed adverse events followed premature cessation of double-antiplatelet therapy. Two years after the stroke, the modified Rankin Scale score for both patients was 2. One patient (0.8%, 1/119) showed an asymptomatic in-stent stenosis of the parent artery at 12-month follow-up.

Recurrence and retreatment

Ten of the 119 aneurysms (8.4%) recanalized between three and 12 months (mean 8 months) after the first procedure. Retreatment was performed in each case using additional coils positioned through the original stent. A second stent within the previously positioned stent was successfully deployed in four aneurysms. Angiography showed completely occlusion at eight-month follow-up for two aneurysms retreated with a second stent. Recurrences were less common in patients with aneurysms <10 mm compared to those with aneurysms ≥10 mm (P=.001) and were more frequently observed in incompletely occluded aneurysms (Table 4).

Discussion

Endovascular embolization of wide-necked aneurysms with preservation of the parent artery remains a technically challenging procedure. Despite the use of new devices and techniques, including balloon remodeling, 3D coils, and liquid embolic agents, recurrence is still a major problem [5]. The application of stents has increased the options for the treatment of wide-necked aneurysms. The stent not only supports aneurysm packing and redirects flow, but it also provides a physical matrix for endothelial regrowth. Since May 2007, when FDA HDE approval was granted for the Enterprise Vascular Reconstruction Device and Delivery System, the Enterprise stent has become a widely used device for the embolization of wide-necked aneurysms. The present study evaluated the short-term outcomes of patients who underwent Enterprise stent-assisted coiling.

In our study, stent deployment failed in 1.8% of patients. Other complications included permanent procedure-related morbidity in 2.3% (3/132) and mortality in 0.6% (1/166) of patients. At follow-up, aneurysm recurrence was found in 8.4% (10/119) of patients. In the literature regarding stent-assisted coil embolization, morbidity rates ranged from 0 to 20% and mortality rates ranged from 0 to 8.9% [6-15].

In our study, thromboembolism was the most common procedure-related adverse event. With regard to in-stent thrombosis, we observed acute clot formation during the procedure in three patients 1.8% (3/166), while two patients developed ischemic stroke during the follow-up period. Interestingly, both the delayed in-stent thromboses and the ischemic stroke cases were related to premature termination of systemic dual-antiplatelet therapy. Kim et al. [12] reported an acute intraprocedural in-stent thrombosis rate of 1.6% (2/127). Mocco et al. [16] showed that the delayed in-stent thrombosis rate was 3%. The benefit of dual-antiplatelet therapy in percutaneous coronary intervention has been well documented [17]. However, data on antiplatelet agents for the prevention of in-stent thrombosis in patients with intracranial stents has not been standardized, and there are widely varying protocols for dual-antiplatelet use among institutions. Based on the relevant cardiology literature, it has since become common practice for neurointerventionalists to administer both aspirin and clopidogrel after stent placement. Still, ischemic complications following these procedures highlight the need for better assessment of the antiplatelet response [18]. In this study, asymptomatic intra-stent stenosis was observed in 0.8% (1/119), which may have been caused by an inflammatory reaction with subsequent intimal hyperplasia. As was reported in a separate article, parent artery stenosis was 3% [16].

The goal of aneurysm treatment should be permanent exclusion of the aneurysm from the circulatory system to prevent rupture or re-rupture. Aneurysm recanalization must be acknowledged as a failure to achieve this goal. Recently, a large meta-analysis reported aneurysm recurrence and retreatment following coil embolization in 20.8% and 10.3% of cases, respectively [19]. In our study, we observed the recanalization of ten aneurysms (8.4%) in follow-up angiograms, nine of which were not completely occluded initially (i.e., class 2 or class 3 aneurysms). No recanalization occurred in small aneurysms that were completely occluded initially. In our study, retreatment was performed in all aneurysms with no adverse events. By comparison, the reported complication rates in patients treated for previously embolized aneurysms ranges from 2 to 3% [19-21].

Our study has several limitations that are related primarily to the retrospective nature of the study and the variable duration of follow-up. Moreover, most of the aneurysms included

and treated in this study were small aneurysms, which are not comparable with large and complex aneurysms.

Conclusion

Our results and short-term follow-up show that Enterprise stent-assisted coil embolization is a safe and effective technique for the treatment of cerebral aneurysms, but its long-term safety and efficacy should be further evaluated.

Acknowledgments

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