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Original Article

Treatment of acutely ruptured wide-necked intracranial aneurysms using self-expanding stent

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Abstract: Objectives: To evaluate the effectiveness and safety of self-expanding stent in treatment of acutely ruptured wide-necked intracranial aneurysms in the acute stage. Method: Treatment of 38 patients with self-expanding stent was retrospectively analyzed. Results: From January 2009 to May 2014, a total of 38 patients with 44 acutely ruptured wide-necked intracranial aneurysms were embolized with self-expanding stents at our center. Immediate post-operative imaging demonstrated that the aneurysms were densely packed in 17 patients, subtotally embolized in 2 patients, and subtotally embolized with residual aneurysm necks in 19 patients. At discharge, the patients were assessed for prognosis and the results revealed nerve dysfunction in 3 patients (7.9%), coma in 6 patients (15.8%), hospital death in 1 case (2.6%). Twenty-eight (73.7%) patients were asymptomatic at discharge. Ten of the 38 patients were followed up by angiography for a period of 3.7 months on average, which showed complete occlusion in 9 patients (90%), remnant aneurysm necks in 1 patient (10%), and no recanalization was observed in all the followed-up patients. Stent related complications also were recorded. Conclusion: Stent-assisted coiling is effective in treating acutely ruptured wide-necked intracranial aneurysms. Angiographic investigation and clinical follow-up is needed for evaluation of long-term clinical outcomes.

Keywords: Ruptured intracranial aneurysms, wide-necked aneurysms, self-expandable stent, coiling

Introduction

Endovascular coiling is an effective treatment and standard care for intracranial aneurysms [1]. It had been very challenging to treat giant aneurysms, complex aneurysms, wide-necked aneurysms and fusiform aneurysms by surgical clipping and endovascular coiling, before the introduction of self-expandable stent. The availability of this device has paved solid ground for effective and safe embolization of these challenging aneurysms [2]. The self-expanding stent promotes dense packing in aneurysm by increasing the neck coverage. In addition, it increases the stability of embolization through comprehensive effects including diverting the blood flow, improving curvature of the parent artery, and promoting fibrosis tissue formation across the neck [3, 4].

Stent-assisted coiling procedures have been mostly performed for patients with unruptured aneurysms. More encouraging, recent attempts in emyloying this technique in treating ruptured aneurysms resulted in satisfying clinical outcomes, although application of stent-assisted coiling in acute subarachnoid hemorrhage is under debate. Chalouhi et al reported 508 cases receiving stent-assisted coiling procedures. Among these cases, 461 (91%) were unruptured aneurysms while 47 (9%) were ruptured aneurysms [4]. And in the Bodily's retrospective series, stent-assisted coiling showed a high degree of success in treating ruptured aneurysms. Of note, stent-assisted coiling reportedly accompanies with more rebleeding events than standard-alone coiling and balloon remodeling coiling do, and more frequent adverse events and poor prognosis than standard-alone embolization [5]. Besides, the optimal antiplatelet medication has yet to be determined for stent-assisted coiling during acutely ruptured phase. In a series of 36 patients, Golshani et al concluded that stent-assisted coiling technique (SACT) is an option for treatment of ruptured wide-necked ruptured aneurysms and for salvage treatment during unassisted embolization of ruptured aneu-

Table 1. Characteristics of patients with ruptured aneurysms treated with stent-assisted coiling (n=38)

Characteristics	Value	Characteristics	Value
		Aneurysm location, No. (%)*	
		Anterior circulation	27 (61.4)
		Posterior circulation	17 (38.6)
Age (years)		Neck size (mm)	
Range	27-81	Range	2-12
Mean ± SD	55.5±12.9	Mean ± SD	
Gender, No. (%)			
Male	14 (36.8)		
Female	24 (63.2)		
Hunt-Hess Grade, No. (%)		Aneurysm shape, No. (%)	
I	12 (31.6)	Saccular	35 (92.1)
II	7 (18.4)	Dissecting	3 (7.9)
III	15 (42.1)		
IV	2 (2.6)		
V	2 (5.3)		

*Forty-four aneurysms in 38 patients.

rysms. But they observed higher complication rate, comparing to that of conventional clipping or coiling of cerebral aneurysms [6]. Therefore, special attention should be paid to avoiding and managing these complications.

Our hospital is in a third-tier city and most patients with intracranial aneurysms visit our hospital within 72 h of aneurysm rupture, the acute phase. In such an emergency situation, careful consideration of timing for surgery, surgical procedure, procedure-related complications and prognosis is critical for clinical benefit. Herein we reported our experience with treatment of ruptured giant aneurysms, complex aneurysms, wide-necked aneurysms, and fusiform aneurysms in the acute phase, by using self-expandable stents. Our results indicate that SACT is an effective therapy for acutely ruptured intracranial aneurysm.

Materials and methods

From January 2009 to May 2014, 38 patients, 14 males and 24 females, with 44 acute rupture of intracranial aneurysms were admitted to our hospital. The patients aged from 27 to 81 years, with an average of 55.5±12.9 years. On admission, they were evaluated by Hunt-Hess scale and the results showed that 12 (31.6%) patients were in Grade I, 7 (18.4%) patients in Grade II, 15 (42.1%) patients in Grade III, 2 (2.6%) patients in Grade IV, and 2 patients (5.3%) in Grade V. Among these 44 aneurysms, 27 were localized in the anterior circulation, while 17 in the posterior circulation. Three patients had dissecting aneurysms. Wide-necked aneurysm is defined as intracranial aneurysm with a diameter of the neck >4 mm or neck-to-dome ratio >2 (**Table 1**).

Stent-assisted coiling is mainly indicated for two groups of patients: (1) those in deed of immediate intervention to prevent recurrent hemorrhage during the acute phase but contraindicating to other surgical procedures; and (2) those whose angiograms after standard-alone embolization or balloon remodeling embolization show high risk of coil protrusion as well as diminishing blood flow of the parent artery. Forty-two stents were delivered totally, 32 Solitaire stents and 10 Enterprise stents. The following stent delivery methods have been used in this study: (1) Jailed-catheter technique, in which the coil delivery microcatheter be placed into the aneurysm sac and then a stent is navigated and immediately delivered across the aneurysmal neck [2]. Seven patients were treated with this method. (2) Trans-cell technique, with which 8 patients were treated. The stent be firstly delivered across the aneurysmal neck and then the microcatheter is placed into the sac [2]. (3) The aneurysm are coiled with or without balloon remodeling technique followed by the stent being delivered across the aneurysmal neck, aiming at reducing the recanalization rate by diminishing intra-aneurysmal flow by diversion and also creating a mesh at the level of the neck to be colonized and covered by endothelial cells. Thirteen patients were treated with this procedure, with 3 cases coiled with balloon remodeling technique and 10 without.

All patients underwent operations under general anesthesia. Anti-platelet therapy is installed as follows: 300 mg of aspirin and 75 mg of clopidogrel were given orally or through the feeding tube post angiography and before

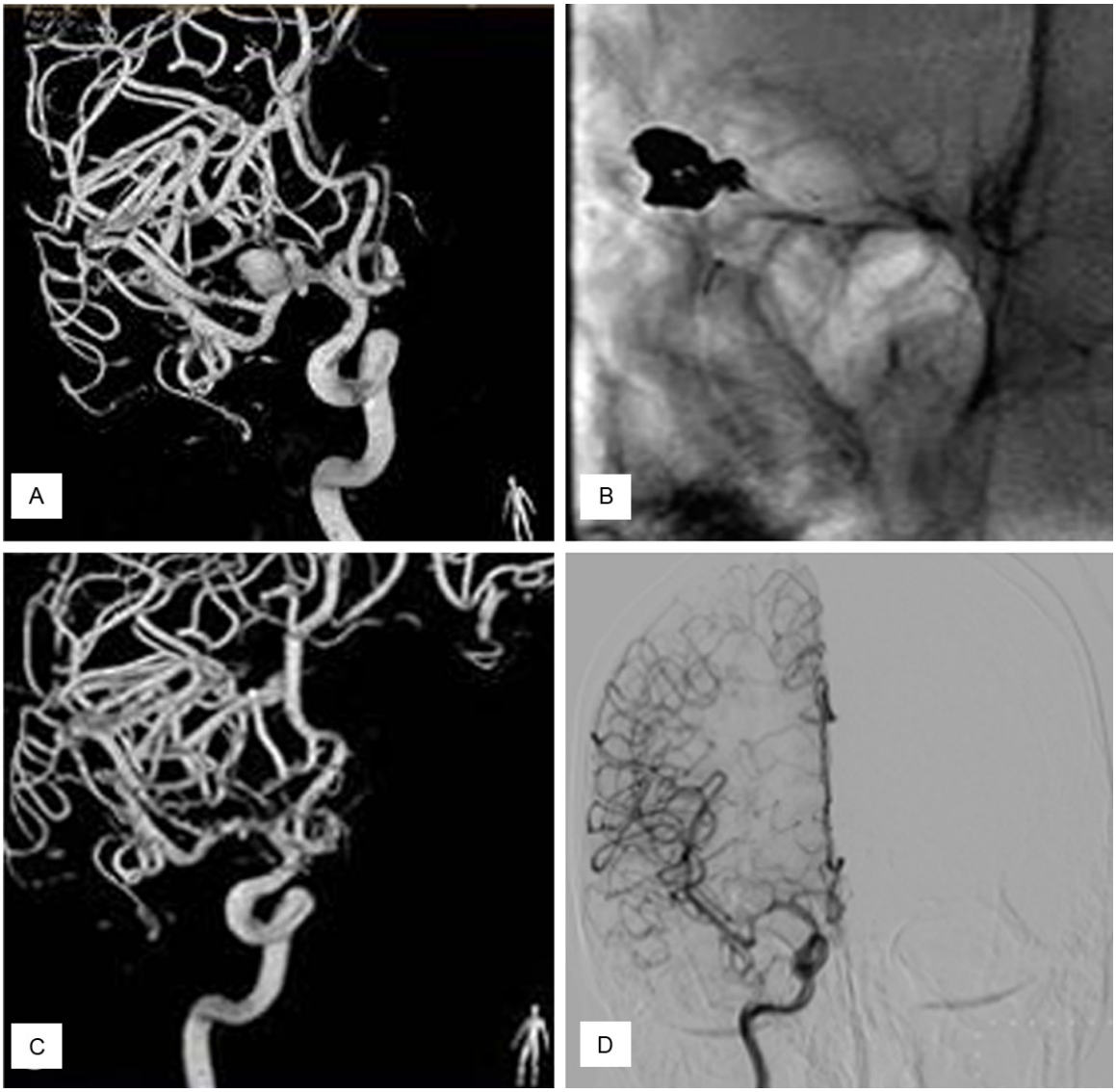

Figure 1. A middle cerebral artery aneurysm (A) was treated with the intracranial self-expanding stent system and coils (B). Complete occlusion of the aneurysm was achieved as shown on immediate post-operative angiography (C) and follow-up radiology 5 months post surgery (D).

general anesthesia. During the operation, anticoagulation with heparin was initially given with a bolus of 3000 IU intravenously followed by 1000 IU per hour.

The postoperative imaging assessment is divided into 3 categories: complete occlusion, neck remnant, and sac remnant [7]. The follow-up angiography was performed at three months post surgery.

Results

In this study, pre-operative angiography identified 44 acutely ruptured wide-necked aneurysms in 38 patients. The intraoperative assessment revealed that the size of aneurysm neck was 4.99 mm. The immediate postoperative imaging showed complete occlusion in 17 (44.7%) patients, neck remnant in 19 (50.0%) patients, and sac remnant in 2 (5.3%) patients (**Figure 1**; **Table 1**). In one patient, the parent artery was occluded after stent-assisted coiling, and thus a second stent was deployed to open it up. The patient experienced transient partial motor aphasia 48 hours post surgery but completely recovered later, with no abnormal findings On CT follow-up. For the patient with left posterior cerebral artery aneurysm and posterior inferior cerebellar artery aneu-

Table 2. Effect and complications of stent-assisted coiling in patients with ruptured aneurysms (n=38)

Variable	Value
Treatment, No. (%)	
Jailed-catheter technique	7 (18.4)
Trans-cell technique	18 (47.4)
Stenting after balloon remodeling coiling	3 (7.9)
Stenting after standard-alone coiling	10 (26.3)
Postoperative instant imaging, No. (%)	
Complete coiling	17 (44.7)
Neck remnant	19 (50.0)
Sac remnant	2 (5.3)
Stent-related complications, No. (%)	
None	33 (86.8)
Intraoperative bleeding	1 (2.6)
Postoperative bleeding	2 (5.3)
Thrombus formation	2 (5.3)
Outcome at discharge, No. (%)	
Fully recovery	25 (65.8)
Partial recovery	4 (10.5)
No treatment benefit	4 (10.5)
Death	1 (2.6)
Against advise discharge	4 (10.5)

rysm, both aneurysms were coiled with the adjunct of Solitaire stent, with neck remnant post operation. Six hours post surgery, the patient's mental status progressively deteriorated. Emergency angiography showed occlusion of both left and right posterior cerebral arteries. Thrombolysis with alteplase through microcatheter was instituted and an Enterprise stent was delivered into the verterbral-basal transitional zone to recanalize the occluded vessels. The patient gained full recovery without any neurological deficit. The clinical characteristics, preoperative angiography, postoperative imaging assessment and the follow-up angiography were overviewed in **Table 1**.

The stent-related complications in this study include intraoperative bleeding in 1 patient, postoperative bleeding in 2 patients, and thrombus formation within the stented segments in 2 patients (one presenting postoperative unconsciousness, and the other presenting mixed aphasia and right hemiplegia due to watershed area infarction) (**Table 2**).

Follow-up angiography was available in 10 patients with an average follow-up duration of 3.7±0.82 months (range 3-5 months), which showed neck remnant in 1 (10%) patient, and total occlusion in 9 (90%) patients. No recurrent aneurysm was revealed. Immediate angiography showed total occlusion of aneurysm in 6 patients, which remained the same during follow-up. Among the three cases with neck remnant shown by immediate post-operative angiography, 2 cases achieved total occlusion, and 1 case remained the same during follow-up as demonstrated by angiography. For the patient with sac remnant shown on post-operative imaging, total occlusion was observed in follow-up (**Table 3**).

Discussion

Wide-necked intracranial aneurysms are heavily challenging for surgical clipping or endovascular coiling, as the complex vascular anatomy compromises the success rate of dense packing coiling. Besides, the inherent intricate architecture of wide-necked aneurysms adds to surgical difficulties and increases surgical risks. Since the introduction of self-expanding stent, this condition can be treated endovacularly. Especially, the remodeling technique of stent-assisted coil placement helps stabilize the coil mass in the sac and avoid coil protrusion into the parent artery and is gaining popularity in treatment of wide-necked complex aneurysms [8, 9]. In fact, stent-assisted coiling technique (SACT) has been employed to treat a wide range of aneurysms with benefit of reducing the likelihood of neck recurrence [2, 3, 10].

Self-expandable intracranial stents can be open-cell or close-cell type, with the most prominent difference between them lying in the design of the cell: close or open. We adopted two close-cell intracranial stents in this study, namely Solitaire stent and Enterprise stent. For open-cell stents, such as Neuroform stent, each individual cell of the stent serves as a separate device to support the arterial wall, fitting better to vascular tortuosity of the parent artery. However, comparing to close-cell ones, the open-cell stents have fewer struts apposing well to the vessel wall, therefore have lower strength, which may adversely affect the stenting density. This is observed in our study that two patients had prolapse of coil into the parent artery and had to be stented again later to keep the parent artery open. The close-cell

Table 3. Follow-up of patients with ruptured aneurysms treated with stent-assisted coiling (n=10)

Immediate post-operative angiography	Follow-up after discharge*		
	Complete coiling	Neck remnant	Sac remnant
Complete coiling (n=4)	6	0	0
Neck remnant (n=3)	2	1	0
Sac remnant (n=1)	1	0	0
Total	9	1	0

*The mean follow-up duration was 3.7±0.82 months.

stents, such as Enterprise stent, allows adjustment of the position of the device in the vessel lumen to optimize coverage of aneurysm neck. On the other hand, due to its close-cell design, Enterprise stent has raised concerns in experimental and clinical studies about its compliance and flexibility to accommodate to the vascular anatomy [11, 12]. Heller et al showed non 3T MRA that, the incomplete delivery rate of Enterprise stent was 55%-a phenomenon not seen with open-cell stents [13]. Thromboembolic complication and stent displacement could account for this high incidence of incomplete delivery with close-cell stent.

In terms of coiling technique, the jailed-catheter technique does not allow modification position of the microcatheter within the aneurysm sac, which commonly results in incomplete embolization and neck remnant. As to the trans-cell technique, tremendous cautions should be exercised when catheterizing the aneurysm through the stent strut in order to minimize risks of stent displacement and stent cell impingement. In our study, four patients receiving initial standard-alone embolization or balloon remodeling embolization underwent salvage stenting because of failure of their initial stentings.

Immediate post-operative imaging showed complete embolization in 44.7%, neck remnant in 50%, and sac remnant in 5.3% of our 38 patients, a result far from satisfying. However, we saw remarkable improvement in follow-up angiography: The total occlusion, rate went up to 72%, rate of neck remnant decreased to 15%, a decent outcome for acutely ruptured wide-necked intracranial aneurysm. This result strongly suggests close monitoring after surgery is necessary to assess the ultimate clinical benefit. However, further prospective studies are needed to explore the long-term stability of stent-assisted coiling and to decrease the rate of stent-related thromboembolism and recurrent hemorrhage.

In conclusion, this study indicates that self-expandable stent-assisted coiling can serve as an effective adjuvant method for the treatment of ruptured complex, wide-necked aneurysms in acute phase.

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Disclosure of conflict of interest

None.

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