Original Article

Stent-assisted coiling in ruptured wide-necked aneurysms: A single-center analysis

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Received: 18 July 2012 Accepted: 10 August 2012 Published: 27 October 2012

This article may be cited as: Alurkar A, Karanam LP, Nayak S, Oak S. Stent-assisted coiling in ruptured wide-necked aneurysms: A single-center analysis. Surg Neurol Int 2012;3:131.
Available FREE in open access from: http://www.surgicalneurologyint.com/text.asp?2012/3/1/131/102946

Abstract

Background: To evaluate the safety and efficacy of stent-assisted coiling of ruptured intracranial wide-necked aneurysms in a setting of acute subarachnoid hemorrhage, without compromising on the antiplatelet regimen.

Methods: Forty-two consecutive patients who underwent stent-assisted coiling for ruptured wide-necked intracranial aneurysms from August 2008 to May 2012 were studied. Demographic data like age, sex, Hunt & Hess grade, Fischer scale, and location, and size of the aneurysms were noted. Complications such as aneurysmal rupture, bleeding complications, thromboembolic events, etc. were documented. Also, 30-day and 1-year outcome was measured using modified Rankin scale (mRS).

Results: Forty-four wide-necked aneurysms were treated in 42 patients with stent-assisted coiling from August 2008 to May 2012 in our institution, out of a total of 248 aneurysms treated endovascularly in the same period. All these patients presented with subarachnoid hemorrhage (SAH) with varying grades and were treated in the acute phase, i.e. within 1 week of the ictus. There were 24 males and 18 females in the age group ranging from 12 to 78 years, with a mean of 45 years. Technical success was achieved in 39 patients with complete angiographic cure (93%). Intraprocedural stent thrombosis was seen in two patients, which resolved with intra-arterial bolus of tirofiban, and both the patients did not have any neurological deficit. Rebleed occurred in two patients of which one patient succumbed. Six patients required external ventricular drain because of worsening hydrocephalus on computed tomography (CT) scan with clinical deterioration. There was one death in our series due to rebleed. Three other patients died in a period of 1 month due to complications not related to the coiling procedure which include vasospasm, pulmonary embolism, and respiratory infection. All the patients were clinically followed up at 1 month, 3 months, 6 months, and 1 year. Also, angiographic follow-up was done at 1 year in 25 patients (72%). All the patients were maintained on clopidogrel 75 mg per day and ecosprin 150 mg per day for a period of 1 year and were advised to continue ecosprin 150 mg per day lifelong.

Conclusion: Even in a setting of acute SAH, stent-assisted coiling can be an effective and safe treatment option with acceptable risks in experienced hands.

Key Words: Stent-assisted coiling, subarachnoid hemorrhage, wide-necked aneurysm
INTRODUCTION

The results of International Subarachnoid Aneurysm Trial (ISAT) established the role of the endovascular method as a safe and effective option in the treatment of ruptured intracranial aneurysms. Advances in software and innovative techniques developed over the past decade have made the endovascular option even more widely acceptable in the treatment of intracranial aneurysms. The recently published Barrow Ruptured Aneurysm Trial (BRAT) concluded that coil embolization resulted in fewer poor outcomes at 1 year follow-up than surgical clipping.

An aneurysm is described as wide necked, if the neck width is greater than 4 mm or dome to neck ratio is less than 2 mm based on the measurements in digital subtraction angiography. These aneurysms pose a challenge to treat both by surgical and endovascular methods. In the endovascular field, these aneurysms are being treated regularly with balloon remodeling with good success rates. However, in very wide-necked aneurysms (dome to neck ratio ≤1), balloon-assisted coiling may not be effective. In these patients, stent-assisted coiling (SAC) gives a better and more durable result by allowing better neck remodeling and dense packing.

In patients with ruptured wide-necked aneurysms, controversy prevails over the use of stents to secure the neck of the aneurysm in the acute phase due to the requirement of loading the patient with antiplatelet drugs to prevent stent thrombosis. The treatment option in our patients was decided in consensus with Neurosurgeon; Neurologist, and the neurointervention team, based on clinical condition, anatomical location, and morphology of the aneurysm and associated co-morbid conditions of the patient. SAC in series of ruptured aneurysms has been reported in the literature; however, there is significant paucity of data with only a few reports.

In our study, we retrospectively analyzed 44 ruptured aneurysms treated with SAC in 42 patients, from a prospectively collected institutional database. We aim to focus on the antiplatelet regimen used by us and describe the outcome with respect to incidence of hemorrhagic and thromboembolic events in these ruptured intracranial wide-necked aneurysms.

Many studies earlier described the role of stent in treatment of complex intracranial aneurysms. Majority of them reported experience with the use of neuroform stent (Stryker Neurovascular, Kalamazoo, MI, USA) in both unruptured and ruptured aneurysms. The Enterprise stent was approved by food and drug administration (FDA) in 2007 for its use in intracranial aneurysms and few studies reported its successful use in wide-necked aneurysms. Solitaire AB is a fully retrievable split design nitinol stent used for the treatment of these aneurysms in both anterior and posterior circulations. Both the Enterprise and Solitaire AB stents were used in our present series and the choice of the stent was based on the operator’s decision in relation to the morphology and anatomical location of the aneurysm.

MATERIALS AND METHODS

The present series includes 42 patients with 44 aneurysms, consisting of 24 males and 18 females in the age group ranging from 12 to 78 years, who underwent endovascular coil embolization using either Enterprise (Cordis Neurovascular, Miami, FL, USA) or Solitaire AB (Solitaire AB neurovascular remodeling device, eV3, Inc., Irvine, CA, USA) stent from August 2008 to May 2012 in our institution. Informed and written high-risk consent was taken in all the cases. Twenty-four patients presented with grade III–IV subarachnoid hemorrhage (SAH) [Hunt & Hess (H&H) grade] in Table 1, whereas the rest had grade I–II. The aneurysm dimensions were assessed by digital subtraction angiography (DSA) and the decision to use the stent was made based on the angiographic evaluation. Procedure was done on the following day of DSA (elective) in 40 cases and the stent was used as a bail-out option in 2 of the patients (patient nos 7 and 27 in Table 1).

Antiplatelet regimen

A loading dose of clopidogrel 300 mg along with aspirin 300 mg was given at least 12 h prior to the procedure with a repeat dose of clopidogrel 150 mg and aspirin 150 mg 2 h prior to the procedure in all the elective cases. In the two patients where bail-out stenting was done, 450 mg of clopidogrel and 150 mg of aspirin was given through the nasogastric tube during the procedure and intravenous tirofiban was started simultaneously (15 ml bolus followed by 10 ml/h infusion intravenously for a period of 6 h). All the patients were maintained on clopidogrel 75 mg per day and ecospirin 150 mg per day for a period of 1 year and were advised to continue ecospirin 150 mg per day lifelong.

Standardized heparin protocol was followed maintaining the activated clotting time (ACT) greater than 250 seconds throughout the procedure.

Majority of the aneurysms were on the intradural internal carotid artery. 15 were on the anterior communicating artery, 8 on the middle cerebral artery, 4 on the basilar artery, and 1 on the A1 segment of the anterior cerebral artery. Enterprise stent was used in 27 patients, Solitaire stent in 12, and “Driver” balloon-mounted stent in 1 patient. Four of the 42 patients (patient nos 6, 21, 23, and 25 in Table 1) had two (double) aneurysms. In two of these patients (patient nos 23 and 25), both the wide-necked aneurysms were coiled, with a single stent...
### Table 1: Details of the patients in our study

| Patient no/age/sex | Ruptured aneurysm location (additional unruptured aneurysm) | H&H grade | Modified Fisher grade | Aneurysm dome size (mm) | Aneurysm neck size (mm) | Fundus to neck ratio | Post-SAH day of coiling | Stent used (size in mm) | Degree of occlusion | Procedural complications | Intracerebral bleed or systemic bleed up to 1 month | Follow-up DSA at 12 months | mRS at 1 month | mRS at 12 months |
|--------------------|-------------------------------------------------------------|------------|-----------------------|-------------------------|-------------------------|------------------------|------------------------|-------------------------|---------------------|------------------------|--------------------------------|-----------------------------|----------------|----------------|
| 1/45/F             | Lt. ICA bifurcation                                         | 2          | 3                     | 15×13.5                 | 12                      | 1.25                   | 3                      | Enterprise (4.5×22) | Subtotal            | None                   | None                  | Stable occlusion          | 1                           | 0              |
| 2/56/M             | Lt. ICA                                                     | 1          | 2                     | 2.5×2.25                | 2.25                    | 1                      | 4                      | Enterprise (4.5×22) | Subtotal            | None                   | None                  | None                        | 1                           | 0              |
| 3/60/M             | A-comm                                                     | 2          | 2                     | 4.5×5                   | 4                       | 1.25                   | 4                      | Enterprise (4.5×28) | Subtotal            | None                   | None                  | Stable occlusion          | 1                           | 1              |
| 4/43/F             | Lt. A1                                                     | 1          | 2                     | 3.6×2.5                 | 3.6                     | 1                      | 3                      | Solitaire (3×20)    | Subtotal            | None                   | None                  | None                        | 1                           | 1              |
| 5/55/F             | Rt. suprachlinoind ICA                                      | 4          | 4                     | 3.5×3                   | 3.2                     | 1.09                   | 5                      | Enterprise (4.5×22) | Subtotal            | None                   | None                  | Stable occlusion          | 1                           | 1              |
| 6/52/M             | A-comm (Lt. P2 aneurysm coiled in the same sitting)        | 2          | 2                     | 5.07×3.08               | 4.16                    | 1.21                   | 3                      | Enterprise (4.5×28) | Total                | None                   | None                  | Stable occlusion          | 1                           | 1              |
| 7/35/F             | Rt. M1                                                     | 1          | 1                     | 8.46×5.39               | 3.61                    | 2.34                   | 2                      | Driver (2.5×13)     | Subtotal            | None                   | None                  | None                        | 1                           | 1              |
| 8/50/F             | Basilar tip                                                | 3          | 3                     | 6.2×3.8                 | 3.7                     | 1.02                   | 6                      | Enterprise (4.5×22) | None                | Stent could not be deployed from basilar to Rt. PCA due to severe tortuosity of basilar and both VAs. Procedure abandoned | Recurrent SAH after 2 months | None                       | 1                           | Patient succumbed to recurrent SAH after 2 months |
| 9/62/F             | Lt. ICA – P-comm origin                                    | 3          | 2                     | 6.46×5.24               | 6.33                    | 0.82                   | 5                      | Solitaire (4×30)    | Subtotal            | None                   | None                  | Stable occlusion          | 1                           | 1              |

(Contd...)
| Patient no/age/sex | Ruptured aneurysm location (additional unruptured aneurysm) | H&H grade | Modified Fisher grade | Aneurysm dome size (mm) | Aneurysm neck size (mm) | Fundus to neck ratio | Post-SAH day of coiling | Stent used (size in mm) | Degree of occlusion | Procedural complications | Intracerebral bleed or systemic bleed up to 1 month | Follow-up DSA at 12 months | mRS at 1 month | mRS at 12 months |
|-------------------|-------------------------------------------------------------|-----------|----------------------|------------------------|------------------------|----------------------|----------------------|-----------------------|----------------------|--------------------------|---------------------------------|---------------------|-----------------|-----------------|
| 10/42/M           | A-comm                                                      | 3         | 4                    | 8.49×4.79              | 3.83                   | 1.25                 | 4                    | Enterprise (4.5×28)   | Total                | Stent thrombosis treated successfully with Inj. tirofiban into the microcatheter | None                | Stable occlusion | 1   |
| 11/74/M           | Rt. MCA bifurcation                                        | 4         | 3                    | 12.4×10.1              | 7.6                    | 1.32                 | 3                    | Enterprise (4.5×22)   | Subtotal             | None                     | None                | Mortality related to vasospasm and respiratory infection | None                | None            | 1   |
| 12/69/M           | Lt. ICA – Ant. choroidal origin                            | 3         | 3                    | 3.03×2.6               | 2.6                    | 1                    | 5                    | Enterprise (4.5×22)   | Subtotal             | None                     | None                | Stable occlusion | 1   |
| 13/48/M           | Rt. ICA – P-comm origin                                    | 2         | 2                    | 8.65×6.54              | 5.9                    | 1.1                  | 3                    | Enterprise (4.5×22)   | Subtotal             | None                     | None                | Awaited | 1   |
| 14/39/F           | A-comm                                                      | 3         | 3                    | 3.9×2.89               | 2.54                   | 1.13                 | 3                    | Solitaire (3×30)      | Total                | None                     | None                | Stable occlusion | 1   |
| 15/52/F           | Rt. ICA                                                    | 4         | 3                    | 6.45×3.1               | 2.89                   | 1.07                 | 5                    | Enterprise (4.5×22)   | Total                | None                     | None                | Neck recanalization* | 1   |
| 16/62/M           | Lt. MCA bifurcation                                        | 2         | 3                    | 7.3×5.2                | 4.8                    | 1.08                 | 5                    | Solitaire (3×30)      | Total                | None                     | None                | Stable occlusion | 1   |
| 17/32/M           | A-comm                                                      | 1         | 2                    | 1.65×2.72              | 2.72                   | 1                    | 4                    | Enterprise (4.5×22)   | Total                | None                     | Rebleed from aneurysm after 3 weeks of coiling, Underwent clipping | None                | Stable occlusion | 3   |
| 18/59/M           | Rt. MCA bifurcation                                        | 4         | 3                    | 9.02×6.17              | 4.71                   | 1.3                  | 3                    | Enterprise (4.5×22)   | Subtotal             | None                     | None                | Stable occlusion | 1   |
| 19/70/M           | Lt. ICA – Ant. choroidal origin                            | 2         | 2                    | 3.2×2.7                | 2.7                    | 1                    | 5                    | Enterprise (4.5×22)   | Subtotal             | None                     | None                | Stable occlusion | 4   |
## Table 1: Contd...

| Patient no/age/sex | Ruptured aneurysm location (additional unruptured aneurysm) | H&H grade | Modified Fisher grade | Aneurysm dome size (mm) | Aneurysm neck size (mm) | Fundus to neck ratio | Post-SAH day of coiling | Stent used (size in mm) | Degree of occlusion | Procedural complications | Intracerebral bleed or systemic bleed up to 1 month | Follow-up DSA at 12 months | mRS at 1 month | mRS at 12 months |
|--------------------|-------------------------------------------------------------|------------|-----------------------|-------------------------|--------------------------|-----------------------|-------------------------|----------------------------|------------------------|----------------------------|----------------------------|-----------------------------|----------------|----------------|
| 20/28/M            | Basilar tip, in a case of Moya Moya disease with occlusion of bilateral ICAs | 1          | 2                     | 4.9×4.2                 | 4.1                      | 1.19                  | 4                       | Enterprise (4.5×28), Enterprise (4.5×22) (Y stenting) | Subtotal                | None                        | None                        | Stable occlusion            | 1              | 0              |
| 21/32/F            | A-comm (Rt. ICA – P-comm origin) | 3          | 2                     | 5.2×4.7                 | 3.7                      | 1.27                  | 3                       | Enterprise (4.5×28)     | Total                  | None                        | None                        | Stable occlusion            | 1              | 1              |
| 22/57/F            | Lt. ICA – Ant. choroidal origin | 1          | 2                     | 6.7×4.8                 | 4.8                      | 1.27                  | 4                       | Enterprise (4.5×28)     | Subtotal                | None                        | None                        | Stable occlusion            | 1              | 1              |
| 23/78/M            | Two aneurysms on Lt. M1 | 3          | 2                     | 8.9×6.8                 | 5.7                      | 1.56                  | 6                       | Enterprise (4.5×37)     | Subtotal                | None                        | None                        | 1              | 1              |
|                    | 5.2×4.5                                                              | 3.7        | 1.21                  | Subtotal                |                          |                       |                          |                          |                        |                            |                            |                |
| 24/45/F            | Basilar tip | 1          | 2                     | 9.7×8.5                 | 7.1                      | 1.19                  | 6                       | Solitaire (4×30)        | -                       | Stent could not be deployed from basilar to Rt. PCA, hence procedure abandoned. Subsequently underwent balloon-assisted coiling at another center | -                          | -                            | -              |
| 25/40/M            | Rt. ICA bifurcation (Rt. 4.6×4.8) | 2          | 3                     | 3.9×4.2                 | 3.8                      | 1.1                   | 4                       | Enterprise (4.5×28)     | Total                  | None                        | None                        | Stable occlusion            | 1              | 1              |
| 26/50/F            | Lt. ICA – Paopthalmic | 1          | 2                     | 22×20                   | 4.9                      | 4.0                   | 5                       | Solitaire (4×30)        | Subtotal                | None                        | None                        | Neck recanalization, refused further Rx | 1              | 1              |

(Contd...)
| Patient no/age/sex | Ruptured aneurysm location (additional unruptured aneurysm) | H&H grade | Modified Fisher grade | Aneurysm dome size (mm) | Aneurysm neck size (mm) | Fundus to neck ratio | Post-SAHT day of coiling | Stent used (size in mm) | Degree of occlusion | Procedural complications | Intracerebral bleed or systemic bleed up to 1 month | Follow-up DSA at 12 months | mRS at 1 month | mRS at 12 months |
|--------------------|-------------------------------------------------------------|------------|----------------------|-------------------------|-------------------------|-----------------------|--------------------------|-------------------------|------------------------|-----------------------------|---------------------------------|-------------------|---------------------|
| 27/12/M            | Lt. ICA bifurcation                                         | 1          | 4                    | 5.7×3.8                 | 2.2                     | 1.72                  | 3                       | Solitaire 3×30          | Subtotal               | None                        | Stent deployed as a bail-out measure to treat coil prolapse during balloon-assisted coiling. | Awaited           | 1                   | 0                   |
| 28/32/F            | Lt. A1–A2 junction                                           | 1          | 1                    | 2.3×2.0                 | 2.8                     | 1.39                  | 7                       | Solitaire (3×20)         | Total                  | None                        | Stent thrombosis on table, treated successfully with Inj. tirofiban. | Awaited           | 2                   | 1                   |
| 29/45/F            | A-comm                                                      | 1          | 2                    | 5.6×3.9                 | 2.8                     | 1.39                  | 6                       | Solitaire (3×20)         | Subtotal small neck remnant | None                        | Stent could not be deployed from Lt. A1 to Lt. A2. Procedure done without stent. | Lost to follow-up | 1                   | 0                   |
| 30/35/M            | A-comm                                                      | 4          | 3                    | 5.2×4.4                 | 3.7                     | 1.18                  | 3                       | Enterprise (4.5×28)      | Subtotal               | None                        | Rebleed immediate post-procedure, during extubation emergency craniotomy and clipping. |                   |                     |                     |
| 31/65/M            | A-comm                                                      | 3          | 3                    | 6.5×5.2                 | 3.9                     | 1.33                  | 3                       | Enterprise (4.5×22)      | Total                  | None                        | Stable occlusion. |                                                | 1                   | 1                   |                     |
| 32 /30/F           | Rt. ICA – P-comm origin                                      | 3          | 3                    | 7.2×5.4                 | 4.1                     | 1.31                  | 6                       | Enterprise (4.5×28)      | Subtotal               | None                        | Stable occlusion. |                                                | 2                   | 1                   |                     |
| 33/49/M            | A-comm                                                      | 4          | 3                    | 3.5×2.8                 | 2.5                     | 1.12                  | 8                       | Solitaire (3×20)         | Total                  | None                        | Stable occlusion. |                                                | 3                   | 1                   |                     |
| 34/56/F            | A-comm                                                      | 4          | 3                    | 5.9×3.8                 | 3.6                     | 1.05                  | 4                       | Solitaire (3×20)         | Total                  | None                        | Stable occlusion. |                                                | 4                   | 2                   |                     |
| Patient no/age/sex | Ruptured aneurysm location (additional unruptured aneurysm) | H&H grade | Modified Fisher grade | Aneurysm dome size (mm) | Aneurysm neck size (mm) | Fundus to neck ratio | Post-SAH day of coiling | Stent used (size in mm) | Degree of occlusion | Procedural complications | Intracerebral bleed or systemic bleed up to 1 month | Follow-up DSA at 12 months | mRS at 1 month | mRS at 12 months |
|-------------------|---------------------------------------------------------------|-----------|-----------------------|------------------------|------------------------|----------------------|-----------------------|-------------------------|-----------------------|------------------------|------------------------------------------------|--------------------------|------------|--------------|
| 36/44/F Basilar tip | 5.5×4.8 | 3.9 | 1.23 | 4 | Enterprise (4.5×28) | Total | None | None | 2 | Pt. succumbed 7 days after coiling to vasospasm, pulmonary embolism |
| 37/69/F A-comm | 3.9×3.2 | 2.8 | 1.14 | 3 | Solitaire (3×20) | Subtotal | None | None | | |
| 38/62/M Rt. ICA – P-comm origin | 6.8×3.8 | 3.7 | 1.05 | 4 | Enterprise (4.5×28) | Total | None | None | 3 | Stable occlusion |
| 39/56/M A-comm | 5.1×3.9 | 3.6 | 1.08 | 2 | Solitaire (3×30) | Total | None | None | 2 | Stable occlusion |
| 40/33/M A-comm | 3.6×3.3 | 2.9 | 1.13 | 4 | Enterprise (4.5×22) | Subtotal | None | None | 3 | Stable occlusion |
| 41/66/M Lt. ICA bifurcation | 4.8×4.1 | 3.8 | 1.07 | 3 | Enterprise (4.5×22) | Total | None | None | 3 | Stable occlusion |
| 42/39/M Rt. ICA – P-comm origin | 7.9×3.5 | 3.5 | 1 | 4 | Enterprise (4.5×28) | Subtotal | None | None | 1 | |

*Coils placed through the struts of the stent*
covering both the aneurysm necks, whereas in the other two patients (patient nos 6 and 21), who had a wide-necked aneurysm and a narrow-necked aneurysm each, the wide-necked aneurysm was treated with SAC and the second aneurysm was treated with bare coiling in the same session.

**Technique**

All the procedures were done under general anesthesia. Femoral access was used in all the patients. A 6-F Envoy guiding catheter was placed in the parent artery (Internal Carotid Artery or Vertebral Artery). In addition, 7-F shuttle (Cook) long sheath was used (triple access) in the 38 patients with anterior circulation aneurysms. The aneurysm was accessed with either Echelon 10 or Prowler select LPES microcatheter combined with either Traxcess 14 (Microvention,) or Transcend 14 (stryker Neurovascular, Kalamazoo, MI, USA) microwires. The microcatheter used for coiling the sac was “jailed” in 33 patients, and in 6 patients the aneurysm was accessed through the struts of the stent.

“Rebar 18” microcatheter was used for the deployment of the Solitaire stent, and Prowler select plus was used to deploy the Enterprise stent. Post-procedure angiogram showed total occlusion in 16 patients [Figure 1 and Figure 2], whereas subtotal occlusion was achieved in the rest. All the patients who were in grade I–III H&H prior to the procedure were reversed from anesthesia and extubated immediately after the procedure, with extreme care taken to prevent the surge of the blood pressure during the extubation. Patients with grade IV H&H were continued on ventilatory support after the procedure, with close monitoring of the vital parameters.

External ventricular drain (EVD) had to be placed in six patients in our series (all these patients presented initially with grade IV SAH) due to worsening hydrocephalus on the computed tomography (CT) scan with clinical deterioration. There was no alteration in the antiplatelet regimen for placement of the EVD in these patients.

**RESULTS**

Forty-four wide-necked aneurysms were treated in 42 patients with SAC from August 2008 to May 2012 in our institution, out of a total of 248 aneurysms treated endovascularly in the same period. All these patients presented with SAH (grade I and II H&H in 18 patients and grade III–IV in 24 patients).

Technical success was achieved in 39 patients, and in 3 patients, stent could not be navigated across the neck of the aneurysm. Two of these technical failures were in cases of basilar tip aneurysms. In the first case, there was difficulty in negotiating the wire into the right distal posterior cerebral artery and in the second case there was severe tortuosity of bilateral vertebral arteries and mid-basilar artery, which prevented the navigation of the stent microcatheter across the neck of the aneurysm. In the third case, which was a wide-necked anterior communicating artery (A-comm) aneurysm, stent catheter was negotiated across the aneurysm neck distally, but there was extreme resistance while advancing the Solitaire stent in the rebar 18 microcatheter with prolapse of the microcatheter. In the first case, partial occlusion of the aneurysm was done with balloon remodeling technique in a different center. No further treatment was done in the second case and this patient refused surgical clipping, rebled and died after a period of 2 months. Subtotal occlusion with residual neck remnant was done in the case of the A-comm aneurysm with balloon assistance, and stent placement was planned at a later date.

Enterprise stent was used in 26 patients, Solitaire AB in 12, and Driver (balloon-mounted stent) was used as a bail-out option in 1 patient. Y stenting was done using two Enterprise stents in one case of basilar tip aneurysm in our series (patient no. 20).

Two patients had intraprocedural stent thrombosis (patient nos 10 and 28) [Figure 3] which was lysed with tirofiban (slow bolus infusion of tirofiban 15 cc via the guiding catheter, followed by maintenance dose of 10 cc/h intravenously for 6 h) and both the patients did not have any neurological deficit on extubation.

There were two cases of rebleed (patient nos 17 and 30 in Table 1) in our series. In the first case, bleeding occurred immediately after the procedure during extubation (probably due to the BP surge during reversal) and emergency clipping was done; however, the patient succumbed on the third day. In the second case, rebleed occurred 3 weeks after the procedure and the patient underwent successful emergency clipping followed by gradual clinical recovery.

One patient had upper gastrointestinal bleed 5 days after the coiling. It was treated uneventfully with Inj. omeprazole drip and withholding the aspirin for 5 days.

Clinical outcome was documented at 1 month, 6 months, and 1 year based on modified Rankin Scale. Good outcome (mRS grade 0, 1, 2) was seen in 30 patients (76.9%) at 1 month follow-up and in 35 patients (89.7%) at 1 year follow-up. Angiographic follow-up could be done in 25 (72%) patients of whom neck recanalization was seen in two patients. Retreatment was done in one patient and one patient refused further treatment. The overall mortality rate in this series was 11.9% (5 deaths). Three patients (nos 5, 11, and 37 in Table 1) died from the complications attributable to the poor grade of SAH. One patient (patient no. 8 in Table 1), whose procedure was a
Figure 1: CT scan shows diffuse subarachnoid hemorrhage (a). Digital subtraction angiogram shows wide-necked paraopthalmic aneurysm (arrows in b, c). Fluoroscopic image (d) shows the stent microcatheter (double arrow) and the jailed microcatheter in the aneurysm (single arrow). Post-procedure angiogram (e) shows complete exclusion of the aneurysm from the circulation, and 1-year follow-up angiogram (f) shows stable occlusion.

Figure 2: CT scan shows subarachnoid hemorrhage predominantly in the anterior interhemispheric fissure (a). CT angiogram shows wide-necked anterior communicating artery aneurysm (arrow in b). Digital subtraction angiogram shows wide-necked inferiorly pointing anterior communicating artery aneurysm (c). Post-procedure angiogram shows exclusion of the aneurysm from the circulation (d). Fluoroscopic image (e) shows the stent (double arrow) and the coil mass (single arrow). Control angiogram shows stable occlusion of the aneurysm (f).
technical failure, died due to rebleed after 2 months and only one patient (patient no. 30 in Table 1) died because of a procedure-related complication (hemorrhage). Thus, the procedure-related mortality was 2.3%.

DISCUSSION

The use of self expanding stents (Enterprise, Solitaire) for aneurysm neck remodeling for intracranial wide-necked aneurysms has been well described.

Pretreatment of the patients with antiplatelet drugs is needed while planning the use of stent in these patients to prevent thromboembolic events, and hence the decision of using stents for these wide-necked aneurysms in the setting of acute SAH remained controversial. Conflicting results were shown in some series where the ruptured aneurysms were included as a subgroup in series of SAC of intracranial aneurysms.

EVD was placed in six of our patients after securing the aneurysm (all were placed within a period of 1 week interval after the procedure) and we did not withhold any antiplatelet agent in any of these patients. All EVDs were placed based on clinical deterioration with increase in hydrocephalus on CT scan. All the patients who required EVD in our series were the ones who had H&H grade IV on admission.

The ventricular drain catheter was placed without a stylet in these patients. Tumialan et al. reported high rate of hemorrhagic complications (80.6%) in their series of seven patients who had undergone SAC of ruptured intracranial aneurysms with EVD or ventriculoperitoneal shunts placed. Two patients among these seven had aneurysm re-rupture, and one patient of elective SAC of unruptured aneurysm who had a periprocedure rupture was also included in the same series. In all our patients, aneurysm was well secured and post-procedure angiograms showed either complete or near-complete occlusion of the aneurysm. We did not encounter any ventriculostomy-related hemorrhagic complications.

Fiorella et al. described a subgroup of six patients with ruptured aneurysms who underwent SAC with neuroform stent, without pretreatment with antiplatelet drugs. They did not use any intraprocedural glycoprotein IIb/IIIa inhibitor. Three patients had acute infarcts on diffusion-weighted magnetic resonance imaging (MRI) and one patient with an initial normal MR later developed in-stent thrombosis. Taylor et al. reported a series of 42 consecutive patients with acutely ruptured intracranial saccular aneurysms treated with SAC, with an antiplatelet regimen of clopidogrel 375 mg loading dose post-procedure followed by 75 mg/day maintenance dose for 3 months in all the patients. Aspirin was given in 37 patients. Intravenous tirofiban was given as a prophylactic treatment in 7 patients, while in 12 patients it was given because of the platelet aggregates within the stent. These operators initially attempted to primarily coil the aneurysm and the decision for use of stent was made during the procedure, hence pretreatment with antiplatelet drugs was not possible.

In this cohort, a total of seven ischemic strokes and three intracerebral hemorrhages were documented. 29% of their patients had intraprocedural in-stent platelet aggregation. In our present series, because of the adequate pretreatment and preloading with antiplatelet agents (clopidogrel and aspirin), we had...
only two cases of in-stent platelet aggregates. In both patients, the thrombus resolved with use of tirofiban, and the patients were asymptomatic without any deficit on extubation. Significantly, none of our patients had any bleeding complication, especially aneurysm rebleed in the hours between loading of antiplatelet drugs and the aneurysm coiling. Lodi et al.[7] in their series of 22 patients of ruptured aneurysms treated with SAC used the standard antiplatelet regimen with prior pretreatment. None of their patients had ischemic or hemorrhagic complications, and they had a good clinical outcome of 82%. We agree with these authors in proper prior pretreatment of the patients with antiplatelet agents and not compromising on the drug strategy even in the setting of acute SAH.

Katsaridas et al.[7] in a subgroup of 33 patients of acutely ruptured aneurysms treated with neuroform stent did not encounter any ischemic or bleeding complications. Their drug strategy included clopidogrel 75 mg and aspirin 100 mg at the end of the procedure or the following morning. Heparin 5000 IU bolus was given with 1500 IU every 1.5 h to maintain ACT of 200, and 2500 IU heparin was given at the end of the procedure. In our series, we followed the standard antiplatelet regimen which completely differs from their strategy and we believe that early pretreatment with antiplatelet drugs reduces the thromboembolic events and in-stent thrombosis which is a major concern in the use of stent in these cases.

In ruptured aneurysms, once bleeding stops, the hemostatic mechanism begins by activation of platelets and formation of thrombus, which over a few hours, increases and forms the thrombus rich in platelets. As aspirin and clopidogrel have no effect on a pre-existing thrombus, the possibility of increase in the rupture or bleeding rates is less likely. Previously published series revealed high rates of thromboembolic complications in ruptured aneurysms when compared to the untreated population.[6,9,20] A loading dose of clopidogrel provides platelet inhibition of 55% in 1 h and 80% within 5 h.[16] Hence, loading doses administered prior to the procedure as in our series significantly reduce the intraoperative thromboembolic events.

**CONCLUSION**

In wide-necked aneurysms, SAC can be a feasible treatment option even in the setting of acute SAH with acceptable risks. Prior antiplatelet agent loading reduces the incidence of thromboembolic complications which is a major concern in these cases. Importantly, this is achieved without a significant risk of bleeding complications during or after the endovascular procedure. However, a larger prospectively designed randomized study is required which will help to validate the same conclusions with a wider acceptance.

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Commentary

Treatment considerations and dilemmas in stent-assisted coiling of ruptured intracranial aneurysms

Two recent articles in Surgical Neurology International analyze their excellent technical experience with stent-assisted coil embolizations of ruptured intracranial aneurysms. The use of stent-assisted coiling is widely applied nowadays in the treatment of unruptured complex or wide-neck intracranial aneurysms, which previously were unamenable to endovascular treatment. Stent-assisted coiling of ruptured intracranial aneurysms, however, is not as widespread and remains somewhat controversial due to the possibility of thrombotic complications and the consecutive need for dual anti-platelet therapy in the presence of an acute subarachnoid hemorrhage. In fact, the use of dual anti-platelet therapy in this patient population is the cause of numerous treatment dilemmas, which are analyzed and discussed in an insightful manner in both articles, but which deserve further elaboration for a neurosurgical perspective.

Due to the prothrombotic features of intracranial stents, there is a strict need for dual anti-platelet therapy, most commonly aspirin and clopidogrel. Yet, no consensus exists in terms of how patients should be loaded prior to stenting. The group of Alurkar and colleagues used a loading dose of clopidogrel 300 mg along with aspirin 300 mg at least 12 h prior to the procedure with a repeat dose of clopidogrel 150 mg and aspirin 150 mg 2 h prior to the procedure. Golshani and colleagues in their multicentric series report non-uniform timing and loading algorithms. Some of these differences are due to whether stent-assisted coiling is planned prior to the intervention, as in the majority of cases of Alurkar and colleagues, or whether stenting is done as a bail-out technique or decided upon intraoperatively. While planning a stent-assisted coiling approach allows a more regulated loading scheme, it also delays definite treatment of the ruptured aneurysm, and may put the patient at risk for a re-bleed during this time window. As intra-procedural dual anti-platelet loading is done in an emergent manner, it shows even greater variability, and limited data in respect to its efficiency exists, prompting many centers to use an additional platelet aggregation inhibitor such as abciximab, a glycoprotein IIb/IIIa receptor antagonist, which has been identified with a high incidence of intracranial hemorrhage (18%) and increased mortality rates.

To further complicate matters, between 5% and 65% of patients will be non-responders to aspirin and an estimated 30% will be resistant to clopidogrel. While it appears intuitive that resistant patients may have higher thromboembolic complication rates due to an absence of platelet inhibition, platelet function testing, which is the only way to objectify a person’s response to anti-platelet therapy, remains controversial and appears not to have been performed in the two articles discussed here.

While stenting on one hand increases the risks of possible thromboembolic complications, the need of having patients on dual anti-platelet therapy on the other hand increases the risks of hemorrhagic complications. Kung and colleagues, for example, looked at hemorrhagic complications in patients who underwent a coiling procedure with and without a stent, demonstrating a significant higher rate of clinical and radiographic hemorrhage for patients on dual anti-platelet therapy, with 3.42 times the odds of a radiographic hemorrhage. Other studies show an even higher risk of ventriculostomy-associated hemorrhagic complications after stent coiling of ruptured aneurysms, with Tumialan and colleagues reporting an 85% complication rate in a small series. While clearly differences may be due to different handling...
of a ventriculostomy under such circumstances, no treatment consensus exists in respect to the safest manner in which to perform a ventriculostomy on dual anti-platelet therapy. Important questions in this respect remain unanswered, such as whether anti-platelet therapy should be stopped, or continued but platelets given, or should the procedure be performed using a Heparin bridge? While part of the problem may be avoided by inserting a ventriculostomy prior to stenting, these treatment dilemmas may still become relevant in the context of malfunctioning ventricular drains that need to be replaced in the intensive care unit.

Finally, doubts remain regarding the efficacy of stent coiling of ruptured intracranial aneurysms. A recent meta-analysis showed a 63% complete occlusion rate after stent coiling, with a technical success rate of 93% and a 2% surgical cross-over rate. Similar numbers are reported in their respective series by Golashani and colleagues, indicating excellent technical endovascular expertise. Even higher occlusion rates were reported by Alurkar and colleagues, indicating a 93% occlusion rate in their series of scheduled stent coiling; yet, they also report two re-bleeds in the postoperative period, one of which was fatal. Clearly, both articles discussed here show a high level of expertise as well as a thoughtful and skilful approach to their patients.

Intracranial stenting for treatment of ruptured aneurysms remains an important endovascular bail-out technique in cases such as thrombosis at the aneurysm neck, or dislocation of coils into the parent vessel. Yet, given the additional risks of both thromboembolic and hemorrhagic complications, including remaining issues in respect to handling of dual anti-platelet therapy in an immediate postoperative setting, and occlusion rates lower than those reported in microsurgical clipping series, one wonders whether routine stent-assisted coiling of ruptured aneurysms should not be reserved only for carefully selected cases.

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