Stent placement in the endovascular treatment of intracranial aneurysms

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Summary

Objective: To analyze the immediate and mid-term angiographic and clinical results of stent placement in the endovascular treatment of intracranial cerebral aneurysms.

Methods: Out of 330 cerebral aneurysms treated by endovascular approach in our neurovascular centre, stents have been used in 18 patients. Twelve aneurysms (66.7%) were acutely ruptured, four (22.2%) were unruptured, two (11.1%) were recanalized after initial coiling. In three patients (16.7%) stent placement was used for revascularization of acute vessel thrombosis during coiling. Angiographic follow-up was obtained in 13 (72.2%) patients (mean 1.8 years, range 0.4–6.6) and clinical follow-up in 13 (72.2%) patients (mean 2.0 years, range 0.2–6.6).

Results: Complete occlusion was achieved in eight (44.4%) patients, a neck-remnant remained in four (22.2%) and an incomplete occlusion in four (22.2%). In the two cases of previously treated aneurysms a neck-remnant remained after secondary stent-assisted coiling.

In four cases thromboembolic events resulted in a transient procedure related morbidity. No permanent procedure related morbidity or mortality was observed. One case of an asymptomatic late in-stent stenosis occurred. On clinical follow-up modified Ranking Score was 0 in 3 patients (23.1%), 1 in 3 patients (23.1%) and 2–3 in 7 patients (53.9%). On angiographic follow-up recanalisation was observed in 5 (38.5% = 5/13) aneurysms.

Conclusion: Even in acutely ruptured aneurysms, stent assisted coiling can be a relatively effective and safe treatment for cerebral aneurysms. One asymptomatic in-stent stenosis occurred indicating that the risk rate of restenosis seems to be lower compared to stent deployment in atherosclerotic lesions, where restenosis rates up to 30% are described.

Key words: intracerebral aneurysm; coiling; endovascular treatment; intracranial stent

Introduction

Treatment of intracranial aneurysms is increasingly performed by endovascular means as an alternative to microsurgical clipping with lower morbidity and mortality rates in selected cases [1]. The introduction of new technical developments in terms of microcatheter improvements, the use of balloon remodelling technique, coils with complex 3D shape, bioactive and hydrogel coils and stent-assisted coiling have led to improved outcome. Nevertheless the endovascular treatment of wide-necked (>4 mm neck or dome-to-neck ratio <2) aneurysms continues to present a technical challenge. The risk of coil protrusion into the parent vessel and subtotal aneurysm occlusion remains a major limitation of coil embolization. The development of intracranial stents has increased the options in the treatment of intracerebral aneurysms with unfavourable anatomy [2–7] and of stenosis in atherosclerotic disease [8–10]. Stent placement across the aneurysm neck enables additional obliteration by denser and safer packing of the aneurysm lumen and may improve aneurysm occlusion by the redirection of flow. Furthermore stent placement has been described as feasible for recanalisation of acute symptomatic intracranial occlusions, which may occur as an acute complication of endovascular treatment of cerebral aneurysms [11–13]. Although stent-assisted coiling has expanded the treatment possibilities, the technique carries the risk of stent misplacement, thromboembolic events and in-stent stenosis or thrombosis. Furthermore long-term antiplatelet medication is necessary in this subgroup of patients.

The purpose of this study was to evaluate our single centre experience and mid-term imaging and clinical results of stent-assisted endovascular coil embolization of intracranial aneurysms.

Clinical material and methods

Patient population

We conducted a retrospective review of medical records and angiographies of patients who underwent endovascular stent placement and coiling for intracranial cerebral aneurysms between March 2001 and November 2007. Anatomical and clinical analysis was carried out on 18 consecutive patients. The patients were selected for endovascular treatment after assessment by the referring neurosurgeon and the interventional neuroradiologist. There were 8 (44.4%) women and 10 (55.6%) men with a mean age of 57.2 years (range from 37 to 81 years). At the time of stent treatment 12 (66.7%) aneurysms were acutely ruptured, 4 (22.2%) unruptured and 2 (11.1%) aneurysms were unruptured recanalised or incompletely occluded after previously being treated using coils only.

Five patients with unruptured aneurysms were symptomatic due to cranial nerve palsy, chronic headache or transient ischaemic attacks due to thromboembolism from large partially thrombosed aneurysms. Initial clinical grading was performed according to the Hunt-Hess grading scale [14] and the World Federation of Neurosurgical Societies grade (WFNS) [15]. Patient data are summarised in table 1.

Procedure

Conventional cerebral catheter angiography was performed using a biplane digital subtraction neuro-angiography (DSA) (Angio G-ring CAS 500, Toshiba, Tokio, Japan). Image data was stored and revaluated using the PACS system. All patients received general anaesthesia. The continuous flush of catheters and devices contained 5000 IU heparin per 1000 ml normal saline, no additional anticoagulation with heparin bolus was administered during the interventions. Angiography was performed with non ionic contrast medium (Iopamiro 300 Bracco, Milano, Italy). Depending on the size of the aneurysm to be treated, normally an Exel-SL 10 or 14-microcatheter (Boston Scientific/Target) was used. The microcatheter was placed coaxially through a 6-F guide catheter (Envoy, Cordis Neurovascular; or Guider, Boston Scientific/Target). By using magnified fluoroscopy and digital biplane road mapping, the microcatheter was navigated into the cerebral vessel, distally from the neck of the aneurysm which was passed with the aid of a 0.010- or 0.014-inch guide wire (Fas-Dasher; Boston Scientific/Target or Silver Speed, Medtronic MIS, Sunnyvale, CA). The microcatheter was exchanged over a long micro guide wire which was used to introduce the stent system. After delivery of the stent by bridging the neck of the aneurysm, the microcatheter was navigated through the mesh of the stent into the aneurysm and stent protected coiling was performed. In two patients, double microcatheter technique was used to avoid navigation of the microcatheter through the stent mesh; after introduction of the first microcatheter into the lumen of the aneurysm the stent was deployed secondarily. Applying this technique, the tip of the microcatheter in the lumen of the aneurysm can be stabilized during the coil application.

The intracranial stents deployed were 10 Neuroform stents (Boston Scientific/Target), 6 Wingspan stents (Boston Scientific/Target), one Jostent Graft Master (Ab-

Table 1

Patient data and aneurysm characteristics.

Pat. no.	Age (yr)/sex	Clinical Findings	WFNS/ H&H	Location	Size	Previous Treatment
1	65/m	SAH	2/2	Vertebral	S	
2	65/f	SAH	1/1	Basilar	S	
3	47/m	diplopy	1/0	Basilar	L	
4	67/f	incidental	1/0	ICA supraophthalmic	S	
5	41/f	SAH	1/1	Basilar tip	M	
6	81/m	SAH	1/2	Acom	S	
7	68/f	SAH	4/4	Basilar tip	M	
8	57/m	SAH	1/1	ICA, anterior choroidal artery	M	
9	38/f	SAH	1/2	Basilar	S	
10	81/f	6th CN palsy	1/0	ICA cavernous	L	
11	50/m	SAH	3/2	Acom	M	
12	37/m	SAH	4/4	ICA supraophthalmic	L	
13	49/f	SAH	1/2	Acom	S	
14	63/m	3rd CN palsy	5/0	Basilar tip	L	Coiling twice
15	49/m	chronic headache	1/0	ICA, C1	L	Coiling
16	57/f	SAH	1/2	Acom	M	
17	60/m	SAH	1/2	ACA, A2	S	
18	55/m	past transient ischemic attack	1/0	MCA, M1	L	Wrapping

m: male; f: female; mo: month; SAH: subarachnoid haemorrhage; CN: cranial nerve; WFNS: World Federation of Neurological Surgeons grade; H&H: Hunt-Hess grading scale; mRS: modified Ranking Scale; ICA: internal carotid artery;
Acom: anterior communicating artery; ACA: anterior cerebral artery; MCA: middle cerebral artery; PCA: posterior cerebral artery;
S: small; M: medium; L: large

bott) and one Medtronic AVE stent (Medtronic). Electrolytically detachable coils (GDC, Boston Scientific) were used in all aneurysms.

The anticoagulation/antiaggregation treatment was decided on a case by case basis and we did not follow a strict protocol. In patients presenting with SAH in the acute phase aspirin 300 mg was administered after stent deployment and coiling of the aneurysm, aspirin 100 mg/d immediately after the procedure and depending on the clinical course clopidogrel 75 mg/d was added. In non-acutely ruptured aneurysms, in whom stenting was not planned aspirin 300 mg/d was given intravenously during the intervention and clopidogrel 75 mg/d was added immediately after the procedure. After the treatment aspirin was given indefinitely and clopidogrel for three months.

Angiographic workup

The aneurysms were classified by their size and neck width and were measured according to their longest axis on selective angiograms. Neck size has been shown to be a crucial determinant for successful endovascular occlusion [16]. The size of the neck was measured according to the projection showing the widest neck. Aneurysm morphology and location is summarised in table 1.

The aneurysmal occlusion rate was evaluated and classified as described by Roy et al. [17]. First angiographic follow-up was routinely obtained after 3 to 6 months. Additional follow-up was obtained using DSA, magnet resonance angiography (MRA) with ultra short echo times [18] or CT angiography. The mean follow-up was 22 months. The changes observed on follow-up imaging were classified as unchanged with a similar degree of aneurysm occlusion rate and recanalised with an increase in the amount of contrast material filling the aneurysm compared with the immediate post treatment angiographic results or the latest follow-up imaging.

Clinical outcome measures

Clinical outcome was assessed at hospital discharge using the modified Rankin Score (mRS) [19]. To determine the clinical outcome in addition to the latest clinical routine follow-up a questionnaire was sent to the patients that allowed calculation of the mRS based on the given answers.

Results

Immediate angiographic outcome

Seven (38.9%) aneurysms were small (<7 mm), 5 (27.8%) were intermediate (7–12 mm) and 6 (33.3%) were large (>12 mm) with a range from 4.5 mm to 22 mm. Six (33.3%) aneurysms had small necks (≤4 mm), whereas 12 (66.7%) had large necks (>4 mm). Eleven (61.1%) showed a dome/neck-ratio of ≤2.

In 16 patients (88.9%) stent-assisted coil embolization was the first-line treatment. In two patients (11.1%) with a previously coiled large basilar tip aneurysm and a large ICA aneurysm, re-canalisation was observed at follow-up and retreatment with stent-assistance was performed. In three patients (16.7%) endoluminal thrombus formation in the parent vessel occurred during coiling and stent placement was used for immediate recanalisation of the vessel and to facilitate further coil embolization.

Complete occlusion with primary stent-assisted coiling was achieved in 8 patients (44.4%), a neck-remnant in 4 (22.2%) and an incomplete occlusion in 4 (22.2%). In the two recanalised or incompletely occluded aneurysms additionally

Case 1

A: Cerebral angiography of patient no 15 showing a large unruptured aneurysm of the left terminal ICA in anteroposterior view.
B: Initial embolization result after coiling with neck remnant.
C: Follow-up angiography performed after ten months showing recanalisation of the aneurysm neck.
D: Stenting (arrows, stent markers) and coiling was performed in the same session.
E/F: Anteroposterior and lateral view depicting the final embolization result with minimal residual perfusion of the medial aneurysm neck (arrow).
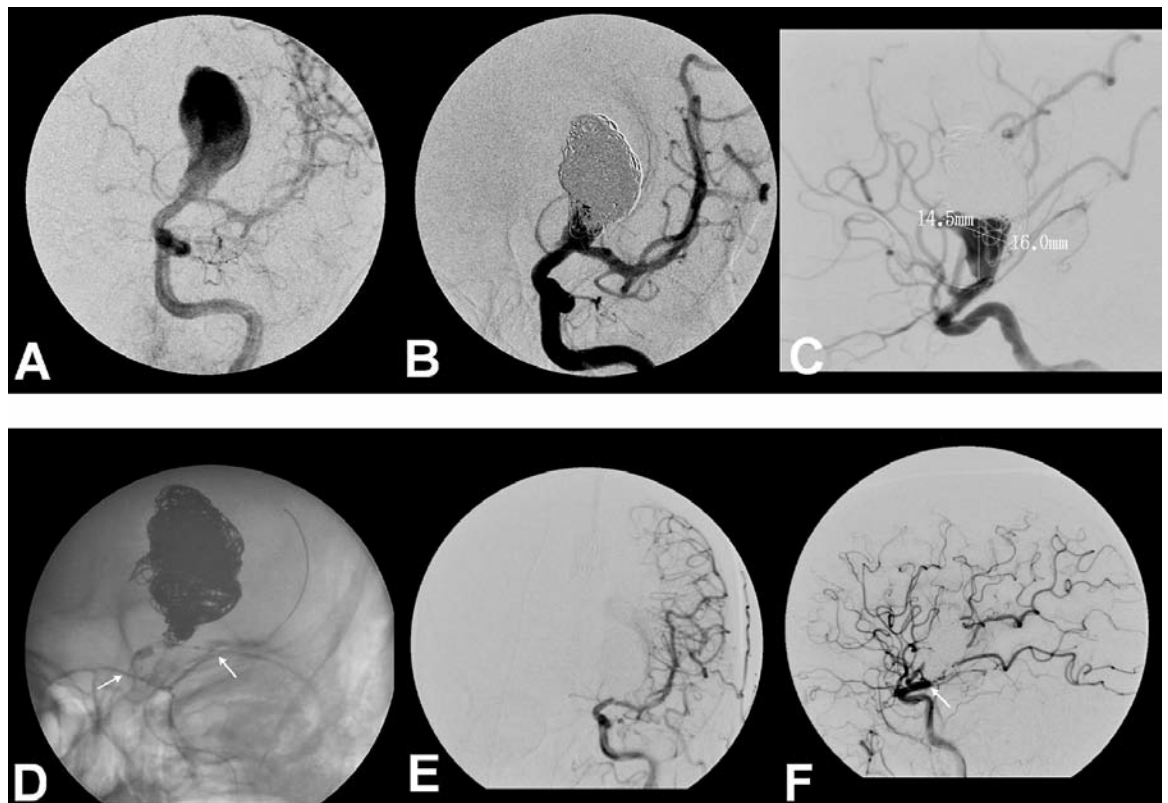
treated with stent-assisted coiling a neck-remnant still remained.

Four (57.1%) of the small aneurysms (<7 mm) were completely obliterated and in 3 (42.9%) aneurysms a neck remnant was observed. Three (60.0%) of the intermediate aneurysms (7–12 mm) were completely occluded, 1 (20.0%) remained with a neck remnant and 1 (20.0%) was incompletely obliterated. One (16.7%) of the large aneurysms (>12 mm) showed complete occlusion, 2 (33.3%) had a neck remnant and 3 (50.0%) were incompletely occluded.

Three (50.0%) of the treated small-necked (≤4 mm) aneurysms were completely occluded and 3 (50.0%) had a neck remnant. Five (41.7%) of the wide necked (>4 mm) aneurysms showed complete occlusion, 3 (25.0%) had a neck rem-

nant and 4 (33.3%) incomplete occlusion. Immediate imaging outcome is shown in table 2.

Intermediate angiographic outcome

Follow-up imaging was obtained in 13 patients (72.2%). The mean imaging follow-up period was 1.8 years (range 0.4 to 6.6 years). Overall recanalisation was observed in 5 (38.5% = 5/13) aneurysms, while 7 (53.8% = 7/13) remained unchanged. Recanalisation was detected in 0% (0/7) of small aneurysm (<7 mm), 20.0% (1/5) of the intermediate aneurysms and in 66.7% (4/6) of the large aneurysms. Recanalisation was found in 14.3% (1/7) of dome/neck ratio ≤2 aneurysms and in 66.7% (4/6) of dome/neck ratio >2 aneurysms.

Six (75.0%.) of the initially eight completely

Table 2

Clinical and imaging outcome.

Pat. no.	Complications	Embolization results	mRS at hospital discharge	Angiographic follow-up/results	Retreatment/ results	Angiographic follow-up	Clinical follow-up	mRS follow-up
1		Occlusion	0	79 mo, occlusion			79 mo	0
2		Neck remnant	2	6 mo, neck remnant unchanged				
3	Thrombus formation with diffusion restriction, symptomatic transient deficit, re-rupture and need for re-coiling	Residual	2	20 mo, residual aneurysm increased	Coiling, occlusion	30 mo, residual	53 mo	1
4		Neck remnant	1	39 mo, neck remnant decreased			50 mo	2
5	Asymptomatic diffusion restriction	Residual	3	44 mo, residual aneurysm increased			50 mo	2
6		Occlusion	6					
7	Thrombus formation at coiling, indication for stent recanalisation, asymptomatic PCA infarction	Occlusion	6					
8	Asymptomatic thrombus formation	Neck remnant	6					
9	Asymptomatic PCA infarction	Occlusion	3	9 mo, occlusion			2 mo	0
10	Inguinal haematoma requiring surgery, asymptomatic in-stent occlusion after six months	Occlusion	4	19mo, occlusion			20 mo	2
11	Transient symptomatic ischaemia G. cinguli	Occlusion	4	6 mo, occlusion			18 mo	3
12	Stent dislocation	Residual	6					
13	Thrombus formation at coiling, indication for stent recanalisation, symptomatic transient neurological deficit	Occlusion	4	6 mo, occlusion			9 mo	1
14	Recanalised coiled aneurysm, at re-coiling thrombus formation and indication for stent recanalisation, asymptomatic ischaemia	Neck remnant	2	9 mo, residual			9 mo	2
15		Neck remnant	1	5 mo, residual			5 mo	2
16		Occlusion	0	6 mo, occlusion			6 mo	1
17	Transient symptomatic ischaemia	Neck remnant	2	Scheduled			5 mo	0
18		Residual	2	2 mo, residual increased			5 mo	3

Case 2

A/B: Cerebral angiography of patient no 17 showing a 5x6 mm ventrally projecting aneurysm of the right anterior cerebral artery at the A3-segment involving the callosomarginal artery. Additionally three lobuli of the aneurysm are seen.

C/D: Lateral and anteroposterior view depicting the final embolization result (arrows, stent markers) with complete occlusion of the aneurysm and preserving of the callosomarginal and pericallosal artery.
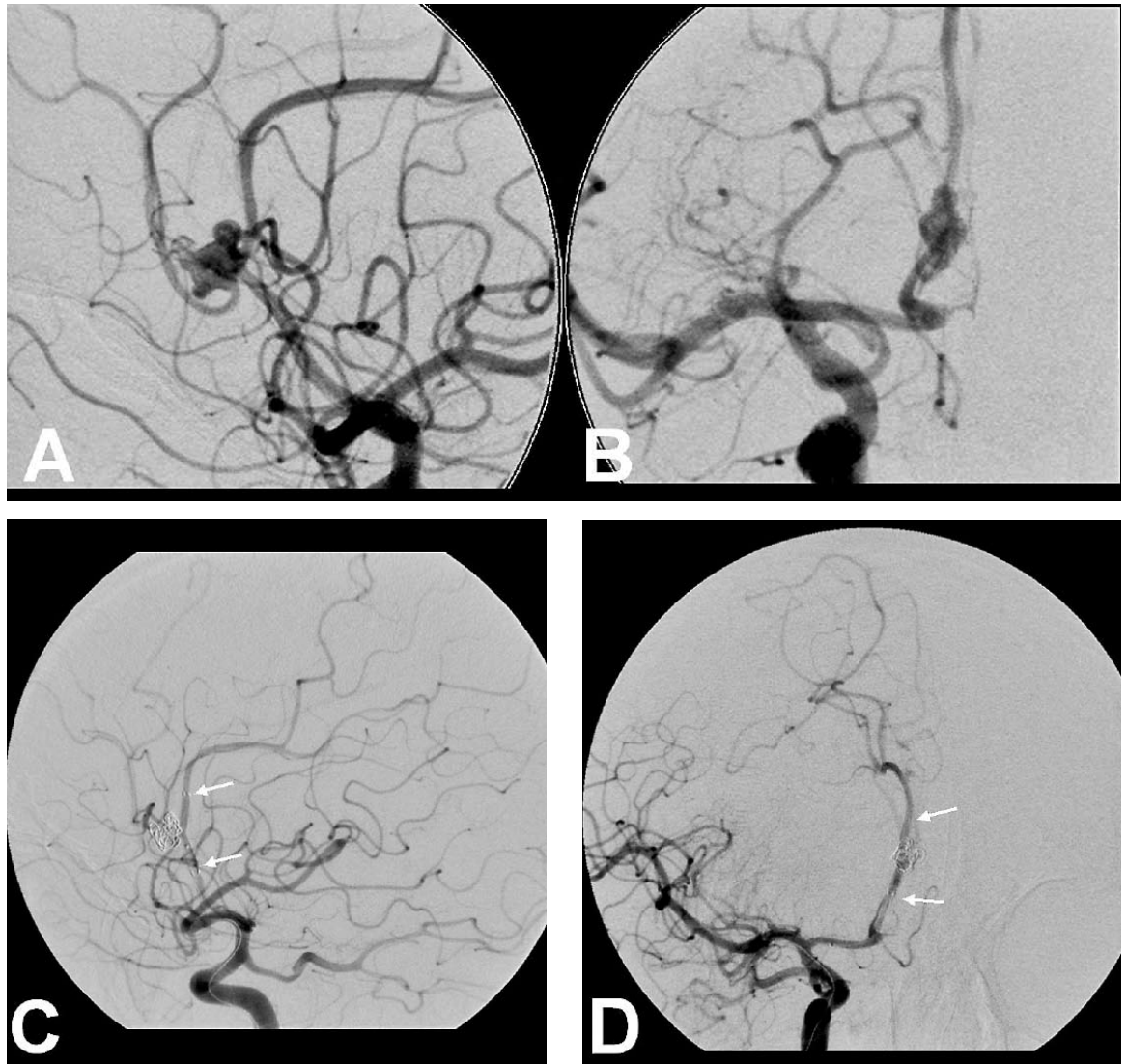
occluded aneurysms remained stable during follow-up. Recanalisation of neck-remnants or residual aneurysms was observed in 50.0% (= 5/10), of which one needed retreatment due to aneurysm rupture. Follow-up imaging outcome is shown in table 2.

Immediate clinical outcome

In the clinical course of all patients, including the acute SAH patients three (16.7%) showed no symptoms (mRS 0), 6 (33.3%) had no significant or slight disability (mRS 1 and 2), two (11.1%) were moderately disabled (mRS 3), three (16.7%) were moderately severely disabled (mRS 4), and four (22.2%) died (mRS 6). Overall, nine (50.0%) patients had excellent or good recovery (mRS 0 to 2) at hospital discharge (table 2).

Intermediate clinical outcome

Clinical follow-up was achieved in 13 (72.2%) patients. The mean duration of the clinical follow-up was 2.0 years (range 2 to 79 months). 23.1% (3/13) of the patients achieved a mRS 0, 23.1% (3/13) a mRS 1, 38.5% (5/13) a mRS 2, and 15.4% (2/13) showed a mRS 3 at the latest clinical follow-up (table 2).

Procedure-related complications, morbidity and mortality

In four patients (22.2%) asymptomatic ischaemia was found at post procedural imaging, detected mainly by diffusion weighted lesions in MRI. In four patients (22.2%) thromboembolic events were observed, but there was no permanent procedure-related morbidity. In one patient (5.6%) with a supraophthalmic ICA aneurysm stent dislocation in the ICA occurred, requiring the introduction of a second stent proximally to the first one to cover the neck of the aneurysm completely. In one patient a post procedural inguinal haematoma occurred, which required a surgical intervention.

There was one rupture of a treated aneurysm. This patient with a basilar tip aneurysm missed follow-up and suffered from a SAH Hunt-Hess Grade 2 22 months after the initial treatment due to compaction of the coils and revascularization of the lumen up to the dome of the aneurysm. He had to undergo an additional coiling procedure. The patient recovered fully after the rebleed and could return to work.

One late asymptomatic stent occlusion with retrograde occlusion of the ICA was detected by

control angiography six months after the treatment of a large cavernous ICA aneurysm. Collateralisation was seen over the anterior communicating artery from the left side. This patient was already taking oral anticoagulation due to atrial fibrillation and remained clinically asymptomatic.

Discussion

The treatment of intracranial aneurysms is increasingly performed by endovascular means, but wide-necked aneurysms continue to present a technical challenge. The risk of coil protrusion into the parent vessel, subtotal aneurysm occlusion and recanalisation of the aneurysm are still major limitations of image guided, endovascular treatment of cerebral aneurysms.

Following the introduction of new self-expandable stents for intracranial application several groups have reported the results of their series, for example, Neuroform stent [2, 3, 5–7, 20–26] (Boston Scientific/Target, Fremont, CA), the Cordis Enterprise stent [27] (Cordis Endovascular, Miami Lakes, FL), the Balt Leo stent [28–30] (Balt, Montmorency, France) or the Wingspan stent [9, 10] (Boston Scientific/Target, Fremont, CA). These flexible stents allow for better navigation in the tortuous intracranial vasculature. Although stent-assisted coiling has expanded the treatment possibilities, there is a potential for stent misplacement, thromboembolic events and the risk of long-term development of in-stent stenosis or thrombosis as well as the need for long-term antiplatelet medication.

The endovascular treatment of this selective subgroup of patients harbouring intracranial aneurysms is difficult and carries a higher interventional risk for complications than aneurysms with a less complex morphology, taking into account the lack of other suitable treatment alternatives. Furthermore, anticoagulation with heparin and premedication with platelet inhibitors in the setting of an acutely ruptured aneurysm is not possible due to the risk of rebleeding.

Stenting strategies

Different stenting strategies regarding the time of stent deployment in relation to coiling are described in the literature, i. e., stenting before coiling, coiling before stenting and stenting alone. In most of the published series stenting is performed before coiling in the same session to avoid possible coil migration, to enable additional obliteration and denser packing of the aneurysm lumen and to protect branches that may be involved in the aneurysm neck [2, 3, 5, 21, 23, 25]. Rarely coiling in a second session as staged treatment is reported [2, 5–7].

Biondi et al. [6] predominantly used stenting after coiling in conjunction with the balloon remodelling technique when safe coil positioning could be obtained without initial stenting. In our institution primary stenting before coil embolization is performed. In one patient the stent was deployed secondarily after introduction of the first microcatheter into the lumen of the aneurysm in order to stabilize the tip of the microcatheter in the lumen of the aneurysm during the coil application afterwards.

In three patients in our series stent placement was not planned in advance and was decided during the procedure for immediate revascularization of a periprocedural thrombus formation and vessel occlusion. The principle and feasibility of stent placement for recanalisation of acute symptomatic
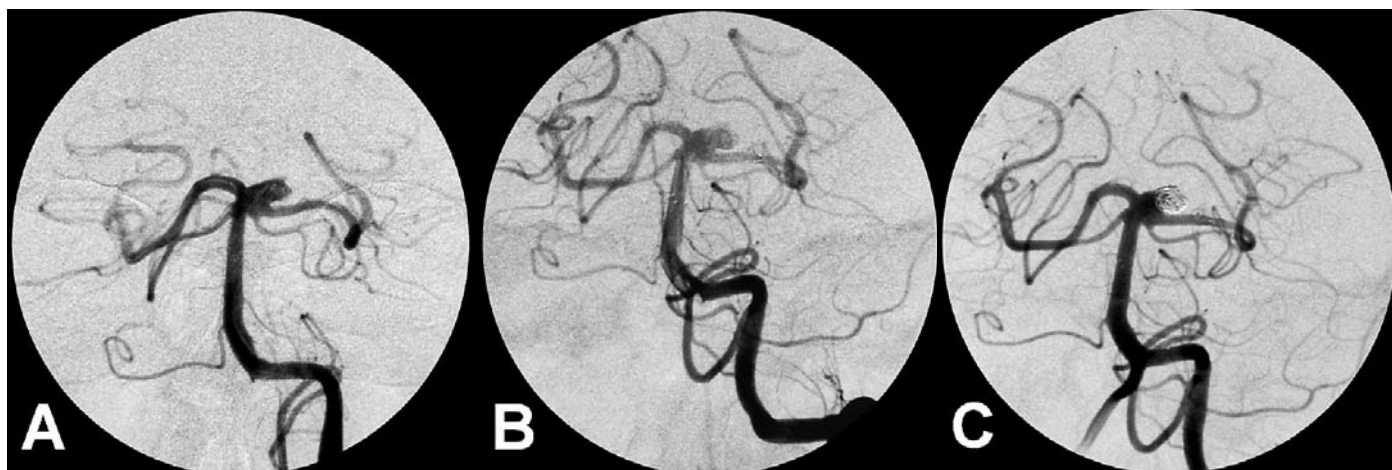
Case 3

A: Cerebral angiography of patient no 2 demonstrating a left laterally projecting 4×4 mm broad necked aneurysm of the basilar tip involving the PCA bilaterally and the left SCA. B: Deployment of a stent into the left P1 segment. C: Postembolization angiogram showing residual filling of the right aspect of the aneurysm neck in order not to risk compromise of the right P1 segment.

intracranial occlusions has been described in the setting of acute stroke treatment [11–13]. In all patients revascularization could be achieved. Only one patient suffered from transient neurological symptoms after the intervention but recovered completely before hospital discharge.

Stent-related complications

In our series the rate of transient procedure-related neurological deficits was 22.2% (4/18), all of them due to periprocedural thromboembolism. Nevertheless, there was no permanent procedure-related morbidity or mortality. In the literature morbidity rates range form 4.8 to 25% and mortality rates from 2.1 to 8.9% [2, 4–6, 21, 24, 31]. The most common adverse events reported are thromboembolic complications confirming the thrombogenicity of stent application [32, 33]. The principles of anticoagulation/antiaggregation in neuroendovascular procedures have been mostly extrapolated from interventional cardiology and stroke trials. Large multicentre trials to further examine the antithrombotic therapy in endovascular interventions are lacking. Therefore, we do not follow a strict protocol at our institution. Depending on the clinical context and the course of the intervention the decisions were taken on a case by case basis.

In our series there was no acute in-stent thrombosis, despite the fact that premedication could not be performed in the majority of patients due to the acute SAH and aspirin was the only immediate medication in the initial post procedural phase in these patients.

There was one case of asymptomatic stent dislocation into the ICA. Lylyk et al [5] reported a technical failure rate of 8% due to delivery difficulties in first generation Neuroform stents. Fiorella et al. [23] encountered technical problems with stent delivery and deployment in only 2 of 53 patients using the Neuroform2 delivery system.

There was one haemorrhagic complication that needed retreatment due to rupture of a previously symptomatic unruptured basilar tip aneurysm 22 months after treatment. This patient, however, missed follow-up and had regrowth of the aneurysm with perfusion from the broad neck to the dome due to massive compaction of the coils.

A total of six patients underwent additional surgical treatment after the endovascular coiling. One patient received external ventricular drainage (EVD) only, three patients received EVD and VP-Shunt, one patient only VP-Shunt and one patient underwent decompressive craniotomy due to generalized brain oedema. There were no surgical complications or special difficulties due to abnormal intraoperative bleeding reported during the operations. The results of our series showed that thromboembolic complications of stenting and coiling in patients in the acute phase of SAH with ruptured aneurysms are more frequent than bleeding complications. A finding that may advocate for a more aggressive antithrombotic therapy but which still lacks clear clinical evidence.

Angiographic results and follow-up

Follow-up imaging showed recanalisation in 25.0% (2/8) of initially completely occluded aneurysms and 50.0% (5/10) of neck-remnants or residual aneurysms resulting in an overall recanalisation rate of 38.5%. Recanalisation from neck remnants to residual aneurysms was observed in 28%. The follow-up in aneurysms after treatment with stent implantation with a mean of 22 months (range 2–79 months) is the longest observation period reported so far. Recanalisation was found in 14.3% (1/7) of dome/neck ratio ≤2 aneurysms and in 66.7% (4/6) of dome/neck ratio >2 aneurysms.

Fiorella et al. [23] reported 23% of recanalisation in 3–6 month follow-up with 52% showing progressive thrombosis, 25% showed no change. Biondi et al. [6] reported a mean follow-up of 9 months (range 3 to 24 months). Initially occluded aneurysms remained occluded and 36% of neck remnants and 33% of residual aneurysms progressed to complete occlusion. Recanalisation to residual aneurysms was observed in 28% of the neck remnants.

Clinical results and follow-up

Clinical follow-up with a mean duration of 24 months showed excellent or good outcome (mRS 0–2) in 11 (84.6% = 11/13) patients and two patients achieved a mRS of 3. The one patient with rupture of a treated aneurysm recovered completely to the previous condition and returned to work. This good clinical mid-term results of patients who survived the initial SAH may indicate that endovascular stent application is relatively safe and well tolerable treatment option for otherwise difficult to treat intracranial aneurysms.

In-stent stenosis/thrombosis in aneurysm stenting compared to restenosis in atherosclerotic cerebrovascular disease

In-stent stenosis or thrombosis is a known complication of angioplasty and stenting for symptomatic atheromatous disease. However, there are only a few studies reporting long-term results after stenting of intracranial vessels in atheromatous cerebrovascular disease and for the treatment of cerebral aneurysms.

The wingspan study [9], examining medically refractory intracranial atherosclerotic stenosis, reported a rate of in-stent stenosis of 7.5% after 6 months. Levy et al. [10] reported on the treatment for symptomatic intracranial atheromatous disease and found a rate of in-stent stenosis of 29.7% and an additionally 4.8% of in-stent thrombosis after an average of 5.9 months. Endothelian disruption and denudation of the vascular wall during stenting in the absence of a func-

tional endothelium in an atheromatous vessel resulting in neointimal tissue formation may play an important role. This reaction is mediated by proliferation and activation of regional smooth muscle cells. A peak of in-stent stenosis is observed between 3 to 6 months after the treatment [34].

It is not known if similar endothelial reactions may also occur after stent placement as a neck bridging device for the treatment of broad neck aneurysms covering the adjacent normal vessel wall. There are even less reports on the incidence and natural history for late in-stent stenosis or thrombosis after stent-assisted coiling of cerebral aneurysms. Biondi et al. [6] reported one (2.4%) asymptomatic stenosis of the parent artery in 42 patients occurring during the initial treatment that could still be observed on follow-up angiography and was successfully treated by angioplasty. In this study with a follow-up ranging from 3 to 24 months no delayed in-stent stenosis was observed. Lylyk et al. [5] observed a progressive thrombosis in one (2%) of 50 patients. Fiorella et al. [24] reported a 5.8% rate (9 of 156 patients) of delayed moderate to severe (>50%) in-stent stenosis after 2 to 9 months, of which two patients needed retreatment to control ischaemic symptoms. Four patients demonstrated either partial or total resolution of the stenosis after 14 to 17 months. Based on these findings a conservative approach in patients with asymptomatic stenosis consisting of continuation or reinstitution of double antiplatelet therapy, close clinical control and follow-up imaging is recommended by the authors.

In our series there was no in-stent thrombosis in the early post treatment phase and only one asymptomatic late in-stent occlusion after six months, which showed partial resolution at further follow-up examinations. The review of these results indicate that an in-stent stenosis or thrombosis in the treatment of intracranial aneurysms may be less common than in the treatment for atherosclerotic cerebrovascular disease. This may be caused by the deployment of very low radial force self-expanding stents in a nonstenotic, nonatheromatous cerebral vessel compared to the use of angioplasty or balloon-mounted stents in atherosclerotic disease.

Conclusion

In our series, stent-assisted coiling was an effective and relatively safe technique for the treatment of broad neck intracranial aneurysms. However the recanalisation rate for these difficult to treat intracranial aneurysms still remains high. Therefore imaging follow-up is mandatory. The risk of delayed in-stent stenosis or thrombosis seems to be lower compared to stent deployment in atherosclerotic lesions. Further studies concerning the long-term durability of stent-assisted coiling and stent tolerance are necessary.

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