ORIGINAL PAPER/*ARTYKUŁ ORYGINALNY*

Neuroform stent-assisted coil embolization: a new treatment strategy for complex intracranial aneurysms. Results of medium length follow-up

Embolizacja spiralami wspomagana założeniem stentu Neuroform – nowa strategia leczenia złożonych tętniaków śródczaszkowych. Wyniki średnioterminowej obserwacji

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Neurologia i Neurochirurgia Polska 2010; 44, 4: 366–374

Abstract

Background and purpose: We present detailed results of using Neuroform stent-assisted coil embolization to treat complex cerebral aneurysms over a three-year period.
Material and methods: Only patients who underwent Neuroform stent-assisted coil embolization were included in this study. We assessed patients' history, aneurysm morphology, indications for stenting, and technical details of the procedures, as well as complications and the midterm follow-up data.
Results: This study included 26 patients with 39 aneurysms. A total of 32 of 39 aneurysms were treated by Neuroform stent-assisted embolization (SAC), whereas 3 aneurysms were stented without coiling, 2 aneurysms coiled without stenting and 2 aneurysms surgically clipped. The indications for use of stent included broad-neck aneurysms ($n = 28$), giant or large aneurysms ($n = 6$), and fusiform aneurysms ($n = 5$). Of the 32 aneurysms treated with Neuroform SAC, we achieved complete (100%) and near complete ($> 95\%$) occlusion in 27 aneurysms, and partial ($< 95\%$) occlusion in 5 aneurysms. Follow-up angiographic data available in 22 of 32 aneurysms treated with Neuroform SAC (68.7%) demonstrated recanalization in 3 aneurysms (13.6%), and stable occlusion in 19 aneurysms (86.4%). There was no delayed progressive embolization or in-stent stenosis.
Conclusions: Direct and midterm follow-up results confirmed that Neuroform stent-assisted coil embolization was a safe

Streszczenie

Wstęp i cel pracy: Przedstawiono szczegółowe wyniki prowadzonego w ciągu trzech lat leczenia złożonych tętniaków naczyń mózgowych za pomocą embolizacji spiralami wspomaganej założeniem stentu Neuroform.
Materiał i metody: Do badania włączono jedynie chorych leczonych za pomocą embolizacji spiralami wspomaganej założeniem stentu Neuroform. Oceniono informacje z wywiadu, morfologię tętniaków, wskazania do założenia stentu oraz szczegóły techniczne procedury, jak również występowanie powikłań i wyniki po połowie okresu obserwacji.
Wyniki: W badaniu wzięło udział 26 pacjentów, u których stwierdzono 39 tętniaków. Spośród 39 tętniaków 32 leczono za pomocą embolizacji spiralami wspomaganej założeniem stentu Neuroform, w przypadku 3 tętniaków zakładano stent bez embolizacji za pomocą spirali, w 2 tętniakach użyto embolizacji bez zakładania stentu, a 2 tętniaki zaklipsowano chirurgicznie. Wskazania do użycia stentu obejmowały: tętniaki o szerokiej szyi ($n = 28$), tętniaki olbrzymie lub duże ($n = 6$) oraz tętniaki wrzecionowate ($n = 5$). Spośród 32 tętniaków leczonych za pomocą embolizacji spiralami wspomaganej założeniem stentu Neuroform pełną (100%) lub prawie pełną ($> 95\%$) niedrożność uzyskano w 27 tętniakach, a częściową ($< 95\%$) niedrożność stwierdzono w 5 tętniakach. W kontrolnych arteriografiach wykonanych w 22 spośród 32 tętniaków (68,7%) ponowne udrożnienie stwierdza-

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Received: 19.10.2009; accepted: 28.05.2010

and effective technique in the treatment of complex cerebral aneurysms. Although clinically significant complications were uncommon and the evaluation at midterm follow-up is encouraging, further studies need to assess the long-term stability and durability of the stent.

Key words: Neuroform stent, aneurysm, coil, embolization, midterm follow-up.

no w 3 tętniakach (13,6%), a utrzymującą się niedrożność – w 19 tętniakach (86,4%). Nie stwierdzano opóźnionej postępującej embolizacji ani zwężenia wewnątrz stentu.
Wnioski: Wyniki bezpośrednio po leczeniu i w połowie okresu obserwacji potwierdzają, że embolizacja spiralami wspomagana założeniem stentu Neuroform jest bezpieczną i skuteczną metodą leczenia złożonych tętniaków naczyń mózgowych. Chociaż powikłania były rzadkie, a wyniki uzyskane w połowie okresu obserwacji są zachęcające, to konieczne są dalsze badania w celu oceny długotrwałej stabilności i wytrzymałości stentu.

Słowa kluczowe: stent Neuroform, tętniak, spirala, embolizacja, średnioterminowa obserwacja.

Introduction

The Neuroform stent is a self-expandable, microcatheter delivering Nitinol stent that has been specifically designed for application to intracranial vessels. The Neuroform stent microdelivery system is divided into three parts: the self-expanding stent itself, a 3F delivery microcatheter, and a 2F stabilizing microcatheter stabilizer. It has converted some previously 'untreatable' aneurysms into endovascular amenable lesions. Only a few series of patients treated with this stent have been reported in the literature [1-7].

Our aim was to report in detail our immediate and available midterm results in the use of Neuroform microstent for the embolization of complex intracranial aneurysms.

Material and methods

Patient selection and characteristics

All patients included in this study represent an all-inclusive group of patients who underwent Neuroform stent-assisted coil embolization in a single department during a 36-month period (December 2004 – December 2007). The patients were included when the neurointerventionalist advised that the aneurysm could not be treated effectively with traditional endovascular techniques. Such a decision was based on analysis of the risk-to-benefit ratio, which had to be equal or superior to that of microsurgical clipping based on the aneurysm location and its anatomical characteristics combined with the patient's clinical status and ability to afford the treatment expenses.

A total of 26 patients harbouring 39 aneurysms met the criteria for treatment. There were 11 males and 15 females, aged from 25 to 69 years: mean age was 48.4 years. The patients' demographics are listed in Table 1. Twenty-three patients presented with ruptured aneurysms; included in the study were 2 aneurysms in 2 different patients that presented as recurrences after primary coil embolization. Three patients had unruptured aneurysms. Regarding the aneurysm types, there were 28 broad neck aneurysms (dome-to-neck ratio < 2 or neck diameter > 4 mm), 6 large aneurysms (dome > 9.5 mm), and 5 fusiform aneurysms. The average dome size of the broad neck aneurysms was 3.6 mm, the average neck size was 2.6 mm, and the average dome-to-neck ratio was 1.38.

Pre-procedural arrangements

Before the stent-assisted coiling procedure was started, each patient or his/her family signed the informed consent. All patients underwent diagnostic cerebral angiography before stent placement. Following diagnostic angiography, the neurointerventionalist determined whether the patient was a suitable candidate for the stent-assisted coiling or not. If a patient had an unruptured aneurysm or was not in the acute stage of aneurysmal subarachnoid haemorrhage (SAH) and was selected for stent use before the procedure, the anticoagulation regimen was started with aspirin (enteric-coated) 100 mg and clopidogrel 75 mg by mouth for 3 days. If the patient was not selected for stent use before the procedure, a bolus dose of clopidogrel 225 mg with

Table 1. Summary of patients treated with Neuroform stent-assisted coiling

Patient No.	Age (years)/ sex	Status	Hunt & Hess grade	Aneurysm characteristics and location	Size (dome/ neck ratio) (mm)	Procedure	Stent size	Immediate DSA results*	Follow-up (months)	Follow-up DSA results
1	38/F	ruptured	II	(BN) PComA/L	5.0/3.0	Stent/Coil	4.5 × 20	complete	9	stable
				(BN) ICA-Ophth/L	5.0/3.0	Stent/Coil	4.5 × 20	complete	9	stable
2	67/M	unruptured	0	(L) AComA	15/12	Stent/Coil	3.5 × 20	near complete	NA	
3	54/F	ruptured	IV	(BN) BA	2.0/2.0	Stent only	4.5 × 15			
				(F) Vertebral/L	2.8/2.0	Stent/Coil	4.5 × 20	near complete	NA	
4	43/F	ruptured	I	(BN) ICA-C2/R	3.5/3.5	Stent/Coil	4.0 × 20	complete	6	stable
5	50/F	ruptured	III	(BN) ICA-C2/R	5.8/5.2	Stent/Coil	3.5 × 20	complete	11	stable
6	45/F	ruptured	IV	(BN) ICA-C4/R	2.4/2.6	Stent/Coil	3.5 × 20	complete	8	stable
7	47/M	ruptured	II	(L) Ophth/R	10/5.0	Stent/Coil	4.5 × 20	complete	6	stable
				(BN) Ophth/L	5.0/4.0	Stent/Coil	4.5 × 20	near complete	6	stable
8	56/F	ruptured	III	(BN) PComA/R	2.5/3.0	Stent/Coil	3.0 × 20	complete	NA	
9	52/F	ruptured	II	(BN) ICA-PComA/L	5.5/2.8	Stent/Coil	3.5 × 15	complete	12	stable
10	47/F	ruptured	I	(BN) AComA	4.4/2.3	Stent/Coil	3.5 × 20	complete	7	recanalization
11	37/M	ruptured	II	(BN) ICA-C2/R	2.2/1.4	Stent/Coil	4.0 × 15	partial	17	stable
				(BN) MCA-M2/R	6.5/3.0	Clipping				
12	62/F	ruptured	II	(BN) AComA/L	3.8/2.0	Coil only				
				(BN) ICA-C6/L	2.1/3.3	Stent/Coil	4.5 × 20	complete	6	stable
13	39/M	ruptured	III	(BN) AComA/L	4.2/3.8	Stent/Coil	4.0 × 20	near complete	NA	
14	58/F	ruptured	IV	(BN) MCA-M2/R	7.7/3.0	Coil only				
				(BN) ICA-C3/R	2.0/1.3	Stent/Coil	4.0 × 20	complete	NA	
15	32/M	ruptured	II	(BN) Ophth/L	4.0/3.0	Stent/Coil	4.5 × 20	complete	11	stable
16	54/M	ruptured	II	(BN) AComA	4.7/2.7	Stent/Coil	4.0 × 15	partial	24	stable
				(BN) PComA/L	5.2/3.1	Stent/Coil	4.0 × 15	complete	24	stable
				(BN) Ophth/L	3.1/3.1	Stent/Coil	4.0 × 15	partial	24	stable
17	69/M	RE	II	(L) PComA/R	10.3/4.1	Stent/Coil	4.5 × 20	complete	NA	
18	25/F	ruptured	II	(BN) ICA-Ophth/L	6.4/3.2	Stent/Coil	3.5 × 20	complete	4	stable
19	26/M	RE	IV	(L) AChoA/L	9.5/1.6	Stent/Coil	4.5 × 20	complete	NA	
20	54/F	ruptured	II	(BN) PComA/R	6.3/6.0	Stent/Coil	4.5 × 15	complete	NA	
21	48/F	ruptured	II	(L) PComA/R	12/3.0	Stent/Coil	4.5 × 20	near complete	12	recanalization
22	69/M	unruptured	0	(F) ICA-C3/L	9.7/8.0	Stent/Coil	4.5 × 20	partial	NA	
				(F) ICA/R	9.0/5.0	Stent only	4.5 × 15			
				(F) BA	26/20	Stent only	4.5 × 20			
23	51/M	ruptured	IV	(F) MCA-M2/R	7.0/10.1	Stent/Coil	3.0 × 20	partial	14	recanalization
				(BN) ICA-C2/R	3.7/3.7	Stent/Coil	4.0 × 20	near complete	14	stable
				(BN) PComA/R	3.0/2.1	Clipping				
24	41/F	RE	0	(L) ICA-Ophth/L	11/4.2	Stent/Coil	4.0 × 20	complete	24	stable
25	39/M	ruptured	II	(BN) MCA-M2/R	7.2/5.4	Stent/Coil	4.5 × 15	complete	NA	
26	56/F	ruptured	II	(BN) ICA-A2/L	4.0/3.0	Stent/Coil	4.5 × 20	complete	8	stable
				(BN) ICA-A3/R	5.0/4.0	Stent/Coil	4.5 × 20	complete	8	stable

**Complete indicates 100%; Near complete indicates > 95%, partial indicates < 95%*

AChoA – anterior choroidal artery, AComA – anterior communicating artery, BA – basilar artery, (BN) – broad-neck, DSA – digital subtraction angiography, (F) – fusiform, ICA – internal carotid artery, (L) – large, L – left, MCA – middle cerebral artery, NA – not available, Ophth – ophthalmic artery, PComA – posterior communicating artery, R – right, RE – recurrent rupture

aspirin 100 mg through a nasogastric tube was usually administered. After femoral vascular access was obtained, a bolus dose of 2000 to 3000 I.U. heparin was administered to achieve an activated clotting time of twice the value of the baseline. After the procedure, heparinization was not reversed. Low-molecular-weight heparin (LMWH) was administered subcutaneously twice a day in a dose of 0.4 mL for 3 days postoperatively. Patients were continued on clopidogrel 75 mg for 6 weeks and aspirin 100 mg for 6 months postoperatively.

Indications

The indications for stent placement were categorized as broad neck aneurysm, fusiform/dissecting aneurysm, large/giant aneurysm, residual aneurysms after primary coil embolization and aneurysms with protruded coils (i.e., for patients in whom coils prolapsed or may prolapse into the parent vessel).

Stent size estimation

Stents are sized on the basis of the largest diameter of the parent vessel in which the stent is to be deployed. However, we usually oversized the stent by 0.5-1.0 mm with an overlap of at least 5 mm on each side of the neck of the aneurysm.

Table 2. Summary of outcomes in reported patients treated with Neuroform stent-assisted coiling

Treatment procedures in 39 aneurysms	
Stent/Coil	32
Stent	3
Coil	2
Clip	2
Occlusion achieved in 32 aneurysms treated by Neuroform stent-assisted coiling	
Partial (< 95%)	5
Near complete (> 95%)	6
Complete (100%)	21
Follow-up data of 22 aneurysms treated by Neuroform stent-assisted coiling	
Progressive	0
Recanalization	3
Stable	19
In-stent stenosis	0

Results

A total of 26 patients (11 males and 15 females, aged from 25 to 69 years: mean age was 48.4 years) harbouring 39 aneurysms met the criteria for Neuroform stent-assisted coiling treatment. Twenty-three patients presented with aneurysmal SAH, whereas 3 patients presented with symptoms not related to the aneurysmal rupture. In regard to the patients with aneurysmal SAH, 2 patients were Hunt and Hess grade I, 13 patients were grade II, 3 patients were grade III, and 5 patients were grade IV.

We used a total of 35 Neuroform stents. Twenty-three Neuroform stents were deployed to cover the neck of 23 broad neck aneurysms, 6 Neuroform stents were implanted to cover the neck of 6 large aneurysms and 3 Neuroform stents to overlap 3 fusiform aneurysms. Additionally, we deployed 3 stents to cover the neck of 1 broad neck aneurysm and to overlap 2 fusiform aneurysms without coil embolization.

Degree of occlusion was ranked as a complete occlusion, near complete occlusion or partial occlusion when 100%, > 95%, or < 95% occlusion was achieved, respectively. Of those 32 aneurysms treated with Neuroform stent-assisted coiling, complete occlusion was achieved in 21 aneurysms (65.6%), near complete occlusion was achieved in 6 aneurysms (18.7%), and partial occlusion was achieved in 5 aneurysms (15.6%: Table 2).

Complications

Two clinically evident thromboembolic complications occurred (patients no. 12 and 23) after stent placement. Patient no. 12 experienced right hemiparesis after deployment of the stent within the left ICA to support the coil embolization of a broad neck aneurysm. However, both of the patients made good functional recovery (Glasgow Outcome Scale score of 4). These 2 patients were treated in the context of acute SAH without pre-treatment with antiplatelet medications. No aneurysmal rupture was encountered during the procedure. There was no mortality related to the procedure.

Stent displacement was observed in 1 patient (patient no. 22). In this case, the initial plan was to deploy the second stent within the first one to achieve a satisfactory overlap over the aneurysm. Unfortunately, the first stent was displaced after the deployment. In this

instance, the distal portion of the stent was displaced into the aneurysm sac located in the upper trunk of the basilar artery. The delivery system could not be navigated easily beyond the landing zone from the parent vertebral artery due to the severe tortuosity of the artery between the aneurysm and the distal part of the parent artery, which resulted in displacement of the distal portion of the stent into the aneurysm sac.

Follow-up arteriography

Follow-up arteriographic data are available in 22 of 32 aneurysms (68.7%) treated with Neuroform stent-assisted coil embolization. The high number of follow-up dropouts (31%) was due to patient non-compliance. The average follow-up time was 12 months (range, 4-24 months). In the available follow-up arteriographies, there was no progressive occlusion or in-stent stenosis. No change was observed in the size of 19 aneurysms. However, recanalization due to the coil compaction process was observed in 3 aneurysms (patients no. 10, 21, and 23: Table 2). Because all the aneurysms treated with Neuroform stent without coil embolization were among the follow-up drop-outs, no follow-up arteriographic data were available.

Illustrative cases

Patient 24

A 41-year-old woman presented with headache. The cerebral arteriogram demonstrated a large aneurysm in the left ICA-ophthalmic artery junction (Fig. 1A). Initially, the aneurysm was coiled, and complete occlusion was achieved (Fig. 1B). A 2-year follow-up arteriogram revealed recurrence of the aneurysm. This recurred aneurysm had a poor fundus-to-neck ratio, and was assessed as a good candidate for stent-assisted coiling (Figs. 1C–D). A Neuroform (4 × 20) stent was successfully deployed in the optimal segment across the aneurysm neck. A subsequent GDC coil was placed safely in the aneurysm sac (Figs. 1E–F). An immediate arteriogram showed complete occlusion (Fig. 1G). A two-year follow-up arteriogram revealed stable occlusion (Fig. 1H).

Patient 10

A 47-year-old woman presented with SAH (Hunt & Hess grade I). Diagnostic cerebral arteriography revealed a broad-neck aneurysm in the right internal carotid artery at the posterior communicating artery origin (Figs. 2A–B). This aneurysm demonstrated a poor dome-to-neck ratio that made her a good candidate for stent-assisted coil embolization. A Neuroform (3.5 × 20) stent was successfully deployed in the optimal segment across the aneurysm neck. A subsequent Cordis Helical Fill coil was placed safely in the aneurysm sac (Figs. 2C–D). The post-procedural course was uneventful. A seven-month follow-up arteriogram revealed residual filling of recurrence.

Discussion

The goal of endovascular aneurysm treatment is to eliminate the aneurysm from the blood circulation and to prevent the flow of blood into the aneurysm by filling the aneurysm sac with embolization material [8]. The introduction of three-dimensional coils, which retain a complex shape after detachment, provided some additional flexibility with respect to the ability to treat patients with complex aneurysms [9]. It is not feasible, however, to perform a coiling procedure for some aneurysms (5-14.5% of cases) [10,11] because unusual tortuosity of the vessels renders access difficult or because the contours of the aneurysm do not permit the coils to sit safely inside. Therefore, larger aneurysms and aneurysms with wider necks typically had lower rates of successful occlusion [1,12,13].

To overcome the problem of complex morphology in aneurysm coiling, Moret *et al*. [14] pioneered the balloon remodelling technique that enables temporary remodelling of the aneurysm neck during coil delivery. We used this technique in 7 patients of our study series (e.g. patient no. 9, Fig. 1).

After the first report of endovascular stent-supported coil embolization for the treatment of experimental carotid sidewall aneurysms in animals in 1994 [15,16], Higashida reported the first use of stents in the human intracranial circulation to prevent backward protrusion of electrodetachable coils in 1997 [2]. Since then, several series of patients treated with self-expandable stents devoted to intracranial aneurysms such as the Neuroform stent [15-18] the Cordis Enterprise stent [19] (Cordis Endovascular, Miami Lakes, FL) or the Balt Leo stent [20] (Balt, Montmorency, France) have been reported.

As reported in other series [15,17,18,21], we observed in our practice that the navigation of the stent

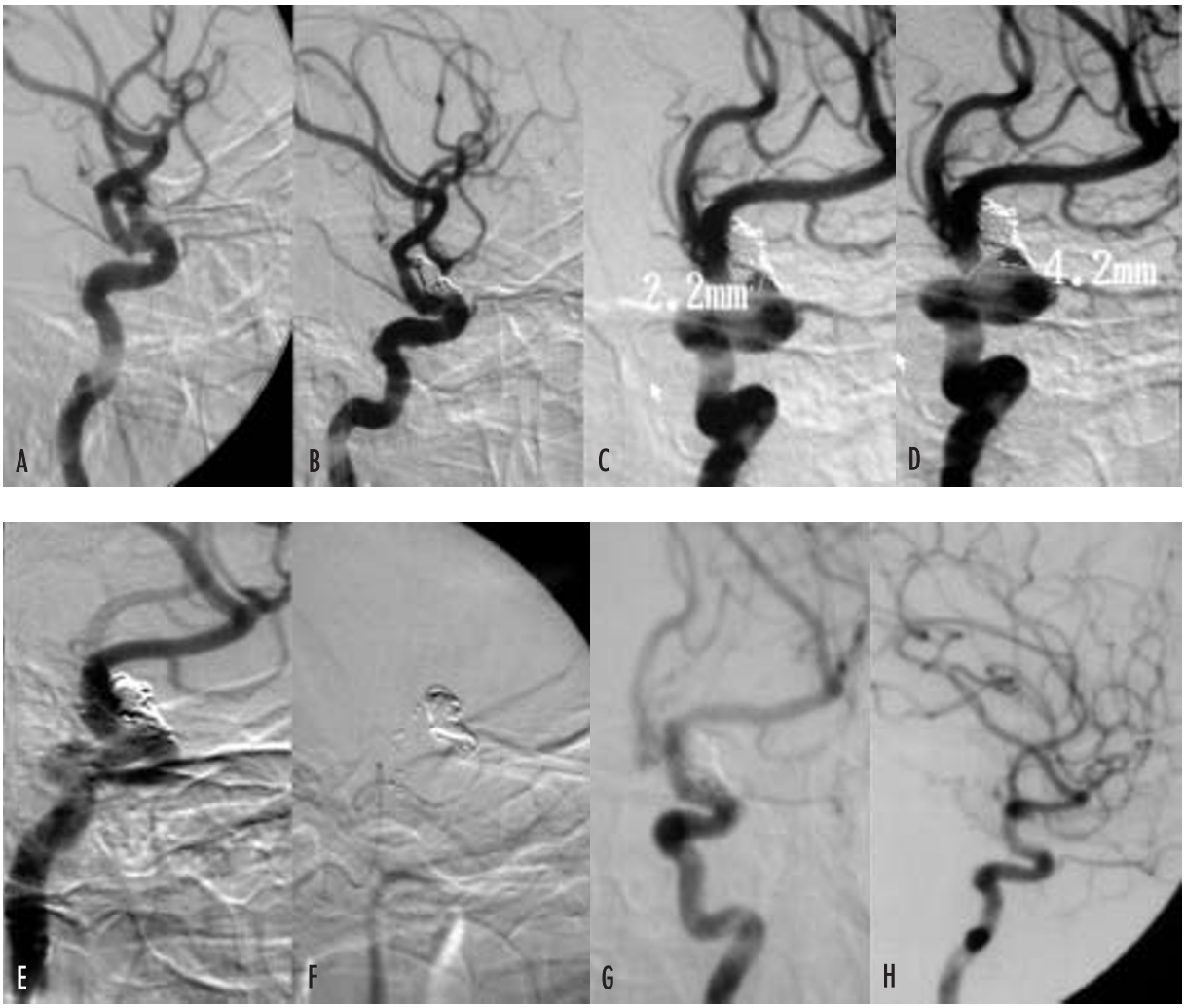

Fig. 1. Arteriogram of a 41-year-old woman who presented with headache. (A) Left internal carotid artery arteriogram demonstrating large aneurysm involving the left internal carotid artery-ophthalmic artery take-off. (B) Control arteriogram showing complete occlusion after coil embolization. (C–D) Two-year follow-up arteriogram revealed residual filling. (E) Post-stenting control arteriogram showing successful stent deployment and coiling with complete occlusion. (F) Unsubtracted film showing the stent and the coils still in the optimal position. (G) Control arteriogram after Neuroform (4 × 20) stenting demonstrating complete (100%) occlusion of the aneurysm. (H) Two-year follow-up arteriogram demonstrating stable embolization of the recurrent aneurysm

delivery system to and beyond the landing zone was not problematic; the actual deployment of the stent is frequently difficult because of binding of the microwire, the stabilizer, and the stent delivery catheter. Lylyk *et al.* [21] reported difficulties in placing the Neuroform stent in 31% of patients, mostly at the beginning of their experience. A second generation of devices resolved this limitation. Fiorella *et al.* [17] confirmed that using the second-generation (Neuroform 2) delivery system alleviated the technical problems with stent delivery and deployment encountered in their initial results [22]. However, the technical advances in the newer generation of this stent (Neuroform 3), which is mounted in a more suitable delivery system, significantly facilitated this stent deployment.

Several case reports of the initial experience with aneurysm stenting have been published, including the use of stents in fusiform and dissecting aneurysms [23-25]. These reports showed satisfactory immediate anatomical exclusion of the aneurysm and safety. The procedure-related morbidity and mortality rates were low; morbidity ranged from 5.8 to 20% and mortality from 2.1 to 8.9% [2,15,21,22]. In our series, we observed a relatively low rate of complications (7.6%

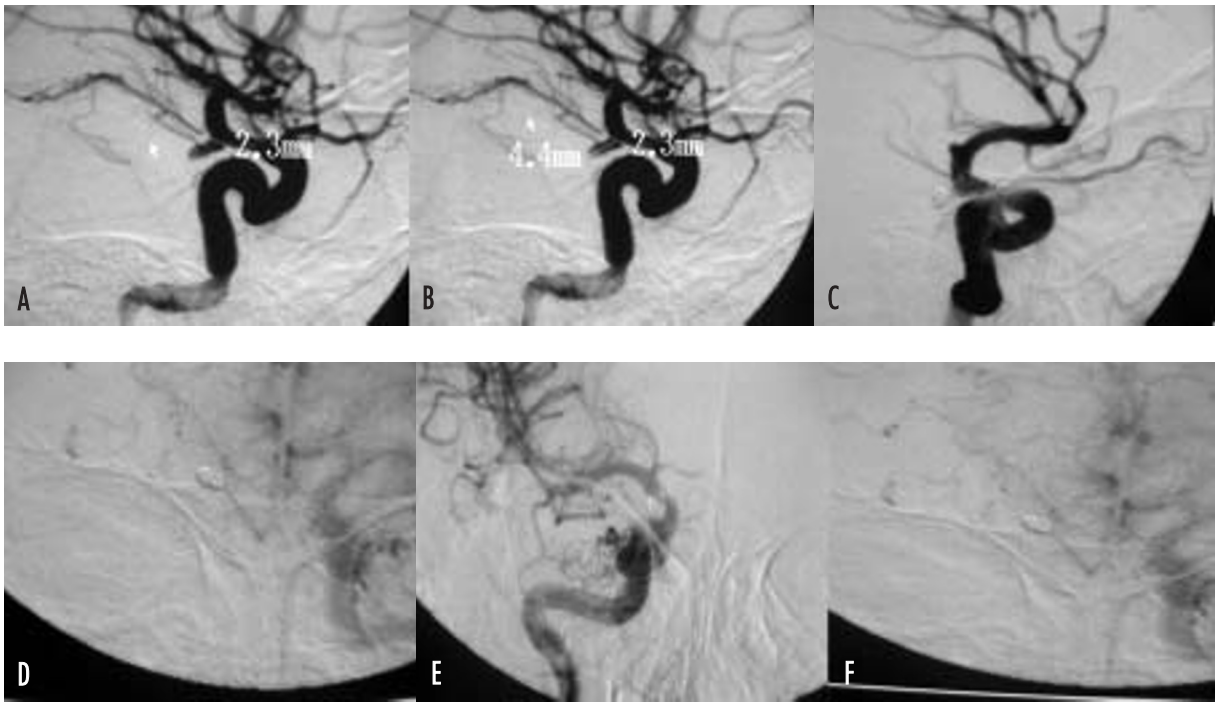

Fig. 2. Imaging study of a 47-year-old woman presenting with subarachnoid haemorrhage (Hunt & Hess grade I). (A, B) Cerebral arteriogram demonstrated a wide-neck aneurysm in the right internal carotid artery at the posterior communicating artery take-off. (C) Subtracted arteriogram after Neuroform (3.5 × 20) stent-assisted coil embolization showed complete occlusion (100%). (D) Unsubtracted anteroposterior image showed the stent and coil in the optimal position. (E) Follow-up antero-posterior cerebral arteriogram revealed residual filling of recurrence. (F) Antero-posterior unsubtracted film showed the stent and the coils still in the optimal position

morbidity and 0% mortality). Our series corroborates that the Neuroform stent is safe and effective in providing a level of parent vessel protection adequate to allow satisfactory packing in complex aneurysms that were not amenable to conventional endovascular treatment.

Liang *et al*. reported their clinical experience and 5-year follow-up results using Neuroform stent-assisted coiling of intracranial aneurysms for 107 patients. They achieved complete occlusion in 57.2%, neck remnant in 27.3% and incomplete occlusion in 15.5% [5]. Biondi *et al.* reported 14 (35%) aneurysm occlusions, 18 (45%) neck remnants, and 8 (20%) residual aneurysms in 40 aneurysms treated with stent-assisted coiling [6]. Wajnberg *et al.* reported their experience with the Neuroform stent for the treatment of 24 wide-necked intracranial aneurysms – the immediate arteriography demonstrated complete occlusion in 70.8%, neck remnant in 16.6% and incomplete occlusion in 12.5% [7]. In our group, immediate arteriographic occlusion rates in 32 aneurysms treated with Neuroform SAC demonstrated complete occlusion in 21 aneurysms (65.6%), near complete occlusion in 6 aneurysms (18.7%), and partial occlusion in 5 aneurysms (15.6%). Small aneurysms were among the most difficult aneurysms to achieve complete occlusion faced in our study group. The small wide-neck aneurysm did not provide enough space to hold the coils and microcatheter tip during coil delivery, which pushed the microcatheter out of the sac before coil detachment.

Obviously, the comparison of arteriographic outcome across reported series is difficult. A standard definition of what constitutes complete occlusion and residual aneurysm filling is lacking and quantification and analysis of the results remain subjective [26]. In addition, few papers report arteriographic follow-up in stenting procedures for aneurysms. However, we recognize the weakness of the study as the relatively high success rate of the combined stenting/coiling treatment in our study group could be the result of the small number of analysed patients with a short follow-up time, which may produce a positive bias in this study. Furthermore, the high number of follow-up dropouts (31%) could also have influenced the mortality/morbidity rates that we have reported.

Our follow-up arteriography revealed no case of progressive occlusion or in-stent stenosis of aneurysms treated with Neuroform stent-assisted coiling, whereas Murayama *et al.* [1] reported rates of 30% and 22%, respectively, in large and small wide-necked aneurysms. The relatively high rate of progressive thrombosis in that series may have contributed to the bioactive coils (Matrix Coil). Fiorella *et al*. [17] reported delayed and severe in-stent stenosis in 3 of 64 patients (4.7%). In our series, asymptomatic stenosis of the parent artery at the proximal end of the stent was not observed. However, our available follow-up data revealed 3 cases with recanalization, which is highly attributed to the coil compaction process.

The thrombogenicity of the Neuroform stents is an important limitation of their use to treat aneurysms, particularly those treated in the context of acute SAH [27]. Dual antiplatelet regimens have been established to be superior to aspirin therapy alone [28]. Clopidogrel is generally used because of its more potent platelet-antiplatelet effect, faster onset of action, and lower incidence of significant adverse effects [29]. Perioperative antithrombotic treatment in our series was described in Methods.

Recently, the LMWH have been shown to be more effective and safer than heparin in the prevention of thromboembolic events after coronary angioplasty and stent placement [30,31]. In our practice, upon completion of the intervention, heparin was discontinued and anticoagulation continued for 3 days with LMWH. Patients were continued on clopidogrel (75 mg) for 6 weeks and aspirin (100 mg) for 6 months postoperatively.

Conclusions

1. Direct and midterm follow-up results confirmed that Neuroform stent-assisted coil embolization was a safe and effective technique in the treatment of complex cerebral aneurysms.
2. Although clinically significant complications were uncommon and the evaluations at midterm follow-up were encouraging, further studies are needed to assess the long-term stability and the durability of the stent.

Disclosure

Authors report no conflict of interest.

References

1. Murayama Y., Nien Y.L., Duckwiler G., et al. Guglielmi detachable coil embolization of cerebral aneurysms: 11 years' experience. *J Neurosurg* 2003; 98: 959-966.
2. Benitez R.P., Silva M.T., Klem J., et al. Endovascular occlusion of wide-necked aneurysms with a new intracranial microstent (Neuroform) and detachable coils. *Neurosurgery* 2004; 54: 1359-1367.
3. Sekhar L.N., Stimac D., Bakir A., et al. Reconstruction options for complex middle cerebral artery aneurysms. *Neurosurgery* 2005; 56 (1 Suppl): 66-74.
4. Wanke I., Doerfler A., Schoch B., et al. Treatment of wide necked intracranial aneurysms with a self-expanding stent system: Initial clinical experience. *AJNR Am J Neuroradiol* 2003; 24: 1192-1199.
5. Liang G., Gao X., Li Z., et al. Neuroform stent-assisted coiling of intracranial aneurysms: a 5 year single-center experience and follow-up. *Neurol Res* 2009 (in press).
6. Biondi A., Janardhan V., Katz J.M., et al. Neuroform stent-assisted coil embolization of wide-neck intracranial aneurysms: strategies in stent deployment and midterm follow-up. *Neurosurgery* 2007; 61: 460-468.
7. Wajnberg E., de Souza J.M., Marchiori E., et al. Single-center experience with the Neuroform stent for endovascular treatment of wide-necked intracranial aneurysms. *Surg Neurol* 2009; 72: 612-619.
8. Richling B. History of endovascular surgery: personal accounts of the evolution. *Neurosurgery* 2006; 59 (Suppl 3): S30-S38.
9. Malek A.M., Higashida R.T., Phatouros C.C., et al. Treatment of an intracranial aneurysm using a new three-dimensional shape Guglielmi detachable coil: technical case report. *Neurosurgery* 1999; 44: 1142-1144.
10. Henkes H., Fischer S., Weber W., et al. Endovascular coil occlusion of 1811 intracranial aneurysms: early angiographic and clinical results. *Neurosurgery* 2004; 54: 268-280.
11. Brilstra E.H., Rinkel G.J., van der Graaf Y., et al. Treatment of intracranial aneurysms by embolization with coils: a systematic review. *Stroke* 1999; 30: 470-476.
12. Shanno G.B., Armonda R.A., Benitez R.P., et al. Assessment of acutely unsuccessful attempts at detachable coiling in intracranial aneurysms. *Neurosurgery* 2001; 48: 1066-1072.
13. Thornton J., Debrun G.M., Aletich V.A., et al. Follow-up angiography of intracranial aneurysms treated with endovascular placement of Guglielmi detachable coils. *Neurosurgery* 2002; 50: 239-249.
14. Moret J., Pierot L., Boulin A., et al. Remodeling of the arterial wall of the parent vessel in the endovascular treatment of intracranial aneurysms. *Neuroradiology* 1994; 36 (Suppl 1): S83.
15. Akpek S., Arat A., Morsi H., et al. Self-expandable stent-assisted coiling of wide-necked intracranial aneurysms: A single-center experience. *AJNR Am J Neuroradiol* 2005; 26: 1223-1231.
16. Alfke K., Straube T., Dörner L., et al. Treatment of intracranial broad-neck aneurysms with a new self-expanding stent and coil embolization. *AJNR Am J Neuroradiol* 2004; 25: 584-591.

17. Fiorella D., Albuquerque F.C., Deshmukh V.R., et al. Usefulness of the Neuroform stent for the treatment of cerebral aneurysms: results at initial (3-6-mo) follow-up. *Neurosurgery* 2005; 56: 1191-1201.
18. Howington J.U., Hanel R.A., Harrigan M.R., et al. The Neuroform stent, the first microcatheter-delivered stent for use in the intracranial circulation. *Neurosurgery* 2004; 54: 2-5.
19. Higashida R.T., Halbach V.V., Dowd C.F., et al. Initial clinicalexperience with a new self-expanding nitinol stent for the treatment of intracranial cerebral aneurysms: The Cordis Enterprise stent. *AJNR Am J Neuroradiol* 2005; 26: 1751-1756.
20. Pumar J.M., Blanco M., Vázquez F., et al. Preliminary experience with Leo self-expanding stent for the treatment of intracranial aneurysms. *AJNR Am J Neuroradiol* 2005; 26: 2573-2577.
21. Lylyk P., Ferrario A., Pasbón B., et al. Buenos Aires experience with the Neuroform self-expanding stent for the treatment of intracranial aneurysms. *J Neurosurg* 2005; 102: 235-241.
22. Fiorella D., Albuquerque F.C., Han P., et al. Preliminary experience using the Neuroform stent for the treatment of cerebral aneurysms. *Neurosurgery* 2004; 54: 6-16.
23. Benndorf G., Campi A., Schneider G.H., et al. Overlapping stents for treatment of a dissecting carotid artery aneurysm. *J Endovasc Ther* 2001; 8: 566-570.
24. Higashida R.T., Smith W., Gress D., et al. Intravascular stent and endovascular coil placement for a ruptured fusiform aneurysm of the basilar artery. Case report and review of the literature. *J Neurosurg* 1997; 87: 944-949.
25. Wakhloo A.K., Lanzino G., Lieber B.B., et al. Stents for intracranial aneurysms: The beginning of a new endovascular era? *Neurosurgery* 1998; 43: 377-379.
26. Katz J.M., Tsiouris A.J., Biondi A., et al. Advances in endovascular aneurysm treatment: Are we making a difference? *Neuroradiology* 2005; 47: 695-701.
27. Yahia A.M., Latorre J., Gordon V., et al. Thromboembolic events associated with Neuroform stent in endovascular treatment of intracranial aneurysms. *J Neuroimaging* 2010; 20: 113-117.
28. Leon M.B., Baim D.S., Popma J.J., et al. A clinical trial comparing three antithrombotic-drug regimens after coronary-artery stenting. *N Engl J Med* 1998; 339: 1665-1671.
29. A randomised, blinded, trial of clopidogrel versus aspirin in patients at risk of ischaemic events (CAPRIE). CAPRIE Steering Committee. *Lancet* 1996; 348: 1329-1339.
30. Daoulah A., Segev A., Leblanc K., et al. Post procedural low molecular weight heparin in patients at high risk of sub acute stent thrombosis. *Cardiovasc Radiat Med* 2003; 4: 182-185.
31. Yan A.T., Goodman S.G. Low-molecular-weight heparins in ischemic heart disease. *Curr Opin Cardiol* 2004; 19: 309-316.