Matrix Detachable Coils for the Endovascular Treatment of Intracranial Aneurysms
Analysis of Early Angiographic and Clinical Outcomes
Christian A. Taschner, MD; Xavier Leclerc, PhD; Henda Rachdi, MD; Alexander Maia Barros, MD; Jean-Pierre Pruvo, PhD

Background and Purpose—Endovascular coil embolization has become an accepted therapeutic option for the treatment of intracranial aneurysms.1 A major limitation of the method is the considerably high recanalization rate observed in the long-term follow-up. The clinical significance of a nonprogressing residual neck has not been determined yet, although it is probably not without hemorrhagic risks.2 Major recurrences are a greater concern. Raymond et al showed in a recent publication that patients who bleed during follow-up had unstable results with progression of residual aneurysms since the previous angiographic assessment.3

To decrease recanalization rates of embolized aneurysms, various modifications to standard platinum coils such as biologically active surfaces, radioactive components, or coated-coils with a swelling hydrogel have been developed and brought to clinical use.4–7 The purpose of these developments is to either enhance intra-aneurysmal clot organization and fibrosis or to increase packing density and thereby improving the long-term results of aneurysm embolization.5–8

A new, coated bioactive coil (Matrix detachable coils; Boston Scientific Neurovascular) has been developed to improve the results of endovascular treatment of intracranial aneurysms.4 These platinum coils are covered with a bioabsorbable copolymer (90% polyglycolide and 10% polylactide). Murayama et al demonstrated enhanced mature collagen formation and fibrosis in the sac and neck of experimental aneurysms treated with Matrix coils.5 The characteristics of Matrix coils have been described previously, and they are considered a safe and reliable application as demonstrated in a recent feasibility study.9 However, the time course of stable aneurysm occlusion after embolization with Matrix coils remains unknown.

The purpose of this study was to evaluate the clinical safety and the angiographic stability of aneurysm occlusion after a 6-month period.

Methods—Twenty-five patients with 25 intracranial aneurysms were treated by selective embolization with a new coated bioactive coil (Matrix; Boston Scientific Neurovascular). Matrix coils were used alone in 6 patients and in combination with Guglielmi detachable coils (GDCs; Boston Scientific Neurovascular) in 19. Angiographic results, procedure-related complications, and adverse neurological events during the follow-up period were recorded. Magnetic resonance angiography was performed at 6 months in all patients.

Results—Initial angiographies demonstrated complete occlusion in 17 patients, residual neck in 7, and a persisting aneurysm in 1. The clinical follow-up showed stable results in all patients. The grade of aneurysm occlusion at 6 months improved in 4 patients, remained stable in 15, and deteriorated in 6. Three patients needed retreatment because of a major aneurysm recanalization. Angiographic recurrences in cases of aneurysms treated with a combination of Matrix coils and GDCs occurred within the expected range for bare platinum coils. Two of 3 patients needing retreatment had been treated with Matrix coils alone.

Conclusion—Stable results were obtained predominantly when Matrix coils were combined with bare platinum coils. A prospective, randomized study is necessary to assess the potential benefit of Matrix coils for patients treated by endovascular techniques. (Stroke. 2005;36:2176-2180.)

Key Words: aneurysm ■ cerebrovascular disorders
Aneurysm location included the cavernous portion of the internal carotid artery (ICA) in 1 case, the ophthalmic portion of the ICA in 4, the anterior cerebral artery (ACA) in 3, the anterior communicating artery (Acom) in 4, the basilar bifurcation in 1, the anterior communicating segment (Pcom) of the ICA in 10, the posterior communicating segment (Pcom) of the ICA in 1, the anterior cerebral artery in 4, the basilar bifurcation in 1, the ophthalmic portion of the ICA in 1 case, the ophthalmic segment of the ICA in 1, the cavernous portion of the internal carotid artery during the embolization; TIA, transitory ischemic attack; I, complete occlusion; II, residual neck; III, residual aneurysm.

Summary of Patients and Aneurysms

<table>
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<tr>
<th>Patient No.</th>
<th>Age</th>
<th>Clinical Presentation</th>
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<th>Maximum Size, mm</th>
<th>Aneurysm Neck, mm</th>
<th>Endovascular Treatment</th>
<th>Follow-Up</th>
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SAH indicates subarachnoid hemorrhage; Asympt, asymptomatic aneurysm discovered by chance; 2nd an., asymptomatic aneurysm discovered in addition to a ruptured aneurysm, treated at a later time; AVM, flow-related aneurysm in association with an arteriovenous malformation; Ophth, ophtalmic segment of the ICA; BA, basilar artery; Cav, cavernous segment of the ICA; TF, thrombus formation in the parent artery during the embolization; TIA, transitory ischemic attack; I, complete occlusion; II, residual neck; III, residual aneurysm.

Treated at our institution by endovascular embolization from February 2004 to September 2004. Twenty patients were admitted through the emergency department for a ruptured aneurysm and classified according the Hunt and Hess (HH) scale: 14 patients were HH grade I; 5 patients were HH grade II; and 1 patient was HH Grade III. An endovascular procedure was the decisive treatment option after consensual agreement between the attending neurosurgeon and the neuroradiologist. The remaining 5 patients had unruptured aneurysms. Endovascular treatment was suggested after discussion of therapeutic options at our interdisciplinary neurovascular board meeting with colleagues from neurology, neurosurgery, neuroradiology, and vascular surgery. Patient data and aneurysm characteristics are outlined in the Table.

Aneurysms

Aneurysm size was determined with the caliper tool on 3D angiographic data and grouped according to the classification of Murayama.10 Fourteen aneurysms were small (4 to 10 mm in diameter) with a small neck (<4 mm), 6 were small with a wide neck (≥4 mm), and 5 were large (11 to 15 mm in diameter). Mean aneurysmal dimensions were 8.1±3.3 mm (mean±SD; range 4 to 15 mm) for the largest diameter and 3.6±1.1 mm (mean±SD; range 2 to 6 mm) for the neck width.

Endovascular Treatment

The complete Matrix coil product line was available for all of our patients. We decided to use Matrix coils predominantly in aneurysms with large necks or an unfavorable dome-to-neck ratio after we experienced packing difficulties with Matrix coils during our initial series of 10 consecutive patients. The use of Matrix coils was deemed justified because, in our view, their potential benefits outweighed their limitation.

The embolizations were performed by 2 experienced interventional neuroradiologists (X.L., J.-P.P.) on a monoplane C-arm angiographic system with 3D rotational angiography (Allura; Philips). The technique of endovascular coiling with Guglielmi detachable coils (GDCs) has been described previously.11 Aneurysm packing was obtained by forming a basket with ≥1 3D coils. In all patients, the first coil deployed was a Matrix 3D coil. The coil basket...
was subsequently filled with smaller Matrix Soft or Matrix UltraSoft coils. In cases of packing difficulties, such as friction between coils or compartmentalization with Matrix Ultra-soft coils, we continued the occlusion with bare platinum coils. The endovascular procedure was completed with immediate angiographic controls, including the working projection used during embolization and a dynamic 3D angiographic series.

**Angiographic Follow-Up**

Magnetic resonance angiographies (MRAs) were performed on a 1.5-T system (Magnetom Vision; Siemens) using a contrast-enhanced FISP (fast imaging steady state precession) and a standard 3D time-of-flight sequence. The scanning protocol has been published recently. For the detection of aneurysmal recanalization, the raw data and the maximum-intensity projections of the corresponding sequences were reviewed. Aneurysmal recanalization was defined as any hyperintense signal appearing within the aneurysmal sac. In cases of suspected aneurysmal recanalization on MRA, a conventional angiography was performed to confirm the diagnosis.

**Image Interpretation**

Immediate conventional angiographic controls, follow-up magnetic resonance angiograms, and conventional follow-up angiograms were independently and blindly reviewed in a randomized fashion by 2 trained neuroradiologists who had not been involved in the endovascular treatment (C.A.T., A.M.B.).

Anatomical results were assigned to 1 of 3 categories according to the Jean Raymond Grading Scale: complete obliteration of the aneurysm including the neck (class 1 or complete occlusion), persistence of any portion of the original defect of the arterial wall as seen on any single projection but without opacification of the aneurysmal sac (class 2 or residual neck), and opacification of the aneurysmal sac (class 3 or residual aneurysm). Cases that led to a disagreement were reviewed at a later time by the 2 previous observers to reach a consensual decision. At follow-up angiography, a recurrence was defined as aneurysm progression between the initial postprocedural angiographic control and the 6-month MRA with change in aneurysm category. The recurrence was qualified as major if its size would theoretically allow retreatment with coils. The decision to re-treat any patient with recanalized aneurysms was discussed at our interdisciplinary neurovascular board meeting. Recanalization rates were analyzed for large aneurysms with wide neck, small aneurysms with wide neck, and small aneurysms with small necks by means of a 2-tailed test. Statistical significance was defined as \( P < 0.01 \).

**Clinical Follow-Up**

Clinical outcomes were graded according to a modified Glasgow Outcome Scale (GOS), and patients were clinically evaluated at hospital discharge. New neurological episodes were noted during the follow-up visits at the outpatient clinic.

**Results**

**Immediate Results**

The total number of coils deployed ranged from 1 to 12 (median 5). We used the remodeling technique in 4 patients because of an unfavorable dome-to-neck ratio. In 6 patients, embolizations were performed with Matrix coils alone. Immediate postprocedural angiograms showed a complete occlusion of the aneurysmal sac in 17 of 25 cases (class 1) and a neck remnant in 7 (class 2). In 1 patient, the embolization had to be stopped because of thromboembolic complications before complete occlusion of the aneurysm (class 3). In 23 of 25 patients, clinical evaluation showed an independent clinical status (GOS 1 to 2), whereas 2 patients required assistance in the activities of daily living on hospital discharge (GOS 3).

**Procedural Complications**

Of 25 total procedures, 5 were complicated with a thrombus formation in the parent artery during the intervention. One patient was clinically symptomatic with an increased dysarthria and hemiparesis immediately after the treatment, with complete symptom resolution within a few days.

**Clinical and Angiographic Follow-Up**

Follow-up data at 6 ± 1.3 months (mean ± SD; range 1 to 7 months) were available for all patients. Imaging findings revealed a complete aneurysm occlusion (class 1) in 17 patients, a neck remnant (class 2) in 4, and a residual aneurysm (class 3) in the remaining 4. The grade of aneurysm occlusion at 6-month follow-up improved in 4 patients (16%), remained stable in 15 (60%), and deteriorated in 6 (24%). Three patients (12%) were re-treated because of major aneurysm recanalization.

Subsequent aneurysm occlusion was observed in 3 small aneurysms with small necks and in 1 large aneurysm with a wide neck. Two of these aneurysms had been treated with Matrix coils alone; in the remaining cases, the percentage of Matrix coils administered was 57% and 38%.

Stability of aneurysmal occlusion at 6-month follow-up was observed predominantly in aneurysms ≥5 mm in size treated with >40% and <90% Matrix.

Aneurysm recanalization at 6-month follow-up occurred in 2 large aneurysms bearing wide necks, in 1 small aneurysm with a wide neck, and in 3 small aneurysms with small necks. Three aneurysms that recanalized had been treated with Matrix coils alone. In the remaining 3 patients with recanalized aneurysms, the percentage of Matrix coils was comparably low, with 40%, 29%, and 26%, respectively. Aneurysm recanalization was not related to aneurysm size (\( P = 0.647 \) in the 2-tailed \( \chi^2 \) test).

No rebleeding occurred during the follow-up period. The clinical evaluation performed at 6 months in all patients showed no changes in the modified GOS.

Three patients with major recurrences required retreatment: 1 patient had a large Pcom aneurysm with a wide neck. After deployment of 208 cm of total coil length (100% Matrix), a residual neck remained visible on the final angiographic control (Figure 1). One patient had a large asymptomatic aneurysm of the ophthalmic portion of the ICA. After administration of 34 cm of coil length (42% Matrix), thromboembolic occlusion of a distal branch of the AC developed. Angiographic controls at that time did not show any opacification of the aneurysmal sac, and the embolization was considered complete. Finally, 1 patient had a small aneurysm of the AC with a wide neck. The intervention was discontinued after administration of 26 cm of total coil length (100% Matrix) because of thrombus formation within the parent artery. Angiographic controls at that stage showed a residual neck.

**Discussion**

The potential benefit of aneurysm treatment with Matrix coils is a reduced recanalization rate because Matrix coils are supposed to promote neointimal formation with subsequent fibrosis protecting the neck of the aneurysm. The present
Another drawback we encountered was the difficulty concerning compartmentalization occurs, the microcatheter has to be repositioned to achieve correct packing. We avoided the use of Matrix coils. The major problem we observed with Matrix was the stiffness of the coils, preventing a good packing. In our experience, Matrix coils did not readily enter the coil package and pushed the microcatheter out of the aneurysm repeatedly. The best results were obtained in those cases in which packing of the aneurysm was finalized with GDC Standard 2D and UltraSoft coils.

We found it difficult to visually estimate the degree of aneurysm packing when Matrix coils were used alone. The Matrix coil volume is composed of 70% copolymer and 30% platinum, which explains why the packing density appears lower on x-ray controls even when the treatment seems complete on angiographic controls.

The difficulties we encountered in completely packing aneurysms with Matrix coils might have been part of the learning process. In our experience, no considerable improvement in practice was observed after >30 patients were treated with Matrix coils. The subsequent occlusion of a number of incompletely treated aneurysms shows that Matrix properties might compensate for a certain degree of underpacking.

Although Matrix coils have been commercially available for >2 years, no data have yet been published on their efficacy and safety. The rate of thrombus formation in the present series was higher than that reported in the literature and occurred more often than in our experience with bare platinum coils. In 2 cases, thrombus formation might have been attributable to the remodeling technique. However, we cannot rule out that this higher rate was related to the Matrix coil alone.

The accuracy of MRA for the follow-up of coiled aneurysms has been demonstrated in various studies compared with catheter angiography serving as a gold standard. Some authors recommend the use of MRA after a good initial correlation with cerebral catheter angiography has been demonstrated. The results of recent studies seem to justify the long-term follow-up by MRA without initial correlation with cerebral catheter angiography. The MRA protocol used in our survey has been subject to a comparative study and showed a significant agreement between techniques with $\kappa=0.93$ ($P<0.0001$). An example of the follow-up by MRA is shown in Figures 1 and 2.

The present prospective single center study may not provide the data necessary to help in medical decision making. We share the view of Raymond that new embolic agents should first demonstrate, within the controlled environment of randomized, prospective scientific trials of a sufficient scale, safety characteristics that are equivalent to standard platinum coils before considering a widespread application.

**Conclusion**

Stable results were obtained predominantly in those cases in which Matrix coils were combined with bare platinum coils. Based on our preliminary data, we discourage the exclusive use of Matrix coils. A prospective, randomized study comparing bioactive coils with bare platinum coils is necessary to assess the potential benefit of Matrix coils to improve long-term results of patients treated by endovascular techniques.
Figure 2. Subarachnoid hemorrhage in a 43-year-old man (patient 23). Conventional angiography (A) shows a 4-mm aneurysm of the anterior communicating artery (black arrow). 3D reconstruction of a dynamic angiography (B) acquired immediately after endovascular treatment demonstrates complete aneurysm occlusion. Contrast enhanced MRA (C) with maximum-intensity projection reconstructions in the frontal plane at 6-month follow-up reveals a recanalization of the aneurysmal neck (white arrowhead). The angiographic control (D) confirms the recanalization. The coils are compacted and have moved upward, and the aneurysm neck is opacified (white arrow).

Acknowledgments

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References


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