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 alternative for the treatment of intracranial aneurysms. The purpose of this study was to evaluate the clinical safety and the angiographic stability of aneurysm occlusion with a new class of biologically active platinum coils 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

Endovascular coil embolization has become an accepted therapeutic option for the treatment of intracranial aneurysms. 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. 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.

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. 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.

A new, coated bioactive coil (Matrix detachable coils; Boston Scientific Neurovascular) has been developed to improve the results of endovascular treatment of intracranial aneurysms. 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. 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. 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 with Matrix detachable coils at 6 months.

Subjects and Methods

Patients
The present report includes 25 patients (mean age 45 years; range 30 to 72 years; 18 women and 7 men) with 25 intracranial aneurysms
Aneurysm location included the cavernous portion of the internal carotid artery (ICA) in 1 case, the ophthalmic portion of the ICA in 1, the anterior communicating artery (AC) in 4, the anterior cerebral artery (AC) in 4, the posterior communicating segment (Pcom) of the ICA in 10, the carotid artery (ICA) in 1 case, the ophthalmic portion of the ICA in 1, the anterior communicating artery in 5, and the basilar bifurcation in 1.

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. Aneurysm packing was obtained by forming a basket with 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. 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 treated at a later time; AVM, flow-related aneurysm in association with an arteriovenous malformation; Opht, ophthalmic segment of the ICA; CB, bifurcation of the intracranial ICA; Acom, anterior communicating artery; 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.

### Summary of Patients and Aneurysms

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age</th>
<th>Clinical Presentation</th>
<th>Aneurysm Location</th>
<th>Maximum Size, mm</th>
<th>Aneurysm Neck, mm</th>
<th>Total Coil Length, cm; No. Coils in Brackets</th>
<th>Matrix Coil Length, cm; No. of Matrix Coils in Brackets</th>
<th>Matrix Coil Length (%)</th>
<th>Complications</th>
<th>Immediate Results (Raymond classification)</th>
<th>Follow-up Results (Raymond classification)</th>
<th>Retreatment Necessary</th>
<th>Outcome Modified GOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>SAH</td>
<td>Pcom</td>
<td>15</td>
<td>6</td>
<td>180 (12)</td>
<td>180 (12)</td>
<td>100</td>
<td>No</td>
<td>II</td>
<td>I</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>48</td>
<td>SAH</td>
<td>Pcom</td>
<td>15</td>
<td>5</td>
<td>208 (12)</td>
<td>208 (12)</td>
<td>100</td>
<td>No</td>
<td>II</td>
<td>III</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
<td>SAH</td>
<td>Oght</td>
<td>15</td>
<td>5</td>
<td>93 (7)</td>
<td>75 (5)</td>
<td>81</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td>SAH</td>
<td>CB</td>
<td>11</td>
<td>4</td>
<td>70 (8)</td>
<td>30 (3)</td>
<td>43</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>45</td>
<td>Asympt.</td>
<td>Oght</td>
<td>11</td>
<td>4</td>
<td>85 (6)</td>
<td>35 (2)</td>
<td>41</td>
<td>TF</td>
<td>I</td>
<td>III</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>SAH</td>
<td>Acom</td>
<td>10</td>
<td>6</td>
<td>104 (10)</td>
<td>50 (3)</td>
<td>48</td>
<td>TF</td>
<td>II</td>
<td>II</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>47</td>
<td>SAH</td>
<td>Pcom</td>
<td>10</td>
<td>4</td>
<td>36 (5)</td>
<td>24 (3)</td>
<td>67</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>49</td>
<td>SAH</td>
<td>Pcom</td>
<td>9</td>
<td>3</td>
<td>66 (10)</td>
<td>25 (2)</td>
<td>38</td>
<td>No</td>
<td>II</td>
<td>I</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>32</td>
<td>SAH</td>
<td>Acom</td>
<td>9</td>
<td>3</td>
<td>18 (3)</td>
<td>12 (2)</td>
<td>67</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>48</td>
<td>SAH</td>
<td>AC</td>
<td>8</td>
<td>3</td>
<td>33 (5)</td>
<td>18 (2)</td>
<td>55</td>
<td>TIA</td>
<td>III</td>
<td>III</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>72</td>
<td>SAH</td>
<td>Pcom</td>
<td>8</td>
<td>3</td>
<td>26 (5)</td>
<td>10 (1)</td>
<td>38</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>36</td>
<td>SAH</td>
<td>Acom</td>
<td>7</td>
<td>5</td>
<td>38 (7)</td>
<td>32 (5)</td>
<td>84</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>38</td>
<td>SAH</td>
<td>BA</td>
<td>7</td>
<td>5</td>
<td>18 (2)</td>
<td>18 (2)</td>
<td>100</td>
<td>TF</td>
<td>II</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>SAH</td>
<td>AC</td>
<td>7</td>
<td>4</td>
<td>26 (3)</td>
<td>26 (3)</td>
<td>100</td>
<td>TF</td>
<td>II</td>
<td>III</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>39</td>
<td>SAH</td>
<td>Pcom</td>
<td>7</td>
<td>3</td>
<td>40 (6)</td>
<td>34 (5)</td>
<td>85</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>51</td>
<td>SAH</td>
<td>Pcom</td>
<td>7</td>
<td>3</td>
<td>32 (4)</td>
<td>26 (3)</td>
<td>81</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>36</td>
<td>2nd an.</td>
<td>Pcom</td>
<td>7</td>
<td>3</td>
<td>26 (5)</td>
<td>18 (2)</td>
<td>69</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>73</td>
<td>SAH</td>
<td>Pcom</td>
<td>7</td>
<td>3</td>
<td>09 (3)</td>
<td>06 (2)</td>
<td>67</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>50</td>
<td>2nd an.</td>
<td>BA</td>
<td>7</td>
<td>3</td>
<td>23 (3)</td>
<td>06 (1)</td>
<td>26</td>
<td>No</td>
<td>I</td>
<td>II</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>32</td>
<td>AVM</td>
<td>Cav</td>
<td>5</td>
<td>4</td>
<td>13 (3)</td>
<td>10 (2)</td>
<td>77</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>42</td>
<td>SAH</td>
<td>Pcom</td>
<td>5</td>
<td>2</td>
<td>16 (3)</td>
<td>16 (3)</td>
<td>100</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>46</td>
<td>2nd an.</td>
<td>Oght</td>
<td>4</td>
<td>3</td>
<td>06 (1)</td>
<td>06 (1)</td>
<td>100</td>
<td>No</td>
<td>II</td>
<td>II</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>43</td>
<td>SAH</td>
<td>Acom</td>
<td>4</td>
<td>3</td>
<td>14 (4)</td>
<td>04 (1)</td>
<td>29</td>
<td>No</td>
<td>I</td>
<td>II</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>38</td>
<td>SAH</td>
<td>AC</td>
<td>4</td>
<td>2</td>
<td>07 (2)</td>
<td>04 (1)</td>
<td>57</td>
<td>No</td>
<td>II</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>51</td>
<td>SAH</td>
<td>Acom</td>
<td>3</td>
<td>2</td>
<td>07 (2)</td>
<td>04 (1)</td>
<td>57</td>
<td>No</td>
<td>I</td>
<td>I</td>
<td>No</td>
<td>1</td>
</tr>
</tbody>
</table>

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; Oght, ophthalmic segment of the ICA; CB, bifurcation of the intracranial ICA; Acom, anterior communicating artery; 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.
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 aneurysm 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 consensus 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 small necks, and in 3 small aneurysms with small necks.

**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 and ≤10 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 χ² 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 controls (Figure 1). One patient had a large, asymptomatic aneurysm of the ophthalmic portion of the ICA. After administration of 85 cm total coil length (41% 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...
analysis in a series of patients treated with Matrix coils revealed aneurysm recanalization in 24% of cases, with 12% of patients requiring retreatment at 6 months. In comparison, the average recanalization rate of bare platinum coils in 4 recent studies was 23.3% within a time period of 12 to 24 months.3,10,13,16 Approximately 15% of patients who underwent GDC coiling needed a second procedure on the same aneurysm within 2 years after the procedure.3,16,17

The present study was not designed to assess efficacy of Matrix coil embolization. Total numbers are small, and recurrence rates that were observed are compatible with any hypothesis (success or failure in decreasing recurrences). Yet we observed a few trends that might help to define an approach on how to introduce Matrix coils into clinical practice.

Based on our preliminary data, we discourage the exclusive 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.12,18–24 Some authors recommend the use of MRA after a good initial correlation with cerebral catheter angiography and in incompletely treated aneurysms shows that Matrix properties might compensate for a certain degree of underpacking.

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.25

**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

C.A.T. is supported by a grant of the Swiss National Science Foundation, funded by the L. + Th. Laroche Stiftung, Basel, Switzerland.

References


