Selective endovascular treatment of 71 intracranial aneurysms with platinum coils

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© Seventy-one intracranial aneurysms were treated by endovascular techniques, with the placement of minicoils inside the aneurysmal sac. Most aneurysms were manifest by hemorrhage (67 cases), and 43 of these were treated within the first 3 days after presentation. At the 1-year follow-up examination, the outcome was scored as good in 84.5% of cases, but the morbidity and mortality rates were 4.2% and 11.3%, respectively. Twenty-nine aneurysms in the anterior circulation and 42 in the posterior circulation were treated. In this series, 23 patients were classified as Hunt and Hess neurological Grade I, 27 as Grade II, 12 as Grade III, nine as Grade IV, and none as Grade V. Thirty-three aneurysms were less than 10 mm in diameter, 28 were 10 to 25 mm, and 10 were larger than 25 mm. The preliminary results from this study appear to justify the emergency treatment of aneurysms by this approach. Aneurysms in the posterior circulation are particularly well suited for this type of surgery.

KEY WORDS • intracranial aneurysm • embolization • coil • endovascular technique

The management of intracranial aneurysms remains controversial. In France, between 4000 and 5000 aneurysms present each year, manifest by hemorrhagic rupture. About 40% of these aneurysms are responsible for sudden death or death from the effects of the initial hemorrhage and 15% have a rapidly progressive course. These figures suggest that diagnosis and treatment before rupture would lower the overall mortality and morbidity rate.

There is general agreement that any new technique that may contribute to the improvement of aneurysm management should be evaluated. Endovascular techniques represent such a treatment and deserve consideration. Since the first publication on the approach to aneurysms via the endovascular route, various series have been published. The earlier studies considered high-risk or inoperable aneurysms as well as bilateral lesions, and detachable balloons were used, with high rates of treatment failure or secondary deflation. Nevertheless, when the types of aneurysms and clinical status of the patients are taken into account, the results may, in retrospect, be considered acceptable.

Aneurysm occlusion with coils was first reported by Hilal in 1988, and has since been refined. Coils of various sizes and shapes can be deposited inside the sac, allowing more homogeneous filling of the lumen and a stable occlusion. The analysis presented here was designed to evaluate the feasibility and stability of this type of selective occlusion with coils. Although this is the largest reported series of endovascular treatment of aneurysms by fiber coils, the number of patients is relatively small when compared to surgical series. Moreover, surgical results may vary from one team to another. Therefore, comparison with any one study carries the risk of being unfair either to the endovascular approach or to surgical treatment.

Clinical Material and Methods

Case Material

From December, 1989, to May, 1992, 71 intracranial aneurysms in 71 patients were treated at our institution. There were 38 men and 33 women with a mean age of 44 years (range 32 to 75 years). Sixty-seven of these patients presented with subarachnoid hemorrhage (SAH) and four with signs of compression. Clinical assessment was performed on admission and on the day of treatment using a modified Glasgow Coma Scale and the Hunt and Hess classification system. Assessment at 6 months posttreatment was scored using the Glasgow Outcome Scale (GOS). The diagnosis of SAH was confirmed on computerized tomography (CT) scans in all...
TABLE I  
Aneurysm location in 71 patients treated with platinum coils

<table>
<thead>
<tr>
<th>Aneurysm Location</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>carotid-ophthalmic artery</td>
<td>12</td>
</tr>
<tr>
<td>posterior communicating artery</td>
<td>6</td>
</tr>
<tr>
<td>anterior communicating artery</td>
<td>7</td>
</tr>
<tr>
<td>middle cerebral artery</td>
<td>4</td>
</tr>
<tr>
<td>vertebrobasilar artery</td>
<td>42</td>
</tr>
<tr>
<td>total aneurysms</td>
<td>71</td>
</tr>
</tbody>
</table>

cases. The extent of bleeding on CT was evaluated using Fisher’s scale. Magnetic resonance (MR) imaging was performed in 52 patients. The diagnosis of intracranial aneurysm was confirmed by four-vessel cerebral angiography in all patients.

Angiographic Data

The aneurysms demonstrated on angiography were located at almost the same frequency in the vertebrobasilar territory as in the anterior territory (59% vs. 41%, Table I). The diameter of the aneurysm was less than 10 mm in 47% of cases (small), between 10 and 25 mm in 39% (large), and more than 25 mm in 14% (giant).

Indications and Timing of Endovascular Treatment

The indication for endovascular treatment was based on a consensus between interventionist neuroradiologists, neurosurgeons, and anesthesiologists. Endovascular treatment was considered primarily for anatomical reasons (giant aneurysms, most posterior circulation aneurysms), clinical reasons (Hunt and Hess Grades III and IV, anesthetic contraindications), or when surgery was refused by the patient or the patient’s family.

Clinical assessment and rating on the day of treatment revealed a good neurological status (Hunt and Hess Grades I and II) in 50 patients (70%), confusion and neurological deficit (Grade III) in 12 (17%), and coma (Grade IV) in nine (13%). Almost one-third of the patients were therefore classified as Hunt and Hess Grade III or IV.

Endovascular treatment was performed as early as possible. In 61% treatment was carried out in the first 3 days post-hemorrhage, in 21% between the 4th and 6th day, in 7% between the 7th and 10th day, and in 11% beyond the 15th day after the first clinical manifestations. Of the eight patients treated after the longest duration, four had presented with SAH and four with signs of compression.

Endovascular Treatment Technique

Endovascular treatment was performed with the patient under neuroleptanalgesia, except when respiratory assistance was required. The procedure was performed under anticoagulation with heparin and intravenous nimodipine administration (1 to 2 mg/hr).

Two catheters (No. 5 and No. 6 French) were inserted via a bifemoral approach. For posterior circulation aneurysms, one of the catheters was placed in a vertebral artery and used as a guide for endovascular treatment; the other was positioned in the contralateral vertebral or ipsilateral subclavian artery and used for control of aneurysm occlusion during the procedure or to position a second occlusion system in the case of hemorrhage. For anterior circulation aneurysms, one of the catheters was placed in the internal carotid artery and the second in the common carotid artery.

Superselective catheterization of the aneurysm was performed with a progressively flexible Tracker-18 microcatheter and a No. 0.16 guidewire. After the microcatheter was positioned inside the aneurysm, superselective angiography was performed (Fig. 1) to assess the

Fig. 1. Angiograms in a 48-year-old man with subarachnoid hemorrhage classified as Hunt and Hess neurological Grade II and treated on the 3rd day post-hemorrhage with coil embolization. Left: Left internal carotid angiogram, oblique anteroposterior view, demonstrating a large anterior communicating artery aneurysm (arrow). Center: Intra-aneurysmal angiogram, oblique anteroposterior view, obtained before embolization, providing good visualization of the aneurysmal sac (solid arrow) and of the microcatheter (open arrow). Right: Left internal carotid angiogram, anteroposterior view, obtained after embolization and performed with compression of the right carotid artery in the neck, demonstrating complete coil occlusion of the aneurysm (arrow) with normal filling of the anterior communicating artery.
TREATMENT OF INTRACRANIAL ANEURYSMS WITH PLATINUM COILS

An aneurysmal neck and the relationships between the aneurysm and the afferent artery and perforating branches. When the best radiological angle was obtained, allowing good definition of the neck, the microcoils were deposited from the bottom of the sac to the neck. The coils, coated with thrombogenic Dacron fibers and available in various shapes and sizes, were selected according to the space to be filled and deposited using a coil pusher.* When the coil mesh was sufficiently dense and occlusion of the aneurysm was confirmed under angiographic control, the procedure was stopped (Fig. 1). Heparin therapy was then discontinued, hemostasis assessed, protamine administered when necessary, and neurological status evaluated. "Complete occlusion" was defined as occlusion of the aneurysmal sac and neck, and "partial occlusion" as an occlusion of more than 90% of the aneurysm.

Angiography was performed at 8 days, 1, 3, and 6 months, and 1 and 2 years posttreatment. A new clinical assessment was performed at 6 months by an independent physician using the GOS.

Results

Sixty aneurysms (84.5%) were completely occluded and the other 11 (15.5%) were more than 90% occluded. The relationship between complete occlusion and aneurysm size is shown in Table 2: 94% of the small aneurysms, 82% of the large aneurysms, and 60% of the giant aneurysms were completely occluded. The mean duration of angiographic follow-up monitoring was 13 months. Clinical outcome at 6 months postprocedure showed good results in 60 patients (84.5%), moderate deficits in three (4.2%), and eight deaths (11.3%).

Relationship of Outcome to Clinical Status

An analysis of outcome in relation to clinical status on the day of treatment provided the following information (Table 3). Among the 50 alert patients classified in Hunt and Hess Grades I and II, the results obtained were good in 47 (94%), while one patient (2%) had a moderate deficit and two (4%) died. Among the 12 patients classified as Hunt and Hess Grade III, outcome was good in nine (75%), while one patient (8%) retained a moderate residual deficit and two (17%) died. Among the nine comatose (Grade IV) patients, results showed a good outcome in four (44%), a moderate neurological deficit in one (11%), and four deaths (44%).

Relationship of Outcome to Aneurysm Size

The relationship between outcome at 6 months after the procedure and aneurysm size was analyzed (Table 4). Among the 33 small aneurysms, good results were shown in 30 patients (91%) and a moderate deficit in one (3%); two patients died (6%). Among the 28 large aneurysms, the outcome was good in 23 patients (82%), one patient (4%) suffered a moderate deficit, and four patients (14%) died. Among the 10 giant aneurysms, there were good results in seven patients (70%), a moderate deficit in one (10%), and two deaths (20%).

Follow-Up Angiography

Follow-up angiography of 11 residual aneurysms showed that seven were unchanged after a mean follow-up period of 12 months, while three had become enlarged. Two of these posttreatment enlargements were revealed by recurrent SAH 7 days and 20 days after subtotal treatment, respectively. Re-embolization was performed, but death occurred in both patients during the following week. The third case of enlargement was diagnosed on follow-up angiography performed 1 month after treatment and was treated by a second endovascular procedure, with a good result.

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* Coils and coil pusher manufactured by Target Therapeutics, Fremont, California.

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Table 2

<table>
<thead>
<tr>
<th>Aneurysm Size</th>
<th>Total Occlusion</th>
<th>Partial Occlusion</th>
<th>Totals</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td>No.</td>
</tr>
<tr>
<td>&lt; 10 mm</td>
<td>31</td>
<td>94</td>
<td>2</td>
</tr>
<tr>
<td>10-25 mm</td>
<td>23</td>
<td>82</td>
<td>5</td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td>6</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>totals</td>
<td>60</td>
<td>84.5</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 3

<table>
<thead>
<tr>
<th>Evaluation on Treatment*</th>
<th>No. of Cases</th>
<th>Evaluation at 6 Months†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good Recovery</td>
<td>Moderately</td>
</tr>
<tr>
<td>Grades I &amp; II (alert)</td>
<td>50</td>
<td>47 (94)</td>
</tr>
<tr>
<td>Grade III (stuporous)</td>
<td>12</td>
<td>9 (75)</td>
</tr>
<tr>
<td>Grade IV (comatose)</td>
<td>9</td>
<td>4 (44)</td>
</tr>
<tr>
<td>totals</td>
<td>71</td>
<td>60 (84.5)</td>
</tr>
</tbody>
</table>

* Clinical assessment on day of treatment was performed according to the Hunt and Hess classification system.† Clinical assessment at 6 months was performed using the Glasgow Outcome Scale. Numbers in parentheses are percentages.

Table 4

<table>
<thead>
<tr>
<th>Aneurysm Size</th>
<th>No. of Cases</th>
<th>Evaluation at 6 Months*</th>
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<tr>
<td></td>
<td>Good Recovery</td>
<td>Moderately</td>
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<tr>
<td>&lt; 10 mm</td>
<td>33</td>
<td>30 (91)</td>
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<tr>
<td>10-25 mm</td>
<td>28</td>
<td>23 (82)</td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td>10</td>
<td>7 (70)</td>
</tr>
<tr>
<td>totals</td>
<td>71</td>
<td>60 (84.5)</td>
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</table>

* Numbers in parentheses are percentages.
Follow-up angiography of completely occluded aneurysms was available in 54 cases, with a mean follow-up period of 13 months. In three cases (5.5%), partial revascularization in the coil mesh was observed at the 3-month angiographic follow-up evaluation. These three patients were treated by adding more coils until total occlusion was achieved; no secondary revascularizations were observed at 6-month follow-up angiography.

Complications

Two SAH's appeared during the procedure due to perforation of the aneurysm sac, once with the guide-wire and once while positioning the first coil. Both cases were treated by insertion of coils, with a good clinical outcome. In four cases the parent vessel was occluded during positioning of the last coils. Two of these patients died of massive infarction and two presented a moderate deficit on long-term clinical assessment. Two embolisms occurred from the guiding catheter, causing death by massive infarction in one patient and a motor deficit in one, which was still apparent at the 6-month assessment. Three posttreatment enlargements were observed (mentioned above); two of these were responsible for death due to hemorrhage and the third was treated by a second coil occlusion procedure. Three patients died of secondary infarction related to the development of vasospasm. The CT scan performed on admission in these cases showed an SAH extending to the cisterns and ventricles. Neurological examination revealed a moderate deficit in one patient and a condition of coma in the other two.

Discussion

Since Luessenhop and Velasquez first described the feasibility of catheterization of the internal carotid artery above the petrous segment in 1964, a great deal of experience has been acquired in endovascular navigation techniques as well as embolization materials. In the absence of vasospasm, all arteries in the circle of Willis can be reached with a risk similar to that of diagnostic cerebral angiography. This allows endovascular treatment of certain malformations that are not surgically accessible. Outcome, in terms of both survival and fusion, has been improved in a number of patients, such as those with vein of Galen aneurysms or complex vascular malformations of the vertebral column or spinal cord. At this time, the treatment of choice for these conditions often consists of endovascular techniques.

Endovascular access to the intracranial aneurysm does not raise any problems, but the safety of endovascular exclusion of the aneurysm from circulation must be equivalent to that of surgery. Early techniques of selective endovascular occlusion of aneurysms used detachable balloons. The recent results published by Higashida, et al., and George are poorer than those reported for surgery but, when the type of aneurysm is taken into account (most of the aneurysms were large or giant), the results may be acceptable. A higher incidence of good results was reported in the series of Romodanov and Shcheglov and of Moret, et al. Both series included small aneurysms with easy access, features considered to be good surgical indications; these aneurysms can be occluded with a single balloon. Overall evaluation of these series shows that the use of detachable balloons remains a reasonable choice for the treatment of certain aneurysms with difficult or dangerous surgical access or when clinical status is a contraindication to surgery. However, it is unlikely that this technique will one day replace surgery, despite the progress achieved, as the failure rate and secondary balloon deflation remain significant problems. More recent papers have reported endovascular treatment of aneurysms using coils instead of balloons, with encouraging preliminary results.

Significance of Aneurysm Site and Size

In our series, most (59%) of the aneurysms were located in the vertebrobasilar circulation and more than one-half (53%) were large or giant. Despite the seriousness of the cases included in our series, good results were obtained in 84.5%, with morbidity and mortality rates of 4.2% and 11.3%, respectively. Good clinical results were obtained for 91% of the small aneurysms.
and 82% of the large aneurysms. Large and giant aneurysms, especially those with a wide neck, raise a specific problem whatever the type of treatment. However, in view of the good results and low incidence of morbidity when using coils, this treatment may be a good therapeutic choice (Fig. 2). The treatment of a larger number of small aneurysms may demonstrate the value of endovascular treatment with coils in this situation.

**Early Endovascular Treatment**

Many authors consider that the best time for aneurysm surgery is before the 3rd day post-hemorrhage if the patient has a satisfactory neurological status. Good results were obtained in this context in most published surgical series. Conversely, the International Cooperative Study on the Timing of Aneurysm Surgery demonstrated no difference between early and late (after 10 days) treatment. Detailed analysis of these results shows that surgical risk is highest in early surgery. This high complication rate is partially compensated for by the elimination of the risk of rebleeding. In late surgery, the surgical risk is minor, but morbidity and mortality rates are similar to those of early surgery due to rebleeding and ischemic complications. If the surgical risks associated with early surgery could be eliminated, this modality would constitute the best therapeutic choice.

The majority of our patients were treated during the 3 days following SAH. The long-term morbidity rate of 4.2% suggests that avoidance of surgical trauma in the first few days after SAH may be an advantage of the endovascular approach and may justify this approach in the early treatment of aneurysms. This approach prevents rebleeding, but does not protect the patient from ischemia due to vasospasm. In our experience, endovascular navigation is easier in the days following SAH, and the risk of mechanical vasospasm and embolic complications during catheterization increases with time. This is in agreement with the Cooperative Study results, which showed a two-fold increase in the risk of angiographic complications after the 4th day post-SAH.

Many authors have stressed the necessity of rinsing the cisterns after SAH to lower the incidence of vasospasm. However, noted that vasospasm occurs most often between the 5th and 9th day post-hemorrhage, even when the cisterns have been rinsed during surgery. Rinsing the cisterns may therefore not be as important as previously thought. However, early surgery allows the introduction of a more aggressive treatment against vasospasm. Rinsing the cisterns was not performed in any of our patients treated by the endovascular approach, but the complication rate and incidence of hydrocephalus were no higher than those of surgical series.

**Outcome and Clinical Grade**

Table 3 shows that better results were obtained in patients in good neurological condition on the day of treatment. Conversely, a high mortality rate was observed in patients in a state of stupor or coma on the day of treatment. This suggests that endovascular treatment with coils may be an effective treatment for patients with good neurological status following SAH. Surgery is usually contraindicated in a comatose patient in the first days following hemorrhage or in a stuporous patient with altered cerebral blood flow. Endovascular treatment may be an alternative treatment to prevent further rebleeding. The clinicopathological studies by Hjørn, et al. showed that only 18% of patients survive a new bleeding episode at 3 months.

**Efficacy of Occlusion and Follow-Up Study of Residual Aneurysms**

In our series, 11 (15.5%) of the aneurysms were not completely occluded. However, it should be pointed out that 40 (56%) aneurysms in our series were large or giant aneurysms with a wide neck. Our experience demonstrated that a tight mesh of coils must be obtained in the aneurysm to prevent revascularization (Fig. 3).

Some authors have conducted a sufficiently long follow-up review of aneurysm remnants after surgery to allow prediction of their future, including remissions, enlargements, stabilizations, and rebleeding. It therefore appears important to compare the outcome of the residual aneurysms in our series with those in the series reported by Feuerberg, et al. In that series, 21 aneurysm remnants were followed for a mean of 8 years; 13 (62%) were unchanged, five (24%) resolved, two (10%) decreased in size, and only one (5%) enlarged and bled. In the series reported by Lin, et al., the percentage of enlargements was higher than in the series of Feuerberg, et al., but was also lower than in our series. In our patients, residual aneurysms were followed for a mean of 12 months. Of the 11 residual aneurysms, eight (73%) were unchanged and three (27%) enlarged.
Two of these three enlargements hemorrhaged, leading to death. The third enlargement was completely occluded with no complications. The outcome in patients with aneurysms partially treated with coils therefore appears to vary from that in surgically treated aneurysm patients. It is disturbing to find that almost one-quarter of coil-treated residual aneurysms may enlarge and rebleed. One explanation may be that aneurysms partially treated via the endovascular approach usually possess a wide neck, generally in the axis of blood flow. Endovascular treatment does not modify this situation. Conversely, surgical clipping allows collapse of the aneurysm, even in the presence of a wide neck, resulting in an alteration of the position of the residual neck in relation to blood flow. Whatever the reason, these lesions should be carefully monitored and all enlarging remnants should undergo emergency treatment. When the remnants are located in the posterior circulation, they may be stabilized by flow modifications. This could be obtained by occlusion of one of the vertebral arteries. The use of controlled detachable coils, such as Guglielmi detachable coils, may reduce the incidence of partially treated aneurysms. Revascularization of apparently completely occluded aneurysms was observed in three cases. All were terminal aneurysms directly subject to the flow “water-hammer effect.”

Complications

Complications may be directly related to the procedure (catheterization of the aneurysm leading to rupture), the use of coils, or bleeding, or to the condition itself. Two SAH’s occurred during coil placement and were controlled by coil occlusion of the breach and by reversal of the anticoagulant action of heparin with protamine sulfate administration; the outcome in both cases was good. Aneurysm rupture was less serious than that caused by excess inflation of a balloon. Occlusion of parent vessels was observed following placement of the last few coils in wide-necked aneurysms. The coils used in our series were not retrievable; controlled detachable coils could possibly reduce the incidence of this complication.

Emboli were observed in patients in whom the partial thromboplastin time was not sufficiently prolonged. Heparin therapy should therefore be used to produce a state of hypocoagulability prior to catheterization.

All patients with vasospasm were treated between the 7th and 10th day post-hemorrhage. As ischemic low-density images were already demonstrated on admission CT scans in these three patients, angioplasty of the vasospasm was not performed.

Management of Unruptured Aneurysms

The autopsy study by Sekhar and Heros established an incidence rate of 5% for ruptured or unruptured intracranial aneurysms. The estimated incidence of aneurysms in the French population is therefore 5%. Over 80% of these ruptures occur in patients between the ages of 30 and 60 years. Therefore, over a 30-year period, at least 120,000 of 300,000 aneurysms will bleed with known consequences. The value of early diagnosis and treatment of unruptured aneurysms should therefore be investigated. Various authors consider the risk of surgical treatment of unruptured aneurysms to be less than that of spontaneous rupture. Surgical treatment of unruptured aneurysms therefore appears to be logical. However, it should be noted that aneurysms less than 10 mm in diameter have a lower risk of rupture than larger lesions. Small aneurysms should be monitored and treated if they change in size or shape. The future of the endovascular approach for this clinical form will probably benefit from coil occlusion. Efficacy and morbidity rates are both much more acceptable than with balloon occlusion. However, unruptured aneurysms with easy surgical access have not yet been treated by this technique, and the follow-up monitoring in ruptured aneurysms treated by coil occlusion is insufficient to determine whether the long-term results are equivalent to those of surgery.

Conclusions

Endovascular coil occlusion of intracranial aneurysms is a recent and evolving technique. Follow-up monitoring is still relatively short and long-term outcome of the coils is unknown. Coil treatment appears to be a promising technique. In the near future, comparison with other teams using the same methods should be of interest. Randomized trials of endovascular coils versus surgery should be designed to allow prospective evaluation of treatment.

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Treatment of intracranial aneurysms with platinum coils


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