Outcomes of Early Endovascular Versus Surgical Treatment of Ruptured Cerebral Aneurysms: A Prospective Randomized Study

Timo Koivisto, MD; Ritva Vanninen, MD, PhD; Heleena Hurskainen, MS; Tapani Saari, MD; Juha Hernesniemi, MD, PhD; Matti Vapalahti, MD, PhD

Background and Purpose—This prospective study was conducted to compare the outcomes of surgical clipping and endovascular treatment in acute (<72 hours) aneurysmal subarachnoid hemorrhage (SAH).

Methods—One hundred nine consecutive patients were randomly assigned to either surgical (n = 57) or endovascular (n = 52) treatment. Clinical and neuropsychological outcome was assessed at 3 and 12 months after treatment; MRI of the brain was performed at 12 months. Follow-up angiography was scheduled after clipping and 3 and 12 months after endovascular treatment.

Results—One year postoperatively, 43/41 (surgical/endovascular) patients had good or moderate recovery, 5/4 had severe disability or were in a vegetative state, and 9/7 had died (NS) according to intention to treat. Patients with good clinical recovery did not differ in their neuropsychological test scores. Symptomatic vasospasm (OR 2.47; 95% CI 1.45 to 4.19; \( P < 0.001 \)), poorer Hunt and Hess grade (OR 2.50; 95% CI 1.31 to 4.75; \( P = 0.005 \)), need for permanent shunt (OR 8.90; 95% CI 1.80 to 44.15; \( P = 0.008 \)), and larger size of the aneurysm (OR 1.22; 95% CI 1.02 to 1.45; \( P = 0.032 \)) independently predicted worsened clinical outcome regardless of the treatment modality. In MRI, superficial brain retraction deficits (\( P < 0.001 \)) and ischemic lesions in the territory of the ruptured aneurysm (\( P = 0.025 \)) were more frequent in the surgical group. Kaplan-Meier analysis (mean ± SD follow-up 39 ± 18 months) revealed equal survival in both treatment groups. No late rebleedings have occurred.

Conclusions—One-year clinical and neuropsychological outcomes seem comparable after early surgical and endovascular treatment of ruptured intracranial aneurysms. The long-term efficacy of endovascular treatment in preventing rebleeding remains open. (Stroke. 2000;31:2369-2377.)

Key Words: cerebral aneurysm ■ clinical trials ■ embolization, therapeutic ■ subarachnoid hemorrhage ■ surgery

Despite developments in the treatment of acute aneurysmal subarachnoid hemorrhage (SAH), the case fatality rate has remained stable,\(^1\)-\(^7\) although the outcomes of good-grade patients with anterior circulation aneurysms have improved significantly.\(^8\) A recent study\(^9\) on the natural history and treatment of unruptured aneurysms has suggested that surgery itself could produce cognitive impairment, neurological morbidity, and mortality more frequently than previously believed. Endovascular treatment of recently ruptured cerebral aneurysms with Guglielmi electrolytically detachable coils (GDC)\(^10\) avoids the well-known difficulties of early surgery on swollen brain tissue and might carry lower morbidity and mortality rates.\(^11\) Endovascular treatment has proved effective in preventing early rebleeding.\(^12\) However, the total obliteration rate of the aneurysms seems lower than that achieved by direct surgery.\(^12\)-\(^21\)

No comparative studies of the long-term outcome of surgical versus GDC treatment in acute SAH have been published so far. The objective of this prospective study was to randomly assign patients with acute (<72 hours) aneurysmal SAH to either endovascular treatment or open surgery and to determine the differences between these treatment modalities in long-term clinical (Glasgow Outcome Scale [GOS]),\(^22\) neuropsychological, and radiological (angiographic occlusion rate; MRI of the brain) outcomes. The high incidence of SAH in Finland (16 to 20/100 000 per year),\(^6\) our defined catchment area (900 000 people) with no referral bias, and our extensive experience with early surgery\(^2\) encouraged us to design and conduct this study.

Subjects and Methods
Study Design, Patients, and Treatment
During the study period between February 1, 1995, and August 31, 1997, 242 patients with proven aneurysmal SAH were treated at our department. Of these, 111 patients (2 were excluded from the analysis after randomization) with acute aneurysmal SAH were
TABLE 1. Excluded Patients from the Consecutive 242 Patients With Proven Aneurysmal SAH

<table>
<thead>
<tr>
<th>Reason for exclusion</th>
<th>No. of Patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large hematoma</td>
<td>35 (26.7)</td>
</tr>
<tr>
<td>Aneurysm morphology not suitable for coiling</td>
<td>33 (25.2)</td>
</tr>
<tr>
<td>&gt;72 h from bleeding</td>
<td>26 (19.9)</td>
</tr>
<tr>
<td>Age &gt;75 y</td>
<td>11 (8.4)</td>
</tr>
<tr>
<td>Patient in moribund state</td>
<td>9 (6.9)</td>
</tr>
<tr>
<td>Coil therapy not available</td>
<td>6 (4.6)</td>
</tr>
<tr>
<td>Previous aneurysmal SAH</td>
<td>3 (2.3)</td>
</tr>
<tr>
<td>Aneurysm location not suitable for ligation</td>
<td>2 (1.5)</td>
</tr>
<tr>
<td>Aneurysm causing mass effect</td>
<td>2 (1.5)</td>
</tr>
<tr>
<td>Patient refused</td>
<td>2 (1.5)</td>
</tr>
<tr>
<td>Patient from abroad</td>
<td>2 (1.5)</td>
</tr>
<tr>
<td>Total</td>
<td>131 (100.0)</td>
</tr>
</tbody>
</table>

Locations of aneurysms in excluded patients

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of Patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>34 (26.0)</td>
</tr>
<tr>
<td>MCA*</td>
<td>59 (45.0)</td>
</tr>
<tr>
<td>ICA</td>
<td>27 (20.6)</td>
</tr>
<tr>
<td>VBA</td>
<td>11 (8.4)</td>
</tr>
<tr>
<td>Total</td>
<td>131 (100.0)</td>
</tr>
</tbody>
</table>

*Significantly more often associated with large hematoma ($P<0.001$).

Neuropsychological assessment was performed by the same neuropsychologist (H.H.) on 3 occasions. The short-term assessment 10 days after treatment was limited to a few tests. Comprehensive evaluation 3 and 12 months after treatment included tests of general intelligence, memory, and selected language abilities and assessment of attention and flexibility of mental processing.24–29 In the tests of learning and memory, parallel sets of tests were used to minimize the retest learning effects, and the order of the sets was randomly alternated. A detailed description of the neuropsychological tests is provided in the Appendix.

The achieved angiographic occlusion rate of the aneurysms was evaluated, by consensus, by a neurosurgeon (T.K.) and an interventional neuroradiologist (R.V.).

In MRI, T2- and proton density–weighted transaxial slices of the brain were evaluated by a neuroradiologist (R.V.) and a neurosurgeon (T.K.) by consensus. The following factors were analyzed: (1) the presence, number, and dimensions of ischemic lesions in (a) the vascular territory of the parental artery of the ruptured aneurysm and (b) other vascular territories; (2) traces indicative of mechanical retraction injury; (3) lesions caused by hematoma; (4) lesions already present in the initial CT examination; and (5) ventricular-to-intracranial width ratio.

Statistics

The intention-to-treat analysis compared endovascular and surgical patients in terms of time to a primary end point event, using Kaplan-Meier survival analysis and the log-rank test. The corresponding analysis was performed separately for patients in preoperative Hunt and Hess grades I–II and grades III–V. The influence of the intended treatment modality and different clinical and anatomic factors on the observed clinical outcome were analyzed. The Mann-Whitney $U$ test for continuous or ordinal scale variables with a non-normal distribution, the $x^2$ test for dichotomized discrete variables, and the Student $t$ test for continuous variables with a normal distribution were applied for group comparisons. Changes in scoring between consecutive neuropsychological tests were analyzed with the paired-samples $t$ test or the Wilcoxon signed rank test. Differences were considered to be statistically significant if the 2-tailed $P$ value was $<0.05$. Multivariate analysis was performed by logistic regression to identify potential predictive factors of 12-month outcome (GOS). A stepwise model-building procedure was performed for the parameters, using $P<0.25$ achieved in univariate analysis. In the final multivariate analysis, the statistical level of significance was set at $P<0.05$. Significance was calculated by the likelihood ratio test. The goodness of fit of the model was estimated with Nagelkerke $R^2$.

Results

Comparability of the Study Groups

The treatment groups had no statistically significant differences in age or gender distribution, in Hunt and Hess or Fisher grades, or in the site or size of the ruptured aneurysms.23 The subgroups undergoing neuropsychological assessments and MRI were equally balanced.

Twelve-Month Clinical Outcome

The 12-month clinical outcomes (GOS) in the surgical and endovascular treatment groups did not differ significantly ($P=0.319$; Table 2). Neither group significantly improved their clinical outcome between 3 and 12 months after treatment.

In univariate analysis, the intended treatment modality, gender of the patient, crossover treatment, and multiplicity of the aneurysms were not statistically significant determinant factors of good recovery (GOS). Because Hunt and Hess grade ($P<0.001$), postoperative symptomatic vasospasm...
need for permanent shunt creation (P<0.001), Fisher grade (P=0.001), size of the aneurysm (P=0.003), age (P=0.015), size of the aneurysmal neck (P=0.024), and hydrocephalus in the preoperative CT (P=0.027) were significantly associated with clinical outcome, they were further included in a backward stepwise multiple logistic regression analysis as independent variables. Postoperative symptomatic vasospasm (OR 2.47; 95% CI 1.45 to 4.19; P<0.001), poorer Hunt and Hess grade (OR 2.50; 95% CI 1.31 to 4.75; P<0.005), need for permanent shunt creation (OR 8.90; 95% CI 1.80 to 44.15; P<0.008), and larger size of the ruptured aneurysm (OR 1.22; 95% CI 1.02 to 1.45; P=0.032) proved to be independent predictors of poorer clinical outcome. For the final model R²=0.514.

Survival Analysis
The Kaplan-Meier survival analysis (Figure 1) was based on the last outcome data obtained by telephone interview. No patients were lost from follow-up. At the time of the last follow-up, 9 patients in the endovascular group and 10 patients in the surgical group had died (Table 3). No rebleedings occurred after the first hospitalization. There was no significant difference in cumulative survival times between the endovascular (mean survival time 1575 days; 95% CI 1403 to 1746 days) and surgical (1572 days; 95% CI 1400 to 1745 days) treatment groups (P=0.8822; Figure 1). The patients with preoperative Hunt and Hess grades I–II (1716 days; 95% CI 1600 to 1832 days) had significantly lower risk of cumulative mortality (P=0.0126) than the patients with grades III–V (1344 days; 95% CI 1104 to 1583 days; Figure 2).

Technique-Related Mortality and Morbidity
The early technique-related morbidity and mortality of endovascular and surgical treatment in the study population have been described earlier.21 One patient in the endovascular and 1 patient in the surgical group died after late surgical treatment of a residual aneurysm (Table 3).

Neuropsychological Evaluation
The number of patients completing all the neuropsychological tasks, their ages, gender and years of formal education were equal in both treatment groups. Only patients who completed all the tasks were included in the analysis. Of these patients, the number of patients with moderate or severe disability (GOS) was small and unequally distributed between the surgical and endovascular groups at both the 3- (7 versus 3) and 12-month (7 versus 1) assessments. The number of tasks not performed did not significantly differ between groups.

Patients with good clinical outcome (GOS) in either treatment group did not have significant differences in their
neuropsychological test scores, and both groups improved their performance between the 3- and 12-month assessments (Table 4).

**Angiographic Results**

One residual basilar aneurysm was operated on again after 3 months with lethal complications. Of the 48 surgical patients alive 12 months after primary treatment, 3 (6%) had undergone crossover treatment, and 2 aneurysms had spontaneously thrombosed.

Of the 45 endovascular patients alive 12 months after primary treatment, 9 (20%) had undergone crossover treatment and 3 (7%) reembolization. In 10 patients (22%) refilling of the aneurysmal neck was present, while in 7 patients (16%) the aneurysmal remnant had thrombosed spontaneously.

Two endovascular patients refused the 12-month angiography. Control angiography was not performed in 5 patients who had primary or additional surgical treatment. In 2 cases the result was confirmed at autopsy; 1 patient developed renal failure, and the result was evaluated by MRA. One patient died before control angiography and had no autopsy; 1 patient lacked control angiography after clipping of a previously embolized aneurysm. The final angiographic results are presented in Table 5.

**MRI of the Brain**

Forty-one endovascular and 47 surgical patients (p=0.808) underwent MRI of the brain 12 months after treatment (Table 6). Claustrophobia prohibited MRI examination in 4 cases, and 2 patients refused.

Ischemic lesions in the parental artery territory were associated with clinical symptoms of vasospasm (P=0.001). Ischemic lesions in other locations were associated with clinical symptoms of vasospasm (P<0.001), with higher Fisher grade (P=0.001), and with ischemic lesions in the parental artery territory (P=0.001).

In univariate analysis, the following MRI variables revealed significant association with poorer clinical outcome: size of the ischemic lesion in the parental artery territory (P<0.001) or in another location (P=0.001); presence of an ischemic lesion in the parental artery territory (P=0.003) or in another location (P=0.005); deficit due to preoperative intracerebral hematoma (P=0.035) and higher ventricular-intracranial width ratio (P=0.040). These were included in a backward stepwise multiple logistic regression analysis as independent variables. In the final model, the presence of an ischemic lesion in the parental artery territory (OR 6.20; 95% CI 1.67 to 23.05; P=0.006) and a deficit due to preoperative intracerebral hematoma (OR 4.23; 95% CI 1.16 to 15.39; P=0.029) proved to be independent predictors of poorer clinical outcome. The $R^2$ of the final model was 0.249.

**Crossover Between Treatment Groups**

Crossover from endovascular to surgical treatment was (n=12) significantly more common than crossover from surgical to endovascular treatment (n=4; P=0.028). Eight endovascular patients were operated on during the primary hospitalization.23 In 4 cases, control angiography revealed that the coils had collapsed so that a significant portion of the aneurysm was refilling; these aneurysms were operated on. Altogether, 4 surgical patients had their significant residual aneurysms treated endovascularly.
In addition to intention-to-treat analyses, all the analyses of clinical, neuropsychological, and radiological results, as well as the Kaplan-Meier survival analysis, were repeated by leaving out the crossover patients. The results did not markedly differ from the original analyses.

Discussion

Prospective, randomized comparisons between embolization and surgery for the treatment of acutely ruptured intracranial aneurysms have been suggested because the published endovascular series have been highly biased by the characteristics of the patients or their aneurysms. The benefits of early surgery have been widely accepted, indicating comparability of the modalities in the early treatment period (within 72 hours). Our single-center study provides detailed clinical, neuropsychological, and radiological outcome data.

The basic characteristics of our patients in both treatment groups were similar in terms of aneurysm location and size, severity of subarachnoid bleeding, and clinical grade of the patients. These variables are also comparable to those presented in the international cooperative study and in our previous study of 1007 patients, with the exception of the large proportion of excluded middle cerebral artery aneurysms (Table 1), the most common aneurysms in our institution.

Clinical Outcome of the Patients

One-year outcome did not significantly differ between groups, as 79% of endovascular versus 75% of surgical patients had good or moderate recovery (GOS). This is in accordance with the results of other surgical series and our previous study, in which 399 of 524 patients (76%) operated on within 3 days after SAH had good or moderate recovery.

Symptomatic vasospasm, the need for permanent shunt creation, size of the ruptured aneurysm, and Hunt and Hess grade proved to be independent predictors of clinical outcome, regardless of treatment modality. The initial effects of SAH have been found to be the most important predictive factors.
Efficacy of Treatment

The aim of treatment is total occlusion of the aneurysm to prevent rebleeding. Incompletely clipped aneurysms have a high probability of growing neck remnants and rebleeding during follow-up.\textsuperscript{41–46} It can be presumed that ruptured aneurysms which are only partially coiled carry at least the same risk for late rebleeding.\textsuperscript{42} No late rebleedings have occurred among our study population, though many had small neck remnants after initial treatment.

The long-term angiographic follow-up was not scheduled identically for both groups, because only the surgically treated patients with residual filling of the aneurysm were controlled. Rebleeding has recently been reported to affect 2.7\% of patients (cumulatively over 10 years), even after complete clipping of the aneurysm.\textsuperscript{47} The estimated incidence of rupture increases to 0.38\% to 0.79\% per year in cases of incompletely clipped aneurysms.\textsuperscript{43} We did not include the completely clipped aneurysms in our angiographic follow-up protocol because the possible regrowth of aneurysmal remnants requires many years.\textsuperscript{41,43,45–48}

The number of endovascularly treated aneurysms partly refilling on 1-year follow-up was relatively high (n=10). On the other hand, 7 of the endovascular aneurysmal remnants were spontaneously thrombosed on follow-up. These numbers, similar to other endovascular series,\textsuperscript{13,40,49} emphasize

### TABLE 5. Primary and Final Angiographic Results of Early Endovascular and Surgical Treatment of Recently Ruptured Aneurysms, According to Site of Aneurysm

<table>
<thead>
<tr>
<th></th>
<th>Endovascular Treatment, n (%)</th>
<th>Surgical Treatment, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Neck Remnant</td>
</tr>
<tr>
<td></td>
<td>Obliteration</td>
<td></td>
</tr>
<tr>
<td>All aneurysms</td>
<td>26 (50.0)</td>
<td>18 (34.6)</td>
</tr>
<tr>
<td>Final results§</td>
<td>40 (76.9)</td>
<td>10 (19.2)</td>
</tr>
</tbody>
</table>

\textsuperscript{§Final result is the last angiographic result available, including the patients with cross-over treatment and those who died. The results improved significantly in both surgical (P=0.016) and endovascular (P=0.001) groups.}

\textsuperscript{1Primary result is the result achieved with intended modality of treatment during the first hospitalization.}

### TABLE 6. MRI Findings in the Brain 1 Year After SAH

<table>
<thead>
<tr>
<th>MRI Finding</th>
<th>Embolization Group (n=40)</th>
<th>Surgical Group (n=47)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventricular/intracranial width ratio</td>
<td>0.24±0.07</td>
<td>0.24±0.08</td>
<td>0.936</td>
</tr>
<tr>
<td>Ischemic deficits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parental artery territory</td>
<td>8 (20%)</td>
<td>21 (45%)</td>
<td>0.018</td>
</tr>
<tr>
<td>Mean diameter, mm</td>
<td>43±40</td>
<td>36±31</td>
<td>0.624</td>
</tr>
<tr>
<td>Other vascular territory</td>
<td>9 (23%)</td>
<td>8 (17%)</td>
<td>0.521</td>
</tr>
<tr>
<td>Mean diameter, mm</td>
<td>30±29</td>
<td>52±30</td>
<td>0.152</td>
</tr>
<tr>
<td>Superficial brain retraction deficits</td>
<td>4 (10%)</td>
<td>21 (45%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deficit caused by preoperative ICH</td>
<td>10 (25%)</td>
<td>11 (23%)</td>
<td>0.862</td>
</tr>
<tr>
<td>Previous lesions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cortical infarctions</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
<td>0.460</td>
</tr>
<tr>
<td>Lacunar infarctions</td>
<td>1 (3%)</td>
<td>3 (6%)</td>
<td>0.621</td>
</tr>
<tr>
<td>Atrophy</td>
<td>1 (3%)</td>
<td>3 (6%)</td>
<td>0.621</td>
</tr>
<tr>
<td>Chronic white-matter lesions</td>
<td>7 (18%)</td>
<td>9 (19%)</td>
<td>0.843</td>
</tr>
</tbody>
</table>

\textsuperscript{Values are numbers of patients unless otherwise indicated. P value indicates the statistical difference in results between the treatment groups.}
the unpredictable nature of these aneurysmal remnants. Regrowth has been shown to occur after as long as 2 years.\textsuperscript{50} Although incompletely coiled aneurysms might behave differently from incompletely clipped aneurysms due to some elasticity of the coil mass,\textsuperscript{11} a high (7.9\%) rebleeding rate for aneurysms with an unstable occlusion has been reported during 3 years of follow-up.\textsuperscript{13}

The final occlusion rate of the aneurysms was clearly improved from the primary angiographic results after retreatment and crossover treatment (Table 5). The surgical treatment group reached an 86\% rate of complete occlusion and a 12\% rate of nearly complete occlusion. This is less than rates reported by others\textsuperscript{3,4,41,43} but may possibly be due to our extremely strict criteria for evaluating the rate of angiographic obliteration. In the patients treated only endovascularly and alive 12 months after treatment, the primary total occlusion rate of 59\% had improved to 77\% at the 12-month angiography (n=34). Reembolization was performed in 3 patients, and refilling (n=6) or spontaneous thrombosis (n=6) of the coiled aneurysm occurred in 12 cases (35\%), emphasizing the importance of long-term angiographic follow-up. When we compare our primary occlusion rate in small aneurysms with a small neck (total occlusion rate 61\%) it is slightly lower than that in the largest series reported (70.8\%).\textsuperscript{17,23} Endovascular treatment is rapidly evolving; remodeling technique,\textsuperscript{51} the new 3-dimensional and stretch-resistant coils, and increasing experience will hopefully improve the overall results.

Embolization of residual aneurysms had no morbidity or mortality, whereas additional surgical treatment resulted in death in 2 cases. The surgical difficulties after incomplete surgical treatment\textsuperscript{41} as well as in treatment of incompletely coiled aneurysms at a later stage\textsuperscript{18,23,52,53} are well known. Although safe re-coiling\textsuperscript{18,54} of an incompletely occluded aneurysm is not always possible, combined treatment can offer good results.\textsuperscript{18,52–55}

Neuropsychological Outcome

The use of a robust clinical outcome scale (GOS) in outcome evaluation of aneurysmal SAH does not reveal persistent neuropsychological deficits. Subtle impairments of cognition and memory have been detected in patients with good neurological outcome.\textsuperscript{56–59} although some studies have failed to detect these minor deficits.\textsuperscript{50,61}

We did not detect any significant difference in the neuropsychological test results between treatment groups. However, the patients in both groups generally improved their performance between the 3- and 12-month assessments, whereas the clinical outcome evaluation failed to show any improvement, which indicates the value of neuropsychological evaluation. The severity of SAH itself causes impairments in cognitive function, which explains why the treatment groups showed similar patterns of impairment, as suggested by others.\textsuperscript{56}

MRI of the Brain

MRI is a sensitive method for detecting and characterizing permanent deficits in brain tissue as a consequence of SAH or treatment. These findings do not necessarily correlate with neurobehavioral functioning,\textsuperscript{62} although correlation of cognitive impairment and localization of cerebral infarcts on CT after clipping of ruptured intracranial aneurysms has been shown.\textsuperscript{63}

Superficial brain retraction injury was commonly seen in surgical patients but showed no correlation with clinical outcome. Surgical patients also showed significantly more ischemic lesions in the parental artery territory of the ruptured aneurysm, but not at remote locations. The clinical symptoms of vasospasm were equally frequent in both treatment groups.\textsuperscript{23} These findings suggest that surgical manipulation of the arteries does cause local vasospasm that leads to ischemic deficits, but surgery itself combined with rinsing of the basal cisterns neither produces nor prevents general vasospasm, as previously suggested.\textsuperscript{23} Definitive diagnosis of vasospasm is difficult in unconscious patients. The 3 deaths in Hunt and Hess grades I–II patients in the surgical group (Table 2) were not related to vasospasm.

Both the presence of an ischemic lesion in the parental artery territory and shunt-dependent hydrocephalus proved to be independent predictors of poorer clinical outcome. These findings, more common in surgical patients,\textsuperscript{23} did not lead to significantly worse outcome than after endovascular treatment; however, the clinical outcome could have been affected in a larger series of patients.

Conclusions

Endovascular treatment of acutely ruptured intracranial aneurysms results in clinical and neuropsychological outcome equal to the outcome of acute surgical clipping of the ruptured aneurysm, thus providing a good alternative and sometimes complementary method of treatment. Endovascular treatment is significantly less-often associated with MRI-detectable brain injury, a factor that must be weighed against the slightly poorer total occlusion rate of the aneurysm and the need for repeated angiographic controls. Endovascular treatment is suitable for a selected group of patients, but its long-term efficacy in preventing rebleeding remains unknown.

Appendix

Detailed Description of the Neuropsychological Tests

General Intellectual Ability

On the basis of 3 verbal subtests of the Wechsler Adult Intelligence Scale-Revised\textsuperscript{26} (Similarities, Vocabulary, and Digit Span), the score for general verbal ability (verbal intelligence quotient) was estimated. The general nonverbal ability (performance intelligence quotient) was estimated on the basis of the Picture Completion test and the Block Design test from the Wechsler Adult Intelligence Scale-Revised.\textsuperscript{26} The full-scale intelligence quotient was calculated on the basis of these 5 subtests. The Modified Boston Naming test\textsuperscript{25} was used to examine naming ability. In this task the subject was asked to name 30 objects presented as line drawings. The score was the sum of correct responses. The Finnish version of the Verbal Fluency Test on letters\textsuperscript{26} was used to evaluate word fluency. Subjects were given 60 seconds to produce as many words as possible beginning with each of the letters P, A, and S, excluding proper names or different forms of the same word. The score was the total number of correct words produced for each letter.
Learning and Memory
Memory was tested by the Wechsler Memory Scale.27 The memory quotient was calculated to assess short-term memory level. Delayed recall from the Logical Memory Subtest27 and the Visual Reproduction Subtest27 was asked 45 minutes later. The scores were the number of recalled items for each subset. Nonverbal memory was also assessed by the Rey Complex Figure.25 The patient was asked to copy a complex geometric figure as well as possible, and 45 minutes later the patient was asked to reproduce as much of the figure as could be remembered. The score was the number of recalled details.

Attention and Flexibility of Mental Processing and Psychomotor Speed
The Stroop Test24 was used to evaluate sustained attention and resistance to interference. In Form A, the subject was asked to read aloud 50 color names printed in black and in Form B to name the color of 50 words printed in a color different from the word itself (interference condition). The scores were the time used to complete each task. The Trail-Making Test29 was also used to evaluate sustained attention, resistance to interference, and response inhibition. In Part A, the subject was asked to draw a line connecting consecutively numbered circles. In Part B, the subject had to draw a line alternating between numbers and alphabets (A–L). The scores were the times required to complete each task. The Finger-Tapping test was used to assess simple psychomotor speed. Tapping rate was determined over 10 seconds in 2 trials for each hand. The scores are the means of both hands.

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References


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