Aneurysms located along the ACoA are the most frequently treated ones at the circle of Willis, representing up to 39%,33,69 The surgical approach to treating these aneurysms located in the interhemispherical fissure may be difficult because of arterial relationships, fundus projection, and barriers presented by the diencephalon. Satisfactory clip occlusion of ACoA aneurysms while attempting to preserve the perforating arteries and maintain the patency of the ACoA and pericallosal arteries can be problematic. In addition, the frequent association of this aneurysm with complex ACoA anomalies, which are encoun-

Treatment of anterior communicating artery aneurysms: complementary aspects of microsurgical and endovascular procedures

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Object. Endovascular and surgical treatment must be clearly defined in the management of anterior communicating artery (ACoA) aneurysms. In this study the authors report their recent experience in using a combined surgical and endovascular team approach for ACoA aneurysms, and compare these results with those obtained during an earlier period in which surgical treatment was used alone. Morbidity and mortality rates, causes of unfavorable outcomes, and morphological results were also assessed.

Methods. The prospective study included 223 patients who were divided into three groups: Group A (83 microsurgically treated patients, 1990–1995); Group B (103 microsurgically treated patients, 1996–2000); and Group C (37 patients treated with Guglielmi Detachable Coil [GDC] embolization, 1996–2000). Depending on the direction in which the aneurysm fundus projected, the authors attempted to apply microsurgical treatment to Type 1 aneurysms (located in front of the axis formed by the pericallosal arteries). They proposed the most adapted procedure for Type 2 aneurysms (located behind the axis of the pericallosal arteries) after discussion with the neurovascular team, depending on the physiological status of the patient, the treatment risk, and the size of the aneurysm neck. In accordance with the classification of Hunt and Hess, the authors designated those patients with unruptured aneurysms (Grade 0) and some patients with ruptured aneurysms (Grades I–III) as having good preoperative grades. Patients with Grade IV or V hemorrhages were designated as having poor preoperative grades. By performing routine angiography and computerized tomography scanning, the causes of unfavorable outcome (Glasgow Outcome Scale [GOS] score < 5) and the morphological results (complete or incomplete occlusion) were analyzed.

Overall, the clinical outcome was excellent (GOS Score 5) in 65% of patients, good (GOS Score 4) in 9.4%, fair (GOS Score 3) in 11.6%, poor (GOS Score 2) in 3.6%, and fatal in 10.3% (GOS Score 1). Among 166 patients in good preoperative grades, an excellent outcome was observed in 134 patients (80.7%). The combined permanent morbidity and mortality rate accounted for up to 19.3% of patients. The rates of permanent morbidity and death that were related to the initial subarachnoid hemorrhage were 6.2 and 1.5% for Group A, 6.6 and 1.3% for Group B, and 4 and 4% for Group C, respectively. The rates of permanent morbidity and death that were related to the procedure were 15.4 and 1.5% for Group A, 3.9 and 0% for Group B, and 8 and 8% for Group C, respectively. When microsurgical periods were compared, the rate of permanent morbidity or death related to microsurgical complications decreased significantly (Group A, 11 patients [16.9%] and Group B, three patients [3.9%]; Fisher exact test, p = 0.011) from the period of 1990 to 1995 to the period of 1996 to 2000. The combined rate of morbidity and mortality that was related to the endovascular procedure (16%) explained the nonsignificance of the different rates of procedural complications for the two periods, despite the significant decrease in the number of microsurgical complications. Among 57 patients in poor preoperative grade, an excellent outcome was observed in 11 patients (19.3%); however, permanent morbidity (GOS Scores 2–4) or death (GOS Score 1) occurred in 46 patients (80.7%). With regard to the correlation between vessel occlusion (the primary microsurgical complication) and the morphological characteristics of aneurysms, only the direction in which the fundus projected appeared significant as a risk factor for the microsurgically treated groups (Fisher exact test: Group A, p = 0.03; Group B, p = 0.002). The difference between endovascular and microsurgical procedures in the achievement of complete occlusion was considered significant (χ² = 6.13, p = 0.01).

Conclusions. The direction in which the fundus projects was chosen as the morphological criterion between endovascular and surgical methods. The authors propose that microsurgical clip application should be the preferred option in the treatment of ACoA aneurysms with anteriorly directed fundi and that endovascular packing be selected for those lesions with posteriorly directed fundi, depending on morphological criteria.

KEY WORDS • cerebral aneurysm • anterior communicating artery • subarachnoid hemorrhage • microsurgery • endovascular treatment
tered in 35% of these cases, often complicates the perioperative analysis. Advances in surgical techniques and the choice between interhemispherical and pterional approaches have greatly improved surgical results.

Since the advent of CT scanning, the combined morbidity and mortality rate of ruptured ACoA aneurysms has been estimated to range between 10 and 40%. Moreover, the use of GDCs has led to several reports on the capacity of endovascular embolization to prevent aneurysm rebleeding during the acute stage of SAH and its usefulness and integration in the therapeutic armamentarium against cerebral aneurysms. The endovascular method appears to be an effective and safe alternative treatment for patients with aneurysms located along the posterior portion of the circle of Willis. Unlike vertebrobasilar aneurysms, for which the microsurgical approach has been successful only in the hands of a limited number of skilled neurosurgeons, microsurgical clip occlusion of aneurysms located along the anterior portion of circle of Willis has resulted in total exclusion of the lesions from the circulation in a higher proportion than endovascular coil placement, with a reasonable risk of postoperative morbidity and mortality. Nevertheless, the current question regarding aneurysms located on the anterior portion of the circle of Willis, has been how to choose between endovascular treatment and the microsurgical approach to offer the patient optimal treatment. To address this question, not only must a careful assessment be made of the morbidity associated with each therapeutic method, but an evaluation must also be made of the quality of sac obliteration. Since 1996, endovascular treatment performed using GDCs has become a routine alternative to microsurgical clip application in the treatment of ACoA aneurysms in our department.

The aim of this prospective longitudinal study was to provide a review of our recent experience in using a combined microsurgical and endovascular team approach in the treatment of ACoA aneurysms (1996–2000). In addition, we also analyzed the treatment results that we obtained during an earlier period (1990–1995) in which microsurgical treatment was used exclusively. We analyzed the causes of morbidity and mortality, the morphological results concerning patency of parent arteries, and the quality of sac obliteration that are associated with each treatment method.

Clinical Material and Methods

Patient Population and Case Management Strategies

This longitudinal prospective study included all 223 patients treated for ACoA aneurysms in the Neurosurgery Department at the University Hospital of Rouen between January 1990 and December 2000. We divided the population into three groups according to the therapeutic method applied to the aneurysm sac. Group A consisted of patients microsurgically treated between 1990 and 1995. Between 1996 and 2000, all patients who were treated were subdivided into Group B, which included all those who were microsurgically treated, and Group C, which included all those who were endovascularly treated. For patients in whom the diagnosis was based on the presence of an SAH (214 patients), the clinical status of each patient at admission was graded according to the Hunt and Hess classification. A CT scan was used to assess the extent and distribution of SAH according to the Fisher scale. Sac treatment was performed as soon as possible after hospitalization. The surgical procedure consisted of a pterional approach ipsilateral to the anterior cerebral artery that irrigated the aneurysm, except in one case of a giant aneurysm that was excluded using the interhemispherical approach. A standard transfemoral transarterial technique was used for GDC embolization. All patients were given routine medical treatment for SAH including the following: absolute bed rest in a darkened room; admission to the intensive care unit if the patient had a Hunt and Hess Grade IV or V; a regimen of SAH anticonvulsant medication; administration of a calcium antagonist (miodipine) as soon as a diagnosis of SAH had been established;

Fig. 1. Left: Three-quarter view angiogram revealing a Type 1 aneurysm in which the fundus projects in front of the axis defined by the pericallosal arteries. Right: Lateral angiogram demonstrating a Type 2 aneurysm in which the fundus projects behind the axis. Lines indicate axes formed by the pericallosal arteries.
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a regimen of antacid agents such as cimetidine (300 mg/day); administration of a minor analgesic for headache; maintaining a fluid and electrolyte balance, which consisted of 1500 to 2000 ml/day during the preoperative period and postoperative induction of hypervolemia by addition of 4% albumin (1000 ml/day) under central venous pressure monitoring; and insertion of an external drainage system for symptomatic ventricular dilation after intraventricular hemorrhage.

Morphological Characteristics of Aneurysms

For each aneurysm, the direction in which the fundus projected and the diameters of the sac and neck were analyzed. The direction of fundus projection around the ACoA was classified after a discussion among the members of the neurovascular team, which was composed of neurosurgeons (P.F., F.P., and O.L.) and endovascular therapists (E.C. and E.G.). We relied on lateral or three-quarter angiographic views to base our evaluation and categorized the aneurysm sac into two types: Type 1, if the aneurysm fundus projected in front of the axis formed by the pericallosal arteries; and Type 2, if the fundus projected behind this axis (Fig. 1). In cases in which the aneurysm sac lay in an intermediate position, the predominant direction was selected. The largest diameter of the aneurysm sac measured on angiograms was classified into three categories: less than 10 mm; 10 to 25 mm; and giant, more than 25 mm. The size of the aneurysm neck was determined on the angiographic projection that best displayed the neck region in relation to the parent artery. The neck size was defined according to the classification proposed by Fernandez Zubillaga, et al., and divided into narrow-necked (≤ 4 mm) and wide-necked (> 4 mm) aneurysms.

Indications for Endovascular and Microsurgical Treatment (1996–2000)

Since 1996, the neurovascular team has discussed the optimal method of sac treatment on a patient-to-patient basis. Initially, factors usually leading to GDC embolization included the advanced age of the patient, poor clinical status at admission, and comorbid medical conditions, suggesting a high risk of surgical complication. Later in our experience and at the present time, the main factor arguing in favor of GDC embolization has been the direction of the sac fundus with respect to the pericallosal arteries. For Type 1 ACoA aneurysms we currently propose microsurgical clip placement and for Type 2 suggest an endovascular approach. The final decision for endovascular treatment is made by the endovascular therapists, in particular, when the ratio between the fundus and neck is sufficient to obtain correct coil packing. Microsurgical treatment has been used to treat 186 aneurysms by direct clip placement (Group A, 83 patients; and Group B, 103 patients). Endovascular treatment has been used to treat 37 aneurysms by packing them with coils (Group C). A supplementary procedure was performed for aneurysm remnants in three patients.

Instances of Morbidity and Mortality

Regarding outcome, all patients were evaluated 6 to 12 months postoperatively according to the GOS. We categorized a patient as having a favorable outcome if the GOS score was 5 and an unfavorable outcome if the patient had a lower score—permanent morbidity (GOS Score 2–4) or death (GOS Score 1). By routinely performing CT scanning and angiography on the 10th postoperative day, we analyzed complications classified as temporary or permanent morbidity, or mortality. The complications were related to either the initial bleeding or to a procedural or medical complication. When several causes could be implicated, we chose the complication that had a major effect on outcome.

Complications of Initial SAH. The initial SAH was considered to be responsible for outcome when the area of hypodensity on the routine CT scan that had been caused by intraparenchymal hemorrhage was identical to the area of the initial hematoma. It was also considered responsible if hydrocephalus was demonstrated on a CT scan as ventricular dilation requiring an internal shunt, when all other causes were ruled out.

Cerebral vasospasm was defined as an arterial narrowing (in a comparison between preoperative and postoperative cerebral angiograms). As a cause of morbidity and mortality, vasospasm required the presence of an infarct on the CT scan, after exclusion of hydroelectrolytic disorders, parent arterial thrombosis, and hydrocephalus.

Procedural Complications. After surgical treatment, several types of complications occurred. Parent artery occlusion of the pericallosal artery or the ACoA was confirmed on postoperative angiograms. Trapping of the ACoA was, unfortunately, a deliberate surgical exclusion of the ACoA by two clips. Occlusion of the perforating artery was diagnosed on a routine CT scan by the appearance of a hypodensity. It was usually located on the genius of the corpus callosum or on the head of the caudate nucleus.

The occurrence of rebleeding, which was suspected if there was severe neurological deterioration, was confirmed on the CT scan by the presence of a new hemorrhage close to the aneurysm sac. After endovascular treatment, we observed an embolic stroke or a hemorrhagic event, produced by an embolus, which complicated the thrombolysis procedure.

All data from each patient were prospectively collected and stored on a personal microcomputer.

Anatomical Results: Residual Aneurysm

The morphological status of the aneurysm, which was evaluated on the basis of a routine control angiogram obtained in each patient, was graded as complete occlusion of the lesion or incomplete. The category complete occlusion was given to aneurysms in which no residual neck was seen on any angiogram. Incomplete occlusion, defined as the presence of a residual aneurysm, was indicated by contrast agent filling a part of the aneurysm neck or fundus.

Statistical Analysis

Data analyses were performed using a statistical software program (Statview; SAS Institute, Cary, NC). Data are expressed as mean values ± standard deviations. Statistical analysis was performed on a personal computer by using paired t-tests, pair-wise comparisons of means, and chi-square tests. A probability value less than 0.05 was considered significant.
The characteristics of the patient population (mean age 49.1 ± 13.4 years and a male/female ratio of 1.4) are detailed in Table 1. In patients who underwent microsurgery (Groups A and B), the clinical status at admission, the type of SAH on the CT scan, the morphological characteristics of the aneurysm (the direction in which the fundus projected, and neck size) and the surgical timing were similar (no significant difference). Patients who underwent endovascularly treated procedures (Group C) had several features that differed from those observed in the microsurgically treated groups: an older mean age; a nonsignificant higher proportion of patients in poor preoperative grades (Fisher exact test, p = 0.3); and a significantly higher proportion of lesions in the Type 2 location (Fisher exact test, p = 0.0001). For the 1996 to 2000 period, among the 81 patients with Type 2 ACoA aneurysms, only 33 were treated endovascularly. The 48 remaining patients were surgically treated because of characteristics observed by the endovascular therapists, specifically: a ratio between the neck and fundus that was too small (52.5% of patients); a supposedly difficult endovascular approach (22.8%); a clinical setback (18.1%); intracranial hypertension (14%); and severe vasospasm (2% of patients). Among the three groups (Groups A, B, and C), no significant difference in outcome distribution was observed ($\chi^2 = 4.53$, two degrees of freedom).

**Clinical Outcome, and Causes of Morbidity and Death**

In the entire population (223 patients) reported in Table 2, 145 patients (65%) attained GOS Score 5 and 78 (35%) had unfavorable outcomes. The rate of patients with favorable outcomes was not significantly different (Fisher exact test, p = 0.158) between the first (1990–1995; 51 patients [61.4%]) and second (1996–2000; 94 patients [67.1%]) periods.

Among patients in good preoperative grades (all groups, 166 patients), a favorable outcome (GOS Score 5) was observed in 134 patients (80.7%) and a permanent morbidity (GOS Score 2–4), or death (GOS Score 1) in 32 patients (19.3%). The rate of patients with unfavorable outcomes was not significantly different (Fisher exact test, p = 0.22) between the first (1990–1995; 16 patients [24.6%]) and second (1996–2000; 16 patients [15.8%]) periods. The rate of causes was distributed as follows without a significant difference between the two periods: initial SAH (Fisher exact test, p = 1; 1990–1995, five patients [7.7%]; 1996–2000, eight patients [7.9%]); procedural complication (Fisher exact test, p = 0.07; 1990–1995, 11 patients [16.9%]; 1996–2000, seven patients [6.9%]); and medical complication (1996–2000, one patient [0.9%]). To analyze the causes of morbidity and death accurately, the microsurgically treated groups were separated from the endovascularly treated group. As detailed in Table 2, direct microsurgical treatment (Groups A and B, 141 patients) resulted in 22 instances of permanent morbidity (15.6%) and four deaths (2.8%). The initial SAH induced complications in 19 patients in Group A and 19 patients in Group B, which eventually led to respective rates of 6.2 and 6.6% permanent morbidity and 1.5 and 1.4% mortality (vasospasm-related ischemia in two patients). Procedures performed in these microsurgically treated groups induced complications in 21 patients in Group A and 15 patients in Group B, which eventually led to respective rates of 15.4 and 3.9% permanent morbidity and 1.5% (rebleeding in one patient) and 0% mortality. The rate of permanent morbidity or death that was associated with complications of microsurgical procedures (Group A, 11 patients [16.9%]; Group B, three patients [3.9%]) decreased significantly (Fisher exact test, p = 0.011) from the period of 1990 to 1995 to the period of 1996 to 2000.

Endovascular treatment of 25 patients with good preoperative grades resulted in three cases of permanent morbidity.
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TABLE 2
Incidence of complications in each group of patients treated for ACoA aneurysms*

<table>
<thead>
<tr>
<th>Cause of Complication</th>
<th>Preop H &amp; H Grades 0–III (166 patients)</th>
<th>Preop H &amp; H Grades IV &amp; V (57 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A (65 patients)</td>
<td>Group B (76 patients)</td>
</tr>
<tr>
<td>related to initial SAH</td>
<td></td>
<td></td>
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<tr>
<td>initial bleeding</td>
<td>4 (6.2)</td>
<td>5 (6.6)</td>
</tr>
<tr>
<td>vasospasm</td>
<td>1 (8)</td>
<td>5 (8)</td>
</tr>
<tr>
<td>(temporarily resolving to GOS Score 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>permanent morbidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(GOS Scores 2–4)</td>
<td>4 (6.2)</td>
<td>5 (6.6)</td>
</tr>
<tr>
<td>death (GOS Score 1)</td>
<td>1 (1.5)</td>
<td>1 (1.3)</td>
</tr>
<tr>
<td>surgical complication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>parent artery occlusion</td>
<td>6 (3)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>perforating artery occlusion</td>
<td>3</td>
<td>2 (1)</td>
</tr>
<tr>
<td>surgery-induced hematoma</td>
<td>1 (1)</td>
<td>2 (1)</td>
</tr>
<tr>
<td>infectious process</td>
<td>1 (6)</td>
<td>8 (8)</td>
</tr>
<tr>
<td>postprocedural rebleeding</td>
<td>2 (2)</td>
<td>0</td>
</tr>
<tr>
<td>temporary morbidity</td>
<td>10 (15.4)</td>
<td>3 (5.9)</td>
</tr>
<tr>
<td>(temporarily resolving to GOS Score 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>permanent morbidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(GOS Scores 2–4)</td>
<td>10 (15.4)</td>
<td>3 (5.9)</td>
</tr>
<tr>
<td>death (GOS Score 1)</td>
<td>1 (1.5)</td>
<td>0</td>
</tr>
<tr>
<td>endovascular complication</td>
<td></td>
<td></td>
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<tr>
<td>embolization stroke</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>hematoma</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>postprocedural rebleeding</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>temporary morbidity</td>
<td>—</td>
<td>—</td>
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<tr>
<td>(temporarily resolving to GOS Score 5)</td>
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<td></td>
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<tr>
<td>permanent morbidity</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>death (GOS Score 1)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>systemic complication</td>
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<tr>
<td>rt ventricular insufficiency</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>myocardial infarctions</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>patients w/ GOS score &lt;5</td>
<td>0 (0)</td>
<td>1 (1.3)</td>
</tr>
<tr>
<td>total patients w/ complications</td>
<td>16 (24.6)</td>
<td>10 (13.2)</td>
</tr>
</tbody>
</table>

* Values represent numbers of patients, with percentages given in parentheses. Numerals listed within brackets indicate patients with a temporary morbidity who eventually attained an excellent outcome (GOS Score 5). — = not applicable.

ity (12%) and three cases of death (12%). The initial SAH was the cause of a 4% permanent morbidity rate and a 4% mortality rate (vasospasm-related ischemia in one patient). Procedural complications occurred in five patients, eventually resulting in an 8% permanent morbidity rate and an 8% mortality rate (intraparenchymal hematoma due to thrombolysis in one patient and embolization stroke in another patient). In this subgroup of patients in a good preoperative status, the combined morbidity and mortality rate (16%) associated with the endovascular procedure explained the nonsignificant difference in the rate of procedural complications for the two periods, despite the significant decrease in microsurgical complications.

Among patients in poor preoperative grades (of all groups, 57 patients), an excellent outcome (GOS Score 5) was observed in 11 patients (19.3%) and either permanent morbidity (GOS Score 2–4) or death (GOS Score 1) in 46 patients (80.7%). The rate of patients with unfavorable outcomes decreased significantly (Fisher exact test, p = 0.06) from the first period (1990–1995; 16 patients [88.9%]) to the second one (1996–2000; 30 patients [76.9%]). The rates of causes were distributed as follows: initial SAH (Fisher exact test, p = 0.23; 1990–1995, nine patients [50%]; 1996–2000, 26 patients [66.6%]); procedural complication (Fisher exact test, p = 0.002; 1990–1995, seven patients [38.9%]; 1996–2000, two patients [5.2%]; and medical complication (1996–2000, two patients [5.1%]). In this subgroup of patients with a good preoperative status, the significant decrease in the number of procedural complications from the period of 1990 to 1995 to that of 1996 to 2000 provided an explanation for the significant difference in unfavorable outcomes. As detailed in Table 2, direct microsurgical treatment (Groups A and B, 45 patients) resulted in 22 cases of permanent morbidity (48.9%) and 13 deaths (28.9%). The initial SAH was responsible for complications in nine patients in Group A and 17 in Group B, which eventually resulted in respective rates of 27.8 and 44.4% permanent morbidity and 22.2 and 18.5% mortality. Procedures in these microsurgically treated groups induced complications in eight patients in Group A and in eight in Group B, providing respective rates of 22.2 and 3.7% permanent morbidity and 16.7% (parent artery occlusion in three patients) and 0% mortality. In addition, one death occurred in a patient in Group B after myocardial infarction. The rate of permanent morbidity or death related to microsurgical complications (Group A, seven patients [38.9%]; Group B, one patient [3.7%]) decreased significantly (Fisher exact test, p = 0.004) from the period of 1990 to 1995 to that of 1996 to 2000. Endovascular treatment of 12 patients resulted in eight cases of permanent morbidity (66.7%) and three

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TABLE 3

Status of the parent artery and morphological characteristics of the aneurysm in 223 patients
who were treated for ACoA aneurysms*

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Occluded Vessel, Group A</td>
<td>Occluded Vessel, Group B</td>
</tr>
<tr>
<td>no. of patients†</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>direction of fundus projection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 1</td>
<td>5 (11.1)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Type 2</td>
<td>12 (31.6)</td>
<td>8 (16.7)</td>
</tr>
<tr>
<td>aneurysm size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 mm</td>
<td>11 (17.7)</td>
<td>6 (7.6)</td>
</tr>
<tr>
<td>10–25 mm</td>
<td>4 (26.7)</td>
<td>2 (11.8)</td>
</tr>
<tr>
<td>giant (&gt;25 mm)</td>
<td>2 (33.3)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>neck size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤4 mm</td>
<td>12 (18.5)</td>
<td>4 (4.9)</td>
</tr>
<tr>
<td>&gt;4 mm</td>
<td>5 (7.8)</td>
<td>4 (18.2)</td>
</tr>
</tbody>
</table>

* Values represent numbers of patients, with percentages given in parentheses.
† Between 1990 and 1995, occluded arteries were found in 20.5% of patients in Group A and permeable arteries in 79.5% of patients in that group. Between 1996 and 2000, occluded arteries were found in 9.3% of patients in Groups B and C and permeable arteries in 90.7% of patients in those groups.

Vessel Occlusion

In each group, the main procedural complication was vessel occlusion of parent or perforating arteries after microsurgery or embolization-induced stroke. As reported in Table 3, the rate of postprocedural vessel occlusion decreased significantly (Fisher exact test, p = 0.02) from the first period (1990–1995; 17 patients [20.5%]) to the second one (1996–2000; 13 patients [9.3%]). After direct microsurgical clip application, 25 patients (13.4%) presented with vessel occlusion. The proportion of vessel occlusions decreased significantly from 20.5% in Group A to 7.8% in Group B (Fisher exact test, p = 0.016). In these microsurgically treated groups, permanent morbidity or death occurred in 18 patients (9.7%), 14 from Group A and from Group B. After endovascular treatment, vessel occlusion occurred in five patients (13.5%) and permanent morbidity or death occurred in all of these. With regard to the 1996 to 2000 period, there was no significant difference in the proportion of unfavorable outcomes as a result of vessel occlusion between patients treated microsurgically (eight patients [7.8%]) and those treated endovascularly (five patients [13.5%]) (Fisher exact test, p = 1).

Regarding the correlation between vessel occlusion and morphological characteristics of aneurysms (Table 3), only the direction in which the fundus projected appeared to be a significant risk factor. In patients treated microsurgically, a significantly higher proportion of vessel occlusion was found among Type 2 aneurysms (Fisher exact test; Group A, p = 0.03 and Group B, p = 0.002). In a comparison of complications related to the microsurgical procedure between the two periods, taking into account the projection of the aneurysms, we only analyzed vessel occlusions and postprocedural rebleeding. For anteriorly projecting aneurysms (Type 1), the proportion of parent vessel occlusion after microsurgical treatment decreased from 11.1% for the 1990 to 1995 period to 0% for the 1996 to 2000 period. For posteriorly projecting aneurysms (Type 2), the proportion of parent vessel occlusion after microsurgical treatment decreased from 31.6% for the 1990 to 1995 period to 16.7% for the 1996 to 2000 period. Postprocedural rebleeding only occurred in cases of posteriorly projecting aneurysms (two cases) during the 1990 to 1995 period.

In Group C, vessel occlusion always occurred in Type 2 aneurysms, but the rate was not significant because of the recruitment criteria. The other morphological criteria were not significantly related to the occurrence of vessel occlusion. Certainly, despite the fact that the rate of vessel occlusion increased with the size of the aneurysm or neck in microsurgically treated patients, no significant difference was demonstrated (Fisher exact test; Group A, aneurysm size [p = 0.35] and neck size [p = 0.5]; Group B, aneurysm size [p = 0.61] and neck size [p = 0.06]).

Residual Aneurysm

The rate of residual aneurysms due to incomplete occlusion was similar for both time periods (Fisher exact test, p = 0.51; 1990–1995, seven patients [8.4%]; 1996–2000, 16 patients [11.4%]). Of the aneurysms to which a clip was surgically applied (Groups A and B), 171 (91.9%) demonstrated complete occlusion, whereas 15 (8.1%) exhibited incomplete occlusion (Table 4). Incomplete occlusion was voluntary and was chosen during microsurgical clip placement in five patients because the aneurysm sac was included in the dilation of the ACoA. The proportion of incomplete aneurysm occlusions was similar in both microsurgically treated groups (Group A, seven patients [8.4%];...
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In this paper we report our experience in the treatment of ACoA aneurysms in 223 patients subdivided into two treatment periods: 1990 to 1995 (Group A, 83 microsurgically treated patients) and 1996 to 2000 (Group B, 103 microsurgically treated patients, and Group C, 37 endovascularly treated patients). In the overall population, 65% of patients attained GOS Score 5. The outcome distribution was not significantly different between the two time periods or among the three groups. Among patients with a good preoperative status, 80.7% attained excellent outcomes (GOS Score 5). Despite the absence of a significant difference in unfavorable outcomes between the two time periods, the combined rate of permanent morbidity and mortality associated with the microsurgical procedure decreased significantly from 16.9% in Group A to 3.9% in Group B. This can be explained by the 16% combined rate of morbidity and mortality that is associated with the endovascular procedure. Among patients with poor grades, we observed a significant decrease in microsurgical complications. With regard to vessel occlusion, the incidence decreased significantly from the 1990 to 1995 period to the 1996 to 2000 period. The only morphological characteristic of aneurysms that we found to be significantly correlated was a posterior projection of the fundus (Type 2). The incidence of complete occlusion of the aneurysm was similar during both periods, but decreased significantly following endovascular procedures when compared with microsurgical treatment. Incomplete occlusion of the aneurysm was related to the direction in which the fundus projected in both microsurgically treated groups and to both aneurysm and neck size in Group B (patients treated microsurgically, 1996–2000).

**Surgical Risk and Fundus Projection**

A review of the literature published after the introduction of CT scanning was conducted with specific attention paid to articles on ACoA aneurysms. Taking these series into consideration, without accounting for patients’ preoperative status and despite the diversity of the criteria, the range of good results (GOS Scores 4 and 5) varied between 74 and 87.5%; excellent results rarely reached as high as 56.4% and the mortality rate lay between 3.5 and 6.8%. In our series, the proportion of excellent results was 65% in the overall population; however, the mortality rate was increased by 10.4%. This high rate, in comparison with that reported in the literature, can be explained by the fact that 25.6% of the patients treated in our series were in poor preoperative grades, which is a markedly higher rate than the 4.8 to 5.6% of patients that is usually reported. When outcome is analyzed according to the preoperative clinical

### Table 4

**Anatomical results and morphological characteristics of aneurysms in 223 patients who were treated for ACoA aneurysms**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>Incomplete Occl, Group A</td>
<td>Complete Occl, Group A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of patients†‡</td>
<td>7</td>
<td>76</td>
</tr>
<tr>
<td>direction of fundus projection</td>
<td>Type 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type 2</td>
<td></td>
</tr>
<tr>
<td>aneurysm size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 mm</td>
<td>4 (6.5)</td>
<td>58 (93.5)</td>
</tr>
<tr>
<td>10–25 mm</td>
<td>2 (13.3)</td>
<td>13 (86.7)</td>
</tr>
<tr>
<td>(giant &gt;25 mm)</td>
<td>1 (16.7)</td>
<td>5 (83.3)</td>
</tr>
<tr>
<td>neck size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤4 mm</td>
<td>3 (4.6)</td>
<td>62 (95.4)</td>
</tr>
<tr>
<td>&gt;4 mm</td>
<td>4 (22.2)</td>
<td>14 (77.8)</td>
</tr>
</tbody>
</table>

* Values represent numbers of patients, with percentages given in parentheses. Abbreviation: Occl = occlusion.
† Between 1990 and 1995, incomplete occlusions were documented in 8.4% of patients in Group A and complete occlusions in 91.6% of patients in that group. Between 1996 and 2000, incomplete occlusions were documented in 11.4% of patients in Groups B and C and complete occlusions in 88.6% of patients in those groups.
status, the combined rate of morbidity and mortality in patients in good preoperative clinical status ranged between 8.1 and 37.2%. In our series, the combined morbidity and mortality rate was 19.3% in patients with a good preoperative status and this increased to 80.7% in patients in a poor preoperative status. In other words, excellent results (GOS Score 5) were attained by 80.7% of patients who had a good preoperative status, but only by 19.3% of those who had a poor preoperative status. These rates are probably representative because we focused on the consecutive recruitment of patients who were treated for ACoA aneurysms within a decade at a single center. These combined morbidity and mortality rates could be monitored during discussions of ACoA aneurysm management with the patient’s family.

A review of surgical series of patients with ACoA aneurysms, revealed that the main cause of unfavorable outcome appears to be the initial SAH with its deleterious consequences, specifically, direct brain damage, hydrocephalus, or vasospasm-related ischemia. In our series, SAH was related to unfavorable outcomes in both microsurgically treated groups (1990–1995 and 1996–2000); it was responsible for approximately an 8% combined rate of morbidity and mortality among patients with a good preoperative status and approximately a 55% rate among those with a poor preoperative status. A review of the literature yielded few articles specifying procedural complications. In their series of 150 patients, Gilsbach, et al. reported unfavorable early outcomes in 33 patients, which were caused by the surgical approach in 10%. In our series, the combined rate of morbidity and mortality that was procedure-related (here microsurgery-related) varied according to the time period: higher (17.9%) for the 1990 to 1995 period and significantly lower for the 1996 to 2000 period in patients who had a good preoperative status. In patients with a poor preoperative status we also observed a significant decrease in microsurgical complications recorded between 1996 and 2000 when compared with those recorded between 1990 and 1995. The reasons for this were multiple. First, the preoperative angiographic analysis was of optimal quality because we used a new angiographic device. Second, the Sylvian fissure was opened medially when the ACoA complex was difficult to expose. Third, the choice of flap side did not only depend on visualization of the aneurysm sac by the afferent anterior cerebral artery, but also on the direction of sac projection, permitting an accurate clip application. Fourth, a temporary clip was more easily used on the afferent anterior cerebral artery, but also on the pericallosal arteries, which surround the lesion like a basket, or posteriorly, posteriorly projecting aneurysms. In these latter projections, the dissection of arteries comprising the ACoA complex, recurrent arteries of Heubner, frontopolar and frontoorbital arteries, and hypothalamic arteries from the neck of the aneurysm were all considered a source of complication. Conversely, for aneurysms with anterior projection, these arteries were avoided. Nathal, et al. in their study of 134 patients with ACoA aneurysms, stressed that clip occlusion of aneurysms with an anterior projection rarely occurred when there were perforating vessels arising from the ACoA. During the dissection and clip occlusion of an aneurysm neck with a superior or posterior projection, however, great care must be taken to spare these perforating vessels. VanderArk and Kempe, in a series of 100 patients, performed an early incision into the ipsilateral gyrus rectus to treat aneurysms with a posterior projection to avoid an early rupture of the fundus before adequate neck dissection. Solomon also recommended this incision in his didactic paper regarding ACoA aneurysms. In that instance, an ACoA aneurysm with a posterior projection, which was treated by the microsurgical approach, was exposed to a high risk of injury to the perforating arteries, parent vessel, or ACoA. Several hypotheses could explain this phenomenon. First there is the necessity of retracting the cerebral parenchyma, which masks the aneurysm sac and the beginning of the pericallosal arteries; second, the closed relationship between the aneurysm sac and either the pericallosal arteries, which surround the lesion like a basket, or the perforating arteries may make sac exposure difficult. Moreover, the difficulty in clip application increases with aneurysm size. Third, the pericallosal arteries adhere to the lateral face of Type 2 aneurysm sacs, which made clip application difficult.

Endovascular Risk

A single study specifically concerned with the endovascular treatment of ACoA aneurysms was reported by Morret, et al. Their results in 36 treated patients, 10 of whom were admitted on an emergency basis, demonstrated the efficacy of this technique. These authors reported technical complication rates of 8.3% for clotting and 2.7% for rupture, which were responsible for morbidity in 2.7% of patients. They obtained complete aneurysm occlusion in

The main surgical complication responsible for unfavorable outcome due to cerebral infarction or disabling stroke was vessel occlusion, which ranged between 1 and 13% of patients. In our series, 13.4% of surgically treated patients presented with vessel occlusion. This prevalence was significantly higher for patients harboring Type 2 aneurysms. The relationship between fundus projection and procedural complication has already been highlighted. Authors of some anatomical studies have reported the preferential location of perforating arteries on the ACoA. Vincentelli, et al. in their study of 60 fixed human brains, indicated that all perforating branches followed a posterior direction and formed an angle with the pericallosal arteries that ranged between 30 and 180°. Perlmutter and Rhoton showed that 90% of perforating arteries arising from the ACoA were branched on the superior and posterior faces. Yasargil also considered this to be a predominant anatomical factor. These authors observed a decrease in positive outcomes and an increase in the mortality rate among patients with superiorly, posteriorly, and inferiorly projecting aneurysms. In these latter projections, the dissection of arteries comprising the ACoA complex, recurrent arteries of Heubner, frontopolar and frontoorbital arteries, and hypothalamic arteries from the neck of the aneurysm were all considered a source of complication. Conversely, for aneurysms with anterior projection, these arteries were avoided. Nathal, et al. in their study of 134 patients with ACoA aneurysms, stressed that clip occlusion of aneurysms with an anterior projection rarely occurred when there were perforating vessels arising from the ACoA. During the dissection and clip occlusion of an aneurysm neck with a superior or posterior projection, however, great care must be taken to spare these perforating vessels. VanderArk and Kempe, in a series of 100 patients, performed an early incision into the ipsilateral gyrus rectus to treat aneurysms with a posterior projection to avoid an early rupture of the fundus before adequate neck dissection. Solomon also recommended this incision in his didactic paper regarding ACoA aneurysms. In that instance, an ACoA aneurysm with a posterior projection, which was treated by the microsurgical approach, was exposed to a high risk of injury to the perforating arteries, parent vessel, or ACoA. Several hypotheses could explain this phenomenon. First there is the necessity of retracting the cerebral parenchyma, which masks the aneurysm sac and the beginning of the pericallosal arteries; second, the close relationship between the aneurysm sac and either the pericallosal arteries, which surround the lesion like a basket, or the perforating arteries may make sac exposure difficult. Moreover, the difficulty in clip application increases with aneurysm size. Third, the pericallosal arteries adhere to the lateral face of Type 2 aneurysm sacs, which made clip application difficult.

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63% of patients. The largest series reporting results of endovascular treatment either on aneurysms located on the posterior circulation alone or on those in both anterior and posterior circulations, 5,9,14,22,37,38,61. In these series, the proportion of technical complications, either clotting or rupture, was assessed to range between 9 and 27%. The rate of procedure-related poor outcomes was estimated to be 3.7% and the incidence of treatment-related deaths to be 1%,4,5.8. The single isolated risk factor was small size of the aneurysm (< 5 mm).

In our series, in patients with a good preoperative grade who underwent endovascular treatment, a procedure-related morbidity rate of 8% and a mortality rate of 8% were observed. In patients with a poor preoperative grade, we found an 8.3% morbidity rate. This result, which was higher than those reported in the literature, may be due to several factors. First, our series is the first in which consecutive ACoA aneurysms from a single center have been reported. The location of the aneurysms may have produced conflicting results, in particular because frequently aneurysms in the vertebrobasilar system are small. Second, our indication for embolization essentially concerned the posterior projection of the aneurysm. Several mechanisms may be implicated: compromise of the perforating arteries; involuntary coil migration into the parent artery or clot progression as previously described;4,6,7 and parent artery occlusion due to aneurysm packing, which is responsible for an angular distortion of the pericallosal arteries. Moreover, three-dimensional angiography would be a useful tool in the accurate assessment of the morphological characteristics of the aneurysm sac.

The second type of incident, related to the endovascular procedure, was hemorrhage, which occurred in three patients. Several types of hemorrhagic events have been described previously. First is aneurysm rupture during the procedure, the prevalence of which was estimated at 2.5% of cases and was responsible for 1% of treatment-related deaths,4,5.8. The main risk factor for aneurysm rupture during therapy was the small sac size. Second, a hemorrhagic event may occur after thrombolysis, as in our two cases. Although this phenomenon is well known among interventional neuroradiologists, it is rarely reported. This situation may be explained by a stroke due to thrombolysis, which is an unfavorable indication. No system is yet available to predict the usefulness of performing thrombolysis. Third, rebleeding after the procedure is related to the existence and size of a residual aneurysm. Despite these complications, Type 2 aneurysms should preferably be treated by an endovascular approach, as suggested by our results. The determining argument that favors aneurysm coil embolization is the morphological characteristics of the sac and not the clinical status of the patient at admission; therefore, presentation of the patient in a poor clinical grade was not a primary indication for coil embolization.

Residual Aneurysm

The aim of both therapeutic procedures was complete exclusion of the aneurysm sac from the circulation. Nevertheless, the identification of the residual aneurysm can be difficult. It must be taken into consideration that, even after complete clip application and angiographic confirmation of no apparent residual aneurysm, the presence of a small aneurysm rest cannot be ruled out. After microsurgical clip application, the incidence of aneurysm rest has been assessed at between 4 and 9%, reaching up to 19% for giant aneurysms.1,11,16,44. Acevedo and colleagues,1 in a major surgical series, found 6.8% of patients in whom aneurysms on the ACoA were incompletely clipped. The presence of athrosclerosis and the application of multiple clips for large aneurysms were not considered to be independent predicting factors for the persistence of a residual aneurysm. The natural history of this residual aneurysm has been reported.11,16,44. The rare disappearance of a residual aneurysm has also been reported in five of 28 cases by Feuerberg, et al.16. Frequently, the residual sac is stable or increased in size. David, et al.,11 found a 19% regrowth rate per year for broad-based residua and a 2.9% rate for dog-ear residua. The risk of hemorrhage from these residual aneurysms is estimated to be between 0.5 and 1.5% per year. In our series of ACoA aneurysms, we observed 8.1% of residual aneurysms after microsurgical clip application, and no patient experienced a rebleeding to our knowledge (our recruitment is regional and we are the only reference center). The proportion of residua, either neck or sac, was significantly evident for Type 2 aneurysms. Determining the optimal position for clip placement on the posterior aspect of the ACoA can be problematic. Other morphological features—aneurysm size and presence of a wide neck—were less significant predictors of residual aneurysms. According to Acevedo and colleagues,1 the sac remnant must be treated. Repeated surgery for an aneurysm rest may result in a 7% rate of procedural complication with an 89% rate of complete occlusion.13,41

After endovascular placement of coils, the incidence of a residual aneurysm is estimated to be 40% in a routine review.4. All the authors of that paper believed that complete exclusion was related to the neck and sac size.15. In our series, we obtained a significant reduction in the percentage of residual aneurysm, that is, 21.6%. The recruitment bias did not permit us to isolate morphological features that have a tendency to lead to residual aneurysm. The short-term efficacy of GDC embolization has been extensively reported,3,9,14,21,37,61 but the long-term outcomes have rarely been described. By performing routine angiography 17 months after endovascular coil embolization resulted in incomplete aneurysm exclusion in 72 patients. Hayakawa, et al.,25 showed a 40% rate of recanalization in small aneurysms with wide necks and a rate greater than 80% in large and giant aneurysms. These angiographic observations are in agreement with histopathological findings after aneurysm packing.5,46. Some researchers who have performed histopathological analyses of GDC-treated aneurysm specimens from humans have postulated that neoendothelial proliferation may occur in narrow-necked aneurysms, but that generally this process appears to be delayed or incomplete.3. Despite a high proportion of incomplete treatment, the risk of rebleeding from these residual aneurysms has only been reported by Byrne.5. That author, studying 317 patients during an average of 22.3 months, observed a rebleeding rate of 0.8% in the 1st year, 0.6% in the 2nd, and 3.4% in the 3rd. Moreover, rebleeding occurred in 8% of patients with an unstable occlusion, but in only 0.4% with a stable occlusion. These results do not suggest, however, that rebleeding is an inevitable consequence of incomplete occlusion.

In our department, the 91.9% rate of complete occlusion...
following microsurgical clip application was significantly higher than the 78.4% rate after endovascular treatment. The two small groups did not allow us to perform statistical tests, but there was a tendency toward an increase in the proportion of incomplete occlusion among large and wide-necked aneurysms.

Proposed Therapeutic Strategy Against ACoA Aneurysms

In several studies the results of aneurysm treatment by endovascular occlusion and microsurgical clip application have been compared.22,26,31,38,43,53–55,60,65,68 Good outcomes have been reported in 33% to 83% of patients after microsurgical clip application and in 11% to 92% of patients after endovascular occlusion. The median proportion of disability and death in these series was respectively estimated to be 7.5% and 7% after microsurgical clip occlusion, and 7% and 8% after endovascular occlusion. The nonrandomized nature of the studies and the small sizes of the patient populations in these studies did not permit the authors to reach a scientific conclusion regarding the efficacy of one treatment compared with another. A single prospective randomized study was performed by Vanninen and associates.65 These authors included 52 patients treated by endovascular coil packing and 57 patients treated by microsurgical clip application. The features of both groups were similar: patient population; characteristics of the aneurysm sac (size, location, and neck width); and preoperative clinical grade. There was no significant difference between the two groups regarding the quality of sac exclusion or postoperative outcome. In fact, the few studies in which the two methods were compared showed no scientific advantages to favor either method.

After a comparison of outcomes in our series between the periods 1990 to 1995 and 1996 to 2000, we found that the introduction of endovascular treatment did not significantly modify the proportion of favorable outcomes among the overall population, the proportion of postoperative parent artery occlusion, or the proportion of incomplete aneurysm occlusion. The choice of procedure for treatment of an ACoA aneurysm, therefore, could be related to the risk of technical complications and the quality of sac exclusion. For ACoA aneurysms with an anterior projection, clip application should result in a low risk of thrombosis combined with a high proportion of complete exclusion. In contrast, ACoA aneurysms with a posterior projection could be considered a high surgical risk. Nevertheless, the clip application procedure results in vessel occlusion and endovascular coil packing should be considered despite the possibility of incomplete exclusion.

Biases and Limitations of the Study

The clinical relevance of these results must be interpreted with caution, and our study may have some bias in the choice of procedure indication. Too many posteriorly projecting aneurysms, which could have been treated by the endovascular procedure, were in fact treated by the microsurgical procedure. This factor may have created a major discrepancy among the groups. Similarly, the low number of endovascular procedures in our series highlights the problem of the learning curve. Nevertheless, the endovascular neuroradiological team has observed the standard-consensus interventional procedure since 1990. Although we believe that our regional recruitment permitted us to include all patients with rebleeding, we cannot entirely exclude the possibility that some rebleeding occurred without our knowledge.

These cautions notwithstanding, we believe that this study represents an accurate review of procedure-related complications after ACoA aneurysm treatment. This series included consecutive patients whose assessment was prospectively performed during a 10-year period. To our knowledge, no similar data have yet been reported for ACoA aneurysm series. Endovascular procedure-related complications warrant further study in a large patient population.

Conclusions

In this longitudinal study we evaluated the therapeutic results attained for ACoA aneurysms in a consecutive series of patients seen in the last 10 years. Since the introduction of endovascular treatment, the combined morbidity and mortality rate associated with the surgical procedure has significantly decreased. The direction in which the fundus projects should be considered a morphological criterion on which to base the choice between endovascular and surgical methods. Our results regarding the vessel occlusion rate after microsurgical clip application suggest that posteriorly directed ACoA aneurysms could be considered to carry a high surgical risk. For this type of ACoA aneurysm, the endovascular alternative could be of major interest. Nevertheless, the complete exclusion rate decreased significantly after the introduction of endovascular coil embolization. Thus, the tendency would be to propose microsurgical clip application for ACoA aneurysms that have an anterior projection and endovascular coil embolization for those with a posterior projection, depending on the morphological criteria.

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