Treatment of ruptured intracranial aneurysms since the International Subarachnoid Aneurysm Trial: practice utilizing clip ligation and coil embolization as individual or complementary therapies

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**Object.** The aim of this study was to analyze the therapeutic decision-making process and outcome in 100 consecutive patients with aneurysmal subarachnoid hemorrhage (SAH) treated since the completion of the International Subarachnoid Aneurysm Trial (ISAT). All patients were evaluated and treated by a neurosurgeon with subspecialty training in both cerebrovascular and neuroendovascular surgery.

**Methods.** One hundred consecutive patients with aneurysmal SAH who had been admitted within 1 week posthemorrhage and who had been treated using either surgical clip application or endovascular coil embolization were included in this analysis. All patients underwent a uniform perioperative protocol. All surviving patients were given a questionnaire to assess their modified Rankin Scale score (mRS) and to grade themselves at 6 months and 1 year postintervention. The cohort consisted of 73 women and 27 men with a mean age of 57.27 years (range 27–87 years). Twenty-nine percent of the patients had a World Federation of Neurosurgical Societies (WFNS) Grade IV or V SAH. Forty-seven patients underwent direct surgical clip application, 41 endovascular embolization, and 12 a combination of the two procedures. Good functional outcome—indicated by mRS scores of 0 to 2 after at least 6 months—was achieved in 71% of patients.

**Conclusions.** Data from the ISAT demonstrated a better functional outcome following endovascular embolization in a selected group of patients with aneurysmal SAH. In routine clinical practice, however, a significant number of patients still benefit from direct surgical clip ligation. Excellent functional results can be realized in a complementary clip ligation and coil occlusion practice in which each patient and aneurysm is evaluated and the two treatment modalities are used individually or, when needed, in combination.

**KEY WORDS** • intracranial aneurysm • subarachnoid hemorrhage • surgery • endovascular embolization • outcome

**RESULTS** of the ISAT have sparked heated debate over the best treatment modality for ruptured intracranial aneurysms: endovascular coil occlusion or surgical clip application. The ISAT was halted prematurely after data from an interim analysis showed better functional outcome at 1 year posttreatment in patients who had undergone endovascular embolization compared with those who had undergone surgical clip ligation. In Europe, particularly the United Kingdom, the study has had a profound effect on the management of ruptured intracranial aneurysms. On the other hand, the ISAT has not had such a significant impact on neurosurgical vascular practices in the US. A major criticism of the ISAT is that only a minority of the patients evaluated at the participating centers were indeed enrolled in the trial. For inclusion in the study, the patient in question had to have an aneurysm judged by both a neurosurgeon and a neurointerventionalist to be equally amenable to surgery or endovascular embolization. As a result, only 2143 of the 9559 patients screened at the participating centers were actually enrolled in the trial. Thus, the results of the study do not necessarily justify embracing endovascular embolization as the therapy of choice for the entire population of patients with ruptured intracranial aneurysms.

In the present study we report on our experience with 100 consecutive patients with ruptured intracranial aneurysms treated since the completion of the ISAT. The unique aspect of the present series is that all patients were admitted, evaluated, and treated by one neurosurgeon (G.L.) who, in addition to completing formal neurosurgical training, received fellowship training in both neuroendovascular technique and cerebrovascular surgery. In our opinion, the present series provides a balanced overview of the treatment of ruptured aneurysms in a clip ligation– and coil occlusion–
Complementary clip ligation and coil embolization

based practice free of any personal, professional, or financial biases.

Clinical Material and Methods

The study was approved by the local institutional review board and involved the retrospective analysis of prospectively collected data as part of an internal quality-control process. The cohort consisted of 100 patients with aneurysmal SAH proven on CT scanning (98 patients) or lumbar puncture (two patients) who had been admitted to the Department of Neurosurgery, University of Illinois College of Medicine at Peoria, between September 2002 and June 2004. All patients were admitted within 1 week of suffering an SAH; 95% were admitted within 48 hours. Admission and evaluation were completed by a neurosurgeon (G.L.) trained in both cerebrovascular and endovascular neurosurgery, and treatment was administered according to a uniform protocol. Five patients who had been admitted and treated by other neurosurgeons during the same period were excluded from our analysis.

Patients with WFNS Grades I through IV SAH were medically stabilized and, when indicated, treated aggressively for increased intracranial pressure using an EVD. Furthermore, an EVD was placed immediately after admission in all patients with decreased mental status or refractory severe headache and CT scanning evidence of acute hydrocephalus. Treatment of the aneurysm was usually instituted within 24 hours of admission to our department. Typically, patients with a WFNS Grade V SAH were treated only if neurological improvement was noted after 24 to 48 hours of continuous ventricular drainage and intravenous administration of mannitol. Note, however, that patients with WFNS Grade V SAH who had presented with an intraparenchymal clot underwent emergency surgical clot evacuation, followed by either clip ligation or coil embolization of the ruptured aneurysm. Those without an intraparenchymal clot whose condition did not improve after aggressive management of increased intracranial pressure and who did not undergo aneurysm treatment were not included in our analysis.

All patients received intravenous tranexamic acid (1 g every 6 hours) from the time of admission until the aneurysm was treated either surgically or endovascularly. Nimodipine (60 mg every 6 hours) was administered to each patient from the time of admission to discharge from acute care or until 21 days of hospitalization. One patient, a 74-year-old woman with a ruptured, calcified giant PCoA aneurysm, suffered rebleeding before the lesion was treated. No treatment of the aneurysm was instituted because of her poor neurological condition after rebleeding, and thus she was not included in our analysis.

Decisions on how to treat an aneurysm were formed on a case-by-case basis, depending on angiography (aneurysm location, size, and shape and tortuosity of the proximal vessels) and clinical data (patient age, baseline neurological condition, and systemic comorbidities). In no instance was the decision to perform surgical clip ligation or endovascular occlusion based on the preferences of the referring physician, the patient, or the patient’s family. All patients and family members were informed of the treatment options, and a final recommendation was provided by the treating neurosurgeon (G.L.) based on the aforementioned characteristics.

All endovascular procedures were performed after inducing general anesthesia and pharmacological paralysis. A heparin bolus (5000 intravenous units) was administered before placing the guide catheter, and full heparinization was maintained throughout the procedure. No balloon-assisted remodeling technique or stent-assisted coil placement procedure was used in the ruptured aneurysms. Most of the endovascular procedures were performed by the treating neurosurgeon (G.L.) and an interventional neuroradiologist (K.F.).

All surgical procedures were performed utilizing a standard anesthesia protocol. A modified orbitozygomatic osteotomy involving removal of the orbital rim and a portion of the zygomatic process of the frontal bone was used for the majority of the ACoA aneurysms, all paraclinoid aneurysms, and large PCoA aneurysms. Surgical retraction was minimized, with the retractors being used only in the final stages of aneurysm dissection. Proximal control was established routinely, but temporary clips were applied only when necessary. Intraoperative angiography studies were obtained only in selected cases.

Postoperatively, all patients were monitored in a dedicated neurosurgical intensive care unit at least until Day 7 post-SAH. In patients with an EVD, continuous drainage was maintained at or 5 cm above the level of the external auditory meatus. No change in the level of the EVD was instituted until at least Day 7 post-SAH. After securing the aneurysm, systolic blood pressure was not corrected until Day 10 posthemorrhage unless sustained systolic blood pressure greater than 220 mm Hg lasted longer than 10 minutes. No transcranial Doppler ultrasonography study was performed. A regimen of euvolemic using crystalloid isotonic solution was followed in each patient. Prophylactically induced hypertension was utilized selectively, usually in patients younger than 60 years who had demonstrated a large amount of subarachnoid blood. Therapeutically induced hypertension was started immediately in cases of neurological deterioration ascribed to vasospasm. Every effort was made to maintain hematocrit levels from 33 to 35%, especially during the period of high risk for vasospasm. Follow-up angiography studies were obtained on Day 7 post-SAH in most patients who had undergone surgical clip ligation and in some patients after coil placement.

All surviving patients were evaluated in the outpatient clinic following hospital discharge. Patients were evaluated 6 weeks after leaving the hospital or 6 weeks after leaving rehabilitation or skilled nursing facilities. A certified nurse practitioner (A.W.) who was aware of the treatment modality used in each patient conducted follow-up telephone interviews routinely at 6 months and 1 year after treatment. On follow up, patients were asked to grade their functional ability based on the mRS by using the same questionnaire utilized in the ISAT (Table 1).12,13 If a patient was unable to complete the questionnaire, he or she could enlist the help of a family member.

Results

The study population consisted of 73 women and 27 men with a mean age of 57.27 years (range 27–87 years). The
patients’ clinical conditions at the time of admission are shown in Table 2. Overall, 71% of patients were in good clinical condition (WFNS Grades I–III).

Locations of the ruptured aneurysms and the treatment modalities used are shown in Table 3. Forty-seven patients, all bearing anterior circulation aneurysms, were treated using surgical clip ligation. Forty-one patients underwent endovascular embolization following surgical exploration when it had been determined that the risk of applying a clip to the aneurysm was greater than originally anticipated. Endovascular embolization of a postsurgical residue was performed in five patients. Leaving the residue was intentional (seen at the time of surgery) in four patients, but unintentional in the remaining patient (it was recognized on a routine postoperative angiogram). Two patients underwent surgical clip application after endovascular exploration.

Three patients were lost to follow up; they had been discharged home after treatment of the SAH. Two experienced no focal neurological deficit, whereas one suffered a nondisabling visual field defect caused by a posterior cerebral artery infarct 2 weeks after SAH. Because these three patients could not be reached to complete the 6-month postoperative questionnaire, they were excluded from our analysis. Of the 97 patients in whom follow-up data were available, 69 (71%) achieved a good outcome (mRS Score 0–2). Outcome according to the admission WFNS grade is summarized in Table 4. Causes of poor outcome (mRS Score 3–5) are listed in Table 5. Poor outcome was attributed to complications of treatment in four patients. In one case, a large paraclinoid aneurysm ruptured during coil insertion, leaving the patient with significant cognitive dysfunction. Another patient harboring a giant ACoA aneurysm with a calcified neck underwent partial clip application followed by endovascular coil placement. After coil insertion the only angiographically visible anterior cerebral artery became occluded, which resulted in bifrontal infarction and disability. One patient with a small ACoA aneurysm awoke confused and agitated after surgery. Serial CT scans showed no evidence of an infarct, but 6 months after surgery the patient continued to require supervision because of short-term memory loss (mRS Score 3). The fourth patient suffered intraoperative rupture of an ACoA aneurysm caused by neck avulsion. Sacrifice of one of the A1 segments resulted in infarction in the anterior cerebral artery territory and poor outcome.

Tables 5 and 6 list the causes of death in 11 patients and poor outcome in 17 patients according to admission SAH grade and treatment modality, respectively. Death was related to rebleeding in two patients: in one case, the patient had a very small (1.5 mm) ACoA aneurysm that had been wrapped during surgery; in the other, rebleeding of a PCoA aneurysm occurred. In the latter patient, the aneurysm was endovascularly embolized, resulting in satisfactory obliteration and no significant residue. He suffered massive rebleeding 1 month later while undergoing inpatient rehabilitation. In this series, only one patient died because of vasospasm. Possible reasons for this very low incidence

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**TABLE 1**

*Questionnaire used to assess the mRS score in patients with aneurysmal SAH*

<table>
<thead>
<tr>
<th>mRS Score</th>
<th>Functional Outcome</th>
<th>Questionnaire Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no symptoms</td>
<td>I have no symptoms &amp; I cope well with life</td>
</tr>
<tr>
<td>1</td>
<td>minor symptoms</td>
<td>I have a few symptoms, but these do not interfere with my everyday life</td>
</tr>
<tr>
<td>2</td>
<td>some restriction in lifestyle</td>
<td>I have symptoms that have significantly changed my life, but I am still able to care for myself</td>
</tr>
<tr>
<td>3</td>
<td>significant restriction in lifestyle</td>
<td>I have symptoms that have significantly changed my life &amp; prevent me from coping fully, &amp; I need some help looking after myself</td>
</tr>
<tr>
<td>4</td>
<td>partly dependent</td>
<td>I have quite severe symptoms, which means that I need help from other people, but my condition is not so bad that I need attention day &amp; night</td>
</tr>
<tr>
<td>5</td>
<td>fully dependent</td>
<td>I have major symptoms that severely handicap me &amp; I need constant attention day &amp; night</td>
</tr>
<tr>
<td>6</td>
<td>dead</td>
<td>—</td>
</tr>
</tbody>
</table>

* Based on Lindley, et al. — = not applicable.

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**TABLE 2**

*Summary of demographic and clinical characteristics in 100 patients with aneurysmal SAH*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (yrs)</td>
<td>57.27</td>
</tr>
<tr>
<td>mean</td>
<td>27–71</td>
</tr>
<tr>
<td>range</td>
<td>27</td>
</tr>
<tr>
<td>male sex (%)</td>
<td>27</td>
</tr>
<tr>
<td>admission WFNS grade (%)</td>
<td>71, 29</td>
</tr>
<tr>
<td>I–III</td>
<td>71</td>
</tr>
<tr>
<td>IV–V</td>
<td>29</td>
</tr>
<tr>
<td>aneurysm size (%)</td>
<td>75</td>
</tr>
<tr>
<td>small (&lt;10 mm)</td>
<td>75</td>
</tr>
<tr>
<td>large (11–25 mm)</td>
<td>14</td>
</tr>
<tr>
<td>giant (&gt;25 mm)</td>
<td>1</td>
</tr>
</tbody>
</table>
Complementary clip ligation and coil embolization

The ISAT is the only large multiinstitutional study in which were compared the outcomes in patients with aneurysmal SAH who had been randomly allocated to undergo endovascular or surgical treatment of the aneurysm.\textsuperscript{15} The trial was prematurely halted in May 2002 after an analysis of the interim results revealed a better 1-year outcome with endovascular than with surgical treatment. Of the patients who had undergone endovascular coil embolization, 76.3\% were independent or only minimally restricted in their lifestyle as assessed using the mRS. Only 69.4\% of the patients in the surgical treatment group had a similar outcome. Publication of the results of this trial has sparked heated debate on the best current treatment for ruptured intracranial aneurysms.

TABLE 4
Outcome by admission WFNS grade in 97 patients treated for aneurysmal SAH*

<table>
<thead>
<tr>
<th>Admission WFNS Grade</th>
<th>Total No. of Patients</th>
<th>mRS Score 0–2</th>
<th>mRS Score 3–5</th>
<th>mRS Score 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>20</td>
<td>17 (85)</td>
<td>2 (10)</td>
<td>1 (5)</td>
</tr>
<tr>
<td>II</td>
<td>45</td>
<td>41 (91)</td>
<td>3 (7)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>III</td>
<td>3</td>
<td>1 (33)</td>
<td>2 (67)</td>
<td>0</td>
</tr>
<tr>
<td>IV</td>
<td>17</td>
<td>7 (41)</td>
<td>4 (24)</td>
<td>6 (35)</td>
</tr>
<tr>
<td>V</td>
<td>12</td>
<td>3 (25)</td>
<td>6 (50)</td>
<td>3 (25)</td>
</tr>
</tbody>
</table>

* The three patients lost to follow up were not considered in our analysis.

Discussion

The ISAT is the only large multiinstitutional study in which were compared the outcomes in patients with aneurysmal SAH who had been randomly allocated to undergo endovascular or surgical treatment of the aneurysm.\textsuperscript{15} The trial was prematurely halted in May 2002 after an analysis of the interim results revealed a better 1-year outcome with endovascular than with surgical treatment. Of the patients who had undergone endovascular coil embolization, 76.3\% were independent or only minimally restricted in their lifestyle as assessed using the mRS. Only 69.4\% of the patients in the surgical treatment group had a similar outcome. Publication of the results of this trial has sparked heated debate on the best current treatment for ruptured intracranial aneurysms.\textsuperscript{2,8,11,13,14,16}

As often happens in large multicenter trials, only a minority of the patients screened at the participating centers were actually enrolled in the ISAT. Of the 9559 patients assessed for eligibility at the participating centers during the enrollment period, 7416 were not enrolled. Among these, 3615 were treated surgically and 2737 endovascularly. Information as to what treatment was chosen for the remaining 1064 patients was obtained from the participating centers. The result of the trial cannot necessarily be extended to the population of patients with aneurysmal SAH as a whole and there is a significant proportion of patients with aneurysmal SAH who continue to benefit from surgical treatment.

Aneurysm Location and Treatment Modality

In our opinion, aneurysm location is one of the major factors in determining the best treatment for ruptured aneurysms. We believe that endovascular treatment is definitively superior to surgical clip ligation of BA bifurcation aneurysms. These lesions, which pose significant technical challenges from a surgical point of view, are very easy to catheterize given their orientation in the same direction as blood flow. In the majority of cases, BA caput aneurysms can be safely treated via coil embolization. Of 11 patients with a ruptured BA bifurcation aneurysm in the present study, eight had an excellent functional outcome (mRS Score 0). Of the two patients with a WFNS Grade V SAH, one died as a result of the primary bleed and the other had a poor functional recovery (mRS Score 4). The remaining patient was lost to follow up. Nine patients underwent follow-up angiography studies, and endovascular retreatment was necessary in one patient because of recanalization.

Currently, the majority of MCA aneurysms are better treated with direct surgical clip ligation. Such aneurysms can be clipped with minimal brain retraction, are relatively superficial, and unless they are giant, can be completely exposed to allow visualization and control of the entire parent vessel–aneurysm complex. On the other hand, we believe that endovascular embolization still has several drawbacks when applied to this subset of aneurysms given their broad complex necks partially incorporating the origin of the M\textsubscript{3} branches. This characteristic increases the risk of periprocedural thromboembolic complications.\textsuperscript{13} In the present series, no complication directly related to surgical treatment was encountered in 18 patients with ruptured MCA aneurysms that had been treated with direct surgical obliteration.

Small PCoA aneurysms can be reached with minimal brain retraction and permanently secured using clip application, with very low surgical morbidity and death. We believe that endovascular treatment, with its associated 5 to 8\% incidence of hemorrhagic and ischemic complications, still carries an increased risk compared with that of surgical therapy for this subset of aneurysms. Therefore, in a patient with a ruptured PCoA aneurysm we consider surgery as the first-line treatment except in elderly patients (> 70 years),...

TABLE 6
Causes of poor outcome and death, according to treatment modality*

<table>
<thead>
<tr>
<th>Cause of Outcome</th>
<th>Poor Outcome (17 patients)</th>
<th>Death (11 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>effects of primary bleed</td>
<td>13 (CA/7; CE/6)</td>
<td>5 (CE/3; CA/2)</td>
</tr>
<tr>
<td>complication of treatment</td>
<td>4 (CA/2; CE/1; CA + CE/1)</td>
<td>0</td>
</tr>
<tr>
<td>rebleeding</td>
<td>0</td>
<td>2 (CA/1; CE/1)</td>
</tr>
<tr>
<td>systemic complications (sepsis)</td>
<td>0</td>
<td>2 (CA/1; CE/1)</td>
</tr>
<tr>
<td>vasospasm</td>
<td>0</td>
<td>1 (CA + CE/1)</td>
</tr>
<tr>
<td>unrelated*</td>
<td>0</td>
<td>1 (CA/1)</td>
</tr>
</tbody>
</table>

* One patient died of acute subdural hematoma after falling 3 months after aneurysm treatment. She had been maintained on a regimen of Coumadin for atrial fibrillation.
those with poor baseline neurological function, and those with large aneurysms in which significant manipulation of the AChA artery can be anticipated.

Anterior communicating artery aneurysms represent a complex problem because neuropsychological deficits are common after surgical clip application, whereas endovascular embolization is associated with a better functional outcome.\(^2\) Quite often, however, ruptured ACoA aneurysms are very small. The risk of aneurysm perforation during embolization is greater in smaller aneurysms.\(^9,10,21\) The risk of perforation during embolization may be greater still in very small ACoA aneurysms. Given the course of the A\(_1\) segment at an acute angle from the ICA bifurcation, it can be difficult to achieve a stable catheter position within a very small aneurysm. We tend to favor surgical clip application for aneurysms smaller than 4 mm (not a small percentage of lesions when ruptured ACoA aneurysms are considered) except in older patients (\(\geq 65\) years) and in those with ACoA aneurysms pointing posteroinferiorly. Other authors have reported improved results after adopting a similar treatment protocol.\(^17\)

**Durability of Treatment**

The lack of absolute protection from aneurysm recanalization and even rebleeding has been considered a major limitation of endovascular treatment. The protection afforded by coil placement is most likely related to a buffer effect provided by the coil mass within the aneurysm sac in the acute phase. With time there is some degree of clot organization within and around the coil mass, with fibrosis of the sac.\(^1\) Complete exclusion of the aneurysm with neointima bridging the aneurysm neck is the exception rather than the rule after endovascular treatment even in lesions that appear to be 100% occluded on serial angiography studies.\(^1\) In the ISAT, 15 episodes of rebleeding were observed during the 1st year after aneurysm embolization.\(^15\) Unfortunately, even after surgery the degree of protection is not 100%. Rebleeding after clip ligation has been known to occur even in the best surgical hands.\(^22\) In the ISAT, five rebleeds were observed in the 1st year after surgery. Data from a recent retrospective multicenter study (major neurovascular centers across the US) have revealed a greater aneurysm rupture rate the 1st year after surgical clip application compared with that previously reported.\(^7\) Our findings are consistent with the data from the ISAT: we also observed an episode of rebleeding in each treatment group, although the bleeding after surgery recurred in a patient who had undergone wrapping of a very small ACoA aneurysm. One year after endovascular embolization, the risk of subsequent rebleeding is negligible.\(^15\) Some patients may need repeated treatment after coil insertion in a ruptured aneurysm. Nonetheless, endovascular treatment repeated months after SAH is, in our opinion, a much safer procedure than coil placement in the context of an acutely ruptured aneurysm. In our series, 26 patients underwent follow-up angiography studies after at least 6 months. Of these, three required repeated treatment, which was uneventful. Another patient required a craniotomy and clip ligation of the recurrent aneurysm.

**Outcome Assessment**

As treatment for ruptured intracranial aneurysms improves, patients and their families have greater expectations. Consequently, the way that outcome is measured must evolve. The ISAT investigators are to be commended for their adoption of the mRS in defining outcome because the scale is more sensitive to quality-of-life issues and patient perceptions than more traditional outcome scales such as the Glasgow Outcome Scale.\(^6,10\) In contrast to previous studies in which outcome was assessed by a member of the treating team, the ISAT allowed patients to grade themselves using mRS classification; we also used this method of assessment. When outcome is assessed with such sensitive and rigorous tools, it is not uncommon to encounter findings that can be quite distressing and frustrating to the treating physician. This situation is well exemplified by two patients in our series. A 40-year-old woman with a history of chronic migraines underwent successful clip ligation of a ruptured small superior hypophyseal aneurysm. She was discharged home 1 week after surgery. Six months later, she experienced persistent disabling headaches and assigned herself an mRS score of 3. Similarly, a 48-year-old construction worker with a ruptured right MCA aneurysm had undergone emergency hematoma evacuation and clip ligation of the aneurysm. Six months later he returned to work at the same pre-SAH level of activity. When asked to rate his condition, however, he assigned himself an mRS score of 3. Both of these patients are included in the poor outcome category in this series.

The ISAT investigators have been criticized for distinguishing between an mRS score of 2 (considered a good outcome) and a score of 3 (considered a poor outcome). In the ISAT, inclusion of patients with an mRS score of 3 in the poor outcome category tipped the balance in favor of endovascular treatment. Note, however, that we fully agree with the ISAT investigators that a significant difference in outcome and quality of life exists between Scores 2 and 3 on the mRS. To paraphrase Wilder Penfield, in the end what counts is whether the patients and beloved ones believe that the operation was a success.

**Clip and Coil, not Clip Versus Coil**

In treating an individual patient with a ruptured aneurysm, multiple factors must be considered in choosing the best course of treatment. Such factors include the aneurysm location, size, shape, and orientation; tortuosity of the proximal vessels and the parent artery; presence of calcifications at the aneurysm neck; neck/dome ratio; and patient’s chronological and biological age, systemic comorbidities, life expectancy, and neurological condition. Additionally, local expertise and an honest and consistent assessment of the complications and results are critically important to evaluate and offer evolving treatment options. An analysis of patient outcomes in our series reveals that excellent results can be obtained in a complementary clip ligation and coil occlusion practice. The two treatment options can be successfully used interchangeably and at times in a complementary fashion to protect the patient from aneurysm re-rupture while trying to minimize complications related to treatment. In our study, 71% of patients were able to function independently posttreatment or with only minor lifestyle restrictions (mRS Scores 0–2) despite having a greater mean age (57.27 years in our series compared with 52 years in the ISAT) and a worse clinical condition on admission.
Complementary clip ligation and coil embolization

(29% WFNS Grades IV and V in our series compared with 5% in the ISAT) than patients enrolled in the ISAT.\textsuperscript{19}

To minimize complications, it is very important to assess the risk/benefit ratio constantly even in the advanced phases of the surgical or endovascular procedure. If risks greater than those originally estimated or if unexpected findings are encountered while performing either surgery or endovascular embolization, the procedure can be halted and the patient treated with the alternative method. This concept is well exemplified by two of our cases. In a young good-grade patient with an SAH from a ruptured PCoA aneurysm, surgery was suggested as the primary therapy. After exposure of the aneurysm, it was evident that the AChA was intimately adhered to a portion of the ruptured sac and that the supraclinoidal ICA was surprisingly involved by extensive atheromatous and calcific changes. Separation of the AChA would have required temporary clip ligation of the calcified ICA. It was determined that applying a clip to the aneurysm in this particular patient would probably involve a risk of major complications greater than the 3 to 5% rate originally quoted to the patient. Thus, surgical exploration was terminated and the aneurysm was successfully treated with endovascular embolization. Similarly, in a 79-year-old woman with a WFNS Grade IV SAH and a ruptured PCoA aneurysm, numerous attempts at coil embolization were unsuccessful because of the high neck/dome ratio. Instead of insisting on higher-risk endovascular techniques such as balloon-assisted or stent-assisted coil placement, uneventful clip ligation of the aneurysm was performed. Eventually, the patient made a good recovery (mRS Score 0).

Conclusions

In medicine, changes in current practice patterns are often the result of gradual evolution rather than dramatic revolution. Treatment of ruptured intracranial aneurysms is currently in a critical evolutionary phase. There is no doubt that as technology improves and newer avenues of treatment are introduced, there will be a continuing impetus toward less invasive treatments. Currently, however, excellent results are obtained when the two treatment modalities of clip ligation and coil occlusion are used interchangeably and at times in a complementary fashion, depending on the unique characteristics of the individual patient.

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References


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