Clinical and Angiographic Follow-up of Ruptured Intracranial Aneurysms Treated with Endovascular Embolization

BACKGROUND AND PURPOSE: Endovascular embolization is a well-established treatment of ruptured intracranial aneurysms, but concern about its long-term stability and its ability to prevent rehemorrhage are still present. We evaluated the long-term clinical and angiographic follow-up of patients with ruptured cerebral aneurysms treated with coiling, focusing on rehemorrhage and changes in aneurysm morphologic features.

MATERIALS AND METHODS: A total of 377 patients with ruptured aneurysms that were treated with endovascular approaches at our institution between 1994 and 2008 were reviewed. Clinical and angiographic data were analyzed from a prospectively collected database.

RESULTS: There were 377 patients with 391 ruptured aneurysms treated for 14 years. Good outcome (Glasgow Outcome Score [GOS], 5) was achieved in 74% of patients, moderate disability or poor outcome in 18%, and 8.8% died. Permanent morbidity or mortality from procedural complications occurred in 2.9%. Complete follow-up was available for 85% of surviving patients, with mean follow-up of 22.3 months. Re-treatment was required in 11% (31 patients). Eight (2.1%) patients had rebleeding, 6 (1.6%) in the hospital within 30 days of treatment, 5 in the first 48 hours. Follow-up imaging was available in 276 aneurysms in 270 patients. Recanalization occurred in 56 of 276 aneurysms (20.3%) regardless of the initial angiographic result, but the risk was higher if a body remnant was left ($\chi^2$, 11.791; $P = .0006$).

CONCLUSIONS: Long-term clinical and angiographic follow-up demonstrates the efficacy of endovascular treatment of ruptured intracranial aneurysms. Rebleeding after treatment is rare, with the greatest risk during the first 48 hours after treatment. Initial angiographic results are not a useful predictor of clinical outcome or rehemorrhage.

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Endovascular coil embolization has emerged within the last 2 decades as a safe and effective treatment option for ruptured intracranial aneurysms. The International Subarachnoid Hemorrhage Trial (ISAT) demonstrated better outcomes for ruptured aneurysms treated with coiling vs clipping, with an absolute risk reduction of 7.4% and a 7-year survival advantage,1 a finding supported by other studies.2,3 However, a high percentage of aneurysmal remnants, unknown long-term stability, and potential rehemorrhage are current concerns with this technique. Incomplete treatment has been reported in 15% to 65%, and recanalization can occur in 14% to 34% of aneurysms treated by endovascular techniques, focusing on rehemorrhage and changes in aneurysm morphologic features.
Institute, Cary, NC) was used for all analyses. A similar analysis was performed in a subgroup of patients (n = 153) with more than 11 months of follow-up to evaluate the long-term results.

**Coiling Technique**

All endovascular treatments were performed with the patients under general anesthesia. Activated clotting time was kept between 250 and 300 seconds by systemic anticoagulation with heparin. The types of platinum coils used were Guglielmi detachable coils (GDC; Boston Scientific, Natick, Mass), MicroCoils (Micrus, San Jose, Calif), MicroPlex coils (Microvention, Aliso Viejo, Calif), and Trufill DCS coils (Cordis, Miami Lakes, Fla). Matrix coils (Boston Scientific) and HydroCoils (Microvention) were the predominant coil in 35 and 36 procedures, respectively. Matrix coils were not used after July 2005 after we demonstrated a greater incidence of major recanalization in patients treated with Matrix compared with bare platinum coils,12 and HydroCoil use stopped after reports of hydrocephalus were published.13-15 The balloon- or stent-assisted technique was used for selected wide-neck aneurysms, with preference given to the use of balloon-assisted technique if possible. Aneurysms were always packed as well as possible, hoping to achieve complete occlusion.

**Follow-up**

We initially performed radiologic follow-up using digital subtraction angiography (DSA) with 3D rotational angiography. Later MR angiography (MRA) became our primary follow-up imaging technique. MRA studies used the “autotriggered elliptical centric-ordered” (ATECO) 3D gadolinium-enhanced technique to evaluate for remnants. The ATECO protocol and its usefulness as a surveillance tool for previously coiled aneurysms have been previously described.16,17 Two follow-up protocols were used during 14 years. Initially, imaging studies were performed before discharge, at 6 months, and at 18 months after treatment. After 18 months, those patients with completely occluded aneurysms were followed up with imaging (angiogram or MRA) once every 2 years, and those with aneurysm remnants were followed up once a year. In 2005, the protocol was changed to include an additional imaging study 2 to 3 months after treatment. Angiographic outcomes were categorized as 1) complete occlusion, 2) neck remnant, and 3) body remnant.18,19

Clinical evaluations were performed in our outpatient brain aneurysm clinic attended by cerebrovascular neurosurgeons and interventional neuroradiologists. Before 1999, outcome was assessed with use of the Glasgow Outcome Scale (GOS),20 and in 1999, we added the modified Rankin Scale.21 Follow-up clinical examinations were performed at 2 and 6 months and then on a yearly basis. Earlier follow-up was scheduled if changes in the aneurysm morphologic features were noted.

**Results**

For the analysis, we divided our cohort into 2 equal groups, each containing a similar number of patients. The first half of our cohort was treated between May 1994 and June 2004 and the second half, between June 2004 and April 2008. In this study, we refer to group 1 as the group of patients treated before June 2004 and group 2 as those treated after June 2004. From 1994 to 2008, endovascular treatment was attempted in 411 patients (453 aneurysms) who presented with ruptured intracranial aneurysms. Twelve patients had 2 aneurysms coiled at the time of rupture, and 1 patient had 3 aneurysms coiled. Treatment was not possible in 34 cases (8.3%) that were excluded from this analysis. Twenty-five failed attempts occurred before June 2004 (12.1%), and 9 (4.4%) occurred after June 2004. A total of 391 aneurysms were treated in 377 patients early after the rupture. Patient characteristics are shown in Table 1 and aneurysm locations in Table 2.

Outcome at discharge of 377 patients is shown in Table 3. Good outcome (GOS, 5) was achieved in 278 patients (74%). Sixty-six patients (18%) had moderate disability or a poor clinical outcome, and 33 patients (8.8%) died. In good-grade patients (Hunt-Hess I–III), 247 (83%) had a GOS of 5 and 16 (5.3%) died, whereas in poor-grade patients (Hunt-Hess IV and V), good outcome or moderate disability (GOS 4 and 5) was achieved in only 44 (56%) and 17 (22%) died.

There were 53 significant procedural complications in 45 patients (12%; Table 4) that resulted in a poor outcome or death in 11 patients (2.9%). Four of these 11 patients had aneurysm perforations, and 5 had a parent-vessel occlusion or distal emboli. An internal carotid dissection occurred in 1 pa-
Complication & No. of Patients (%) & No Deficit & Transient Morbidity & Permanent Morbidity & Mortality & Complication Outcome \\
--- & --- & --- & --- & --- & --- & --- \\
Aneurysm perforation & 23 (6.1) & 13 & 6 & 1 & 3 & Aneurysm perforation occurred in 23 patients (6.1%). There were 16 aneurysm perforations (8.5%) in group 1 and 7 (3.7%) in group 2. Aneurysm perforation resulted in transient morbidity or no deficit in 19 (82.6%) of 23 patients, permanent morbidity in 1 patient, and death in 3 patients (4 poor outcomes of 23 [17.3%]). \\
Parent vessel occlusion & 15 (4.0) & 11 & 3 & 1 & 0 & Parent vessel occlusion occurred in 15 patients: 16 patients (8.5%) in group 1, and 6 patients (3.2%) in group 2. Thromboembolic complications resulted in transient morbidity or no deficit in 17 (77.3%) of 22 patients, permanent morbidity in 4 (18.2%), and death in 1 (4.5%). This patient who died had an associated aneurysm perforation. \\
Distal emboli & 11 (2.9) & 4 & 3 & 3 & 1 & Distal emboli occurred in 11 patients: 10 patients (5.3%) in group 1, and 1 patient (0.5%) in group 2. Six patients had an early rehemorrhage, defined as less than 30 days’ postcoiling (5 within 48 hours of treatment). Outcomes of rehemorrhages were poor (Table 6). Four of the patients who had rebleeding were in group 1, and 3 patients who had rebleeding were in group 2. Complete occlusion at the time of coiling was achieved in 2 of the 6 aneurysms that re-bled early. One patient treated with a combination of Matrix and bare platinum coils had rebleeding at 5.5 months. The rebleeding rate with Matrix (2.8%) was similar to the overall results. There was no rebleeding in patients treated with HydroCoil or a combination of HydroCoil and bare platinum. \\
Mass effect & 1 (0.3) & 0 & 0 & 1 & 0 & Mass effect occurred in 1 patient. \\
Arterial dissection & 2 (0.5) & 1 & 0 & 0 & 1 & Arterial dissection occurred in 2 patients: 1 patient (0.5%) in group 1, and 1 patient (0.5%) in group 2. \\
Parent vessel rupture & 1 (0.3) & 0 & 0 & 0 & 1 & Parent vessel rupture occurred in 1 patient. \\

Table 4: Neurologic outcome in patients with significant procedural complications

| Complication | Outcome | No. of Patients (%) | No Deficit | Transient Morbidity | Permanent Morbidity | Mortality |
|--------------|---------|---------------------|------------|--------------------|---------------------|----------|
| Aneurysm perforation | 23 (6.1) | 13 | 6 | 1 | 3 |
| Parent vessel occlusion | 15 (4.0) | 11 | 3 | 1 | 0 |
| Distal emboli | 11 (2.9) | 4 | 3 | 3 | 1 |
| Mass effect | 1 (0.3) | 0 | 0 | 1 | 0 |
| Arterial dissection | 2 (0.5) | 1 | 0 | 0 | 1 |
| Parent vessel rupture | 1 (0.3) | 0 | 0 | 0 | 1 |

Table 5: Glasgow Outcome Scale stratified by Hunt and Hess grade at presentation of 292 patients at last follow-up

| Hunt and Hess | Glasgow Outcome Scale | 1 | 2 | 3 | 4 | 5 |
|--------------|-----------------------|---|---|---|---|---|
| I (120)      | 0 | 1 | 0 | 5 | 114 |
| II (61)      | 0 | 0 | 0 | 1 | 60 |
| III (67)     | 0 | 0 | 5 | 4 | 58 |
| IV (42)      | 0 | 1 | 7 | 6 | 28 |
| V (2)        | 0 | 1 | 0 | 0 | 1 |
| Total (292)  | 0 | 3 | 12 | 16 | 261 |

Abciximab (ReoPro; Eli Lilly, Indianapolis, Ind) was used in 27 patients for thrombus formation at or near the parent vessel/coil interface. Since August 2002, abciximab has been used in 27 (11%) of 237 patients. The drug was either given intravenously as a bolus (25 μg/kg) or intra-arterially at a lower dose (4–12 mg titrated to response) through a microcatheter near the intraluminal clot. Our current protocol is to use the full, single intravenous dose, and in only a few cases did we give the 12-hour intravenous infusion following the initial intravenous or intra-arterial bolus. Most patients (25/27) had no neurologic deficits related to thromboembolic complications. One patient experienced permanent neurologic sequelae from the distal emboli, and another had a second hemorrhage from the aneurysm the following day and was retreated with surgical clipping. Technical complications without clinical significance occurred in 2 patients: coil herniation into the parent vessel in 4 patients, coil stretching in 2 patients, stent inadvertently deployed proximal to the aneurysm in 1 patient, and traumatic catheterization of the urethra in 1 patient.

Complete follow-up was achieved in 292 (85% of surviving) patients. GOS at last follow-up is shown in Table 5. The average interval between treatment and the last follow-up was 22.3 months (range, 20 days to 119.8 months). Additional treatment was required in 31 patients (11%). Eleven (3.7%) were re-treated with surgical clipping and 21 (7.1%) underwent additional embolization, with 5 requiring a third embolization. One patient was initially re-treated with coils and subsequent clipping. At their last clinical examination, 245 patients (84%) had no clinical deficits. Rehemorrhage after coiling occurred in 8 patients (2.1%). Six patients had an early rehemorrhage, defined as less than 30 days’ postcoiling (5 within 48 hours of treatment). Outcomes of rehemorrhages were poor (Table 6). Four of the patients who had rebleeding were in group 1, and 3 patients who had rebleeding were in group 2. Complete occlusion at the time of coiling was achieved in 2 of the 6 aneurysms that re-bled early. One patient treated with a combination of Matrix and bare platinum coils had rebleeding at 5.5 months. The rebleeding rate with Matrix (2.8%) was similar to the overall results. There was no rebleeding in patients treated with HydroCoil or a combination of HydroCoil and bare platinum. A total of 166 subjects had follow-up durations longer than 11 months. Information on 153 patients was used to analyze which factors were associated with aneurysm recanalization and the need for re-treatment (13 patients were excluded because of unavailable information regarding aneurysm recanalization). The presence of a body remnant after coiling was significantly related to aneurysm recanalization (P < .0001) and with the need for re-treatment (P = .0433). The very small number of rebleedings (2 in this subgroup) did not allow for any statistical correlation.

Imaging Results

Immediate postcoiling angiography demonstrated complete occlusion of 170 (43%) of the aneurysms, a neck remnant in 142 (36%), and a body remnant in 79 (20%). Follow-up imaging after discharge was available for 276 (70.6%) of the aneurysms (270 patients [71.6%]). At the time of last follow-up, recanalization was observed in 56 (20.3%) of 276 aneurysms: 26 (18.8%) for group 1 and 30 (21.7%) for group 2. From the 170 aneurysms with initial complete occlusion, follow-up imaging was obtained in 121 aneurysms (118 patients). Forty-seven aneurysms (71.9%) remained stable, with no change in imaging after discharge was available for 276 (70.6%) of the aneurysms (270 patients [71.6%]). At the time of last follow-up, recanalization was observed in 56 (20.3%) of 276 aneurysms: 26 (18.8%) for group 1 and 30 (21.7%) for group 2. From the 170 aneurysms with initial complete occlusion, follow-up imaging was obtained in 121 aneurysms (118 patients). Eighty-seven aneurysms (71.9%) remained stable, with no change in their angiographic appearance after initial treatment. Thirty-four aneurysms (28%) recanalized, with 17 developing neck remnants and 16 developing body remnants. The average time between treatment and detection of recanalization was 9.6 months (range, 0.1–46 months). Eight (6.6%) of the 121 were re-treated (4 coiled, 4 clipped). Of the 142 aneurysms with neck remnants on initial angiogram, 106 aneurysms (104 pa-
† Patient given intravenous abciximab.

* Recanalization evident on post rehemorrhage angiography.

Far.4,9,11 The second rebleed occurred less than 6 months from treatment. This latter rebleed led to changes in our practice regarding the immediate angiographic result. The most common procedural complication was intra-procedural rupture (6.1%). This rate is similar to that of reports in the literature.11,18,32,34 In our cohort, a small size (defined as an aneurysm sac smaller than 5 mm) had no influence in the rate of intra-procedural rupture. The risk for intra-procedural perforation was 7.6% for aneurysms less than 5 mm and 5.0% for aneurysms more than 5 mm ($\chi^2 = 0.715; P = .3979$). Other authors have demonstrated an increased risk for perforation in small aneurysms. Nguyen et al35 recently demonstrated that the risk for rupture increases from 2.3% for aneurysms more than 5 mm to 1.6% for aneurysms less than 5 mm.

Outcome after rehemorrhage was poor, with a 62.5% mortality rate, concurrent with another series reporting high mortality rates after early re-rupture.4,8 It is interesting to note that rebleeding rates were not different in completely occluded aneurysms compared with aneurysms with neck or body remnant ($\chi^2 = 1.135; P = .28$), a result supported by others. Rebleeding occurred after complete occlusion in 2 patients, a neck remnant in 4, and a body remnant in 2. Sluzewski et al28 also found no significant difference in the risk for rehemorrhage between complete and incomplete occlusion, with 4 of 6 early (<30 days) rerecurrents occurring after complete occlusion of the aneurysm. Different results were shown by investigators in the Cerebral Aneurysm Rerupture After Treatment study on predictors of rehemorrhage after treatment of ruptured intracranial aneurysms, who found the degree of aneurysm occlusion to be highly predictive of the risk for rerupture, which increased progressively as the packing attenuation decreased.27 Accordingly, there was no difference in the re-treatment rates of aneurysms with neck remnant (9.4%) compared with completely occluded (6.7%) aneurysms ($\chi^2 = 0.776; P = .38$). As expected, aneurysms with a body remnant at the end of the coiling were re-treated more often (24% re-treatment rate) than lesions completely occluded or left with a neck remnant ($\chi^2 = 5.959; P = .0146$). In ruptured aneurysms, we no longer strive for complete occlusion in every case because those with a neck remnant have a similar natural history as those that are completely occluded. We do not struggle for a perfect angiographic result because the complication rate may increase with attempts to achieve the ideal picture.

Periprocedural complications occurred in 12% of our patients, with permanent morbidity or mortality rate related to the procedure in 2.9%, a complication rate similar to other studies. Our permanent morbidity and mortality rates were lower than other single-center studies on ruptured aneurysms.3,18,30-33 This may reflect our conservative strategy regarding the immediate angiographic result. In our cohort, a small size (defined as an aneurysm sac smaller than 5 mm) had no influence in the rate of intra-procedural rupture. The risk for intra-procedural perforation was 7.6% for aneurysms less than 5 mm and 5.0% for aneurysms more than 5 mm ($\chi^2 = 0.715; P = .3979$). Other authors have demonstrated an increased risk for perforation in small aneurysms. Nguyen et al35 recently demonstrated that the risk for rupture increases from 2.3% for aneurysms more

### Table 6: Data on patients with rehemorrhage after coil embolization ($n = 8$)

| Age | Sex | Initial HH | Location of Treated Aneurysm | Size  | Immediate Angiographic Result | Time to Rebleeding (Days) | Intervention  | GOS  |
|-----|-----|------------|-------------------------------|-------|-------------------------------|---------------------------|---------------|------|
| 62  | Male| 4          | BA                            | 14 mm | Body remnant                  | 3606                      | None          | 1*   |
| 61  | Male| 1          | VA                            | 6.3 mm| Neck remnant                  | 161                       | Recoiling     |      |
| 84  | Female| 2          | MCA                           | 3.0 mm| Complete occlusion            | 29                        | None          | 1    |
| 59  | Female| 4          | AcomA                         | 6.0 mm| Neck remnant                  | 5                         | None          | 4    |
| 46  | Female| 1          | MCA                           | 6.5 mm| Body remnant                  | 1                         | None          | 1    |
| 67  | Female| 2          | AcomA                         | 5.0 mm| Complete occlusion            | 1                         | None          | 1    |
| 42  | Male | 5          | Pericallosal                  | 5.3 mm| Neck remnant                  | 1 Clippering              | 41            |      |
| 70  | Male | 3          | AcomA                         | 6.1 mm| Neck remnant                  | 1                         | None          | 1    |

Note: GOS indicates Glasgow Outcome Scale, HH; Hunt and Hess; BA, basilar artery; VA, vertebral artery; MCA, middle cerebral artery; AcomA, anterior communicating artery.

* Recanalization evident on post rehemorrhage angiography.

† Patient given intravenous abciximab.

tients) had follow-up imaging. Fifty aneurysms (47%) became completely occluded, and 46 (43%) were stable. Ten aneurysms (9.4%) developed body remnants. The average time between treatment and detection of recanalization was 6.3 months (range, 2.0–11 months). Ten of the 106 (9.4%) aneurysms were re-treated: 5 were recoiled once, 3 were recoiled twice, 2 were clipped, and 1 was recoiled and subsequently clipped. Of the 79 aneurysms with body remnants on immediate postcoiling imaging, 49 (in 49 patients) had follow-up imaging. Twenty-two aneurysms (45%) showed favorable evolution with smaller remnants or complete occlusion, and 15 (31%) were stable. Twelve aneurysms (24%) showed recanalization with interval enlargement of the body remnant. All 12 were retreated: 6 were recoiled once, 2 were recoiled twice, and 4 were clipped. The average time between treatment and detection of recanalization was 6.7 months (range, 0.2–24.2 months).

Discussion

The primary goal of treatment of a ruptured aneurysm is to prevent rehemorrhage. However, rehemorrhage after treatment is still an issue. The ISAT trial demonstrated an overall rehemorrhage rate of 4.9%, with an incidence of rebleeding after surgical clipping of 1.2%.1 Rebleeding risk after surgical clipping has been reported to be low, varying from 1.9% to 3.2%, higher with incomplete sac occlusion.22-25 Recanalization is a known issue with endovascular treatment, but its impact on rebleeding rates is not completely clarified. Despite recanalization rates as high as 38%, reports on the incidence of rebleeding after coiling vary.26-30 In our study, the overall incidence of rehemorrhage was 2.1%, with time until rebleeding ranging from 0 days to 118.6 months (almost 10 years). Six of the 8 patients had a subsequent hemorrhage within 30 days of treatment, 5 within 48 hours. We found a risk for rebleeding of 1.6% during the first 30 days after coiling, decreasing to 0.7% after that. There were 2 episodes of late rebleeding, 1 almost 10 years after treatment, the longest interval between treatment and rebleeding after endovascular embolization reported so far.4,9,11 The second rebleed occurred less than 6 months from treatment. This latter rebleed led to changes in our practice regarding follow-up imaging. Ruptured aneurysms treated with coiling are now imaged with MRA before discharge, at 2 to 3 months and then 6 months after treatment for assessment of early recanalization. Follow-up imaging is then performed yearly or every other year, depending on the presence of a remnant.
than 3 mm to 11.7% for those less than 3 mm. Our size categorization was arbitrary, and the cutoff value for small aneurysms was at 5 mm. The results may have been different if very small lesions (< 3 mm in size) were analyzed separately.

Thromboembolic complications occurred in 5.8% of all patients and were more frequent in the first half of our experience (8.5% of patients in group 1 and 3.2% of patients in group 2 \(\chi^2, 3.859; P = .0495\)). A major difference between the 2 groups is the introduction of abciximab (ReoPro) during endovascular procedures after 2004. Abciximab, a monoclonal antibody glycoprotein IIa/IIIb inhibitor, has shown to be very effective in the treatment of acute thromboembolic complications during endovascular procedures. We used abciximab (intravenously or intra-arterially) in 27 patients when thrombus was evident during the procedure, and there were no symptomatic thromboembolic events in 93% of these patients. One patient had an ischemic stroke in the motor cortex, and another had a subsequent hemorrhage from the treated aneurysm the following day and underwent craniotomy and clipping. Intracerebral hemorrhages have been described with abciximab use.\(^3,7\)

### Table 7: Complication rates in Groups 1 and 2

| Author | No. of Patients | Mean Follow-up Time in Months (Longest Follow-up) | Procedural Complications (Permanent Morbidity and Mortality) | Recanalization Rate | Rehemorrhage (Early/Late) |
|--------|----------------|-------------------------------------------------|-------------------------------------------------------------|-------------------|-------------------------|
| Present study, 2008 | 377 | 22.3 (120) | 12% (2.9%) | 20.3% | 1.6%/0.5% |
| Akawa, 2007 | 22 | 50.4 (NS) | NS | 10% | NS/2.6% |
| Sluzewski, 2005 | 393 | 47.7 (120) | NS | NS | NS/1.27% |
| Friedman, 2002 | 83 | 19.1 (112) | 19% (2%) | 15% | 0%/0% |
| Sluzewski, 2003 | 160 | 37.1 (72) | NS (3.8%) | 25% | NS/1.2% |
| Kremer, 2002 | 79 | 41 (74) | NS | NS | NS/3% |
| Byrne, 1999 | 317 | 22.3 (65) | NS | 14.7% | NS/1.6% |

Table 8: Long-term follow-up studies after coiling of ruptured intracranial aneurysms

| Author | No. of Patients | Mean Follow-up Time in Months (Longest Follow-up) | Procedural Complications (Permanent Morbidity and Mortality) | Recanalization Rate | Rehemorrhage (Early/Late) |
|--------|----------------|-------------------------------------------------|-------------------------------------------------------------|-------------------|-------------------------|
| Present study, 2008 | 377 | 22.3 (120) | 12% (2.9%) | 20.3% | 1.6%/0.5% |
| Akawa, 2007 | 22 | 50.4 (NS) | NS | 10% | NS/2.6% |
| Sluzewski, 2005 | 393 | 47.7 (120) | NS | NS | NS/1.27% |
| Friedman, 2002 | 83 | 19.1 (112) | 19% (2%) | 15% | 0%/0% |
| Sluzewski, 2003 | 160 | 37.1 (72) | NS (3.8%) | 25% | NS/1.2% |
| Kremer, 2002 | 79 | 41 (74) | NS | NS | NS/3% |
| Byrne, 1999 | 317 | 22.3 (65) | NS | 14.7% | NS/1.6% |

Note:—NS indicates not studied.

**Study Limitations**

Our study had some limitations. There were 15% of patients lost to follow-up, and imaging was not available in all. The long study period encompassed a shift in management strategies and multiple technical advances, which made comparison difficult. Follow-up imaging was initially done exclusively with DSA and later shifted to gadolinium-enhanced MRA. This change could have resulted in differences in interpretation of the imaging results, though the high sensitivity of MRA in the detection of aneurysm remnants after coiling was demonstrated by our group. The modified Rankin Scale, a more sensitive measure of outcome, was not incorporated into our database until 1999. Despite the limitations, our study was among the largest in single-center studies (Table 8) on the long-term follow-up of endovascular treatment of ruptured aneurysms.\(^4,9,11,26,29,30,39\)
Conclusions

Long-term clinical and angiographic follow-up after coiling of ruptured aneurysms confirms its efficacy as a primary treatment technique. Rebleeding rates after treatment are low, but recanalization remains an issue, even in aneurysms that are initially completely occluded. Long-term imaging follow-up is advised. Initial angiographic appearance is not a good predictor of rehemorrhage, recanalization, and long-term outcome.

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