**Background and Purpose**—We sought to describe the clinical outcome and angiographic results obtained in the endovascular therapy of ruptured posterior circulation cerebral aneurysms using Guglielmi detachable coils (GDC) over a 7-year period.

**Methods**—A retrospective analysis was performed of 112 patients evaluated at the University of California at San Francisco Medical Center between June 1991 and August 1998. The Hunt-Hess grade at presentation of treated patients was I in 26 patients (24%), II in 24 (22%), III in 27 (25%), IV in 24 (22%), and V in 8 (7%). Clinical follow-up for the total population was achieved in 104 of 109 patients (96%), with a mean duration of 13.1 months. Angiographic follow-up for the subset excluding parent vessel occlusion cases was obtained in 93% of cases, with a mean duration of 7.2 months.

**Results**—Technical success, defined as the ability to catheterize and embolize the aneurysm with GDC, was achieved in 109 of 112 of cases (97%). The mean angiographic occlusion rate, or projected area of the aneurysm occluded by the coils, for all 110 successfully treated aneurysms was 94.6%. At latest clinical follow-up, 81 of 109 patients (74%) achieved good recovery with Glasgow Outcome Scale (GOS) score of I, 10 of 109 (9%) were moderately (GOS II) and 5 of 109 (5%) were severely (GOS III) disabled, 1 of 109 (1%) remained in a vegetative state (GOS IV), and 12 of 109 (11%) were dead. Of the subset of 77 patients with Hunt-Hess grades I to III, 68 (88%) achieved a good clinical outcome (GOS I). A statistically significant correlation was demonstrated between Hunt-Hess grade at presentation and final GOS outcome score ($\chi^2=41.4$, $P<0.0005$). Procedure-related permanent morbidity was 2.8% (3/109 patients). Repeated hemorrhage was observed in a single patient (0.9%) with a partially treated aneurysm.

**Conclusions**—The observed favorable outcome and low morbidity in this group of high-risk patients point to GDC embolization as an effective method for the endovascular management of patients with ruptured posterior circulation aneurysms. (Stroke. 2000;31:100-110.)

**Key Words:** cerebral aneurysm ■ embolization, therapeutic ■ occlusion ■ outcome ■ subarachnoid hemorrhage
for endovascular treatment with the use of GDC (Target Therapeutics) at the University of California at San Francisco (UCSF) Medical Center. A retrospective analysis and review were undertaken of the hospital and outpatient charts, the operative report, and all angiographic, CT, and MR studies. This was supplemented by follow-up clinical examination and telephone interviews.

**Angiographic Analysis**

Quantitative measurement of aneurysm size was performed with the use of digital subtraction angiographic projections obtained with externally placed 1-cm reference washers to correct for geometric magnification. Studies performed after 1996 used an on-board angiographic digital computer (Toshiba Corporation) for measurement of aneurysm height, width, and neck size. The analysis included determination of aneurysm shape, degree of aneurysm occlusion, and extent of aneurysm recanalization. The angiographic projections of the aneurysm used during initial treatment and subsequent follow-up studies were separately analyzed by 2 neuroradiological radiologists to determine the rate of occlusion of the aneurysm, which is the proportion of the projected area of the aneurysm occluded by coil placement. A third independent neuroradiologist was called on for arbitration in cases of discrepancy. One hundred percent occlusion was assigned only to aneurysms with dense packing and no contrast filling of the aneurysm fundus or neck. Aneurysm neck remnants were determined with respect to the total projected area of the aneurysm.

**Clinical Outcome Measures**

Clinical condition at the time of treatment was determined with the Hunt-Hess grading scheme. Outcome was measured with the Glasgow Outcome Scale (GOS) in which GOS I corresponds to good recovery and resumption of normal life despite minor deficits, GOS II to a moderately disabled but independent patient, GOS III to a severely disabled [but conscious] patient who is dependent on others for daily support, GOS IV to a persistently vegetative state, and GOS V to death; the Quality of Life Outcome Scale (QOL) in which QOL 1 corresponds to a patient with normal lifestyle, QOL 2 to a patient with minor neurological dysfunction but who is able to perform activities of daily living without help, QOL 3 to a patient needing assistance with daily activities, QOL 4 to one unable to perform activities of daily living and requiring full-time care, and QOL 5 to death); the Quality of Life Outcome Scale (QOL) in which QOL 1 corresponds to a patient with normal lifestyle, QOL 2 to a patient with minor neurological dysfunction but who is able to perform activities of daily living without help, QOL 3 to a patient needing assistance with daily activities, QOL 4 to one unable to perform activities of daily living and requiring full-time care, and QOL 5 to death); and the modified Rankin scale. Members of the UCSF neurovascular neurology team performed initial inpatient neurological examinations. Clinical data were obtained from neurological examinations by UCSF neurovascular neurologists during follow-up angiographic studies, from examinations by patients’ referring neurosurgeons and neurologists, and by telephone interviews with a neurosciences clinical nurse specialist.

**Clinical Management and Technical Complications**

Additional information included the interval between SAH and treatment, dates of retreatment, medical history and complications, initial signs and symptoms and their progression or resolution, rebleeding, presence or absence of vasospasm, treatment of vasospasm, adverse events during diagnostic angiography, adverse events during GDC embolization, and delayed complications. Adverse events were categorized by type of adverse event, imaging characteristics, and adverse event outcome.

**Statistical Analysis**

Clinical information, procedural information, follow-up, and angiographic data of all endovascular aneurysm treatments performed at UCSF since 1991 were maintained in a database, and statistical analysis was performed with the SAS Institute software package. ANOVA was used to compare outcome scores versus presentation and treatment characteristics, and the Tukey-Kramer honestly significant difference correction was used for comparison as appropriate. Additionally, Pearson’s χ² test was used to determine marginal homogeneity among nominal variables. A value of P≤0.05 was considered statistically significant.

**Embolization Technique**

The majority of cases used relied on general anesthesia by a dedicated neuranesesthesiology team with neumoscular blockade to prevent patient motion and improve control over patient hemodynamics in the case of an adverse event such as aneurysm perforation. A 6F or 7F vascular access sheath (Avanti, Cordis Endovascular) was inserted in the common femoral artery. Complete diagnostic angiography was performed through a 5F UCSF-II (Cordis) or 7F Berenstein (USCI-Bard) catheter with the use of biplane high-resolution digital subtraction angiography to evaluate the presence and extent of vasospasm and other intracranial vascular anomalies. After the optimal orthogonal view for embolization was determined, a baseline activated clotting time was obtained, and the patient was given a weight-based bolus of intravenous heparin (70 U/kg body wt). A repeated activated clotting time was obtained after the initial bolus, and additional heparin was administered to achieve a value between 250 and 300 seconds. Maintenance heparin was administered hourly at half the initial bolus dose. The heparin was reversed with an appropriate dose of intravenous protamine sulfate at the end of the procedure. After therapeutic anticoagulation was confirmed, a 6F (Envoy, Cordis) thin-walled, straight guide catheter was placed for vascular access. With the use of magnified real-time fluoroscopy and digital road-mapping techniques, a microcatheter (0.010F to 0.018F) was placed coaxially through the guide catheter and directed into the aneurysm with the aid of a microguidewire (0.010F to 0.016F). In cases of complex vascular anatomy, the microcatheter was appropriately steam-shaped to accommodate complex curves. GDC embolization of aneurysms was performed with GDC T10 (Target Therapeutics) electrolytically detachable coils. In cases of saccular aneurysms that had a definable neck, coils were used to obliterate the aneurysm fundus without impinging on the parent vessel. In fusiform ruptured aneurysms, the coils were used to occlude the aneurysmal segment of the parent vessel. Patients who underwent intentional parent vessel occlusion did not routinely undergo long-term follow-up surveillance angiography after determination of satisfactory occlusion at the end of the initial study with documentation of complete flow arrest. This management protocol was determined on the basis of the observation that a completely occluded parent artery does not undergo late recanalization.

**Results**

**Patient Demographics and Clinical Presentation**

The mean age was 52 years; age ranged from 18 to 79 years. There were 77 women (69%) and 35 men (31%). All patients in this series had an acute or subacute SAH and were classified according to Hunt and Hess. The median time to treatment after initial SAH was 4 days. The stratification of treated patients was as follows: grade I in 26 patients (24%), grade II in 24 patients (22%), grade III in 27 patients (25%), grade IV in 24 patients (22%), and grade V in 8 patients (7%).

**Aneurysm Characteristics and Morphology**

The most prevalent location was at the basilar bifurcation in 55 patients (49%) (Figure 2). Among treated aneurysms, 40 (37%) were saccular in shape and had a narrow neck (<4 mm), 14 (13%) were saccular and harbored a wide neck (>4 mm), 25 (23%) were fusiform, 19 (18%) were irregularly shaped or multilobed, and 8 (7%) were giant. Figure 3 shows a histogram distribution of the aneurysms by neck size (Figure 3A) and largest fundus dimension (Figure 3B).
Angiographic and Neurological Follow-Up

Angiographic follow-up was obtained in 76 of 82 patients (93%) treated with preservation of the parent vessel, with a mean angiographic follow-up of 7.2 months (range, 1 day to 55 months). Clinical follow-up was achieved in 104 of the 109 treated patients (95%). The mean duration of neurological follow-up was 13.1 months (median, 9.5 months; range, 5.1 to 56 months).

Technical Success

Endovascular treatment was successfully performed in 109 of 112 patients (97%; Figure 4). In 3 patients (3%), the decision to abort treatment was made after attempts to deploy the coils in the aneurysm were not successful. In 1 case with a fusiform left vertebral artery aneurysm and a contralateral right vertebral artery occlusion, the coils could not be placed without compromising flow in the parent vessel. In a second case of a fusiform basilar artery aneurysm, coils could not be placed that did not encroach on the parent vessel lumen. In the third case of a basilar tip aneurysm that incorporated the posterior cerebral arteries in the neck, no coil conformation could be found that did not encroach on the posterior cerebral arteries.

Angiographic Outcome

In this series of 110 aneurysms, 82 aneurysms were treated with preservation of the parent vessel, and 76 of 82 (93%) underwent follow-up angiography; the distribution of dura-
tion between initial procedure and latest angiographic follow-up is shown in Figure 5A. The initial mean angiographic occlusion rate for all 110 successfully treated posterior circulation aneurysms was 94.6%. The mean percent occlusion at final angiographic follow-up was 94.9%. The initial and final angiographic occlusion rates were determined by aneurysm type for the subset of non–parent vessel occlusion aneurysms that underwent angiographic follow-up (n = 82) (Figure 6).

Aneurysms at the most common location, the basilar bifurcation (n = 53), showed an initial occlusion rate of 96.6% and final occlusion rate of 95.1%. The results indicate occlusion at latest follow-up of >90% in all locations except for lesions of the basilar trunk, which were characterized by a wide neck and difficult morphology. Figure 7 illustrates a case of basilar tip aneurysm.

Overall, 54% of the non–parent vessel occlusion aneurysms were embolized to 99% to 100%, 40% were occluded to 90% to 99%, and 6% were incompletely occluded (≤90%) after initial embolization. Aneurysm neck size was found to be correlated with a lower final percent occlusion (Figure 8A). The final occlusion rate in the subset of aneurysms with neck size <4 mm showed significantly higher final occlusion compared with those with neck size of 4 to 6 mm (P<0.05) and those with neck size ≥8 mm (P<0.0001). Similarly, a trend was also identified between aneurysm fundus size and final extent of occlusion, with aneurysms with a fundus >12 mm having a significantly lower rate of final occlusion than those measuring 3 to 6 and 6 to 9 mm (P<0.002) (Figure 8B).

Recanalization After Treatment

Of the 76 aneurysms with angiographic follow-up, 77.6% (59/76) showed no evidence for recanalization, while 22.4% (17/76) did. Analysis of the aneurysms demonstrating recanalization revealed that 88.2% (15/17) had either a neck size >4 mm (16 aneurysms) or were fusiform (1 aneurysm). Two patients with initial 100% occlusions showed evidence of recanalization on follow-up angiography. The first showed 3% recanalization at 7 months and underwent no further treatment. The second was a patient
with a basilar tip aneurysm initially showing 15% recanalization at 28-month follow-up who underwent an unsuccessful attempt at retreatment. The patient returned 16 months later with further recanalization to 25% and underwent successful retreatment with occlusion of 99%. A follow-up angiogram 9 months later showed no change in aneurysm appearance.

Clinical Outcome

Clinical follow-up for >1 month was achieved in 104 of 109 treated patients (95%; mean duration, 13.1 months) (Figure 5B). At latest follow-up, 74% (81/109) of patients showed good recovery (GOS I), 9% (10/109) had moderate disability (GOS II), 5% (5/109) were severely disabled (GOS III), 1% (1/109) were vegetative (GOS IV), and 11% (12/109) were dead (Figure 9A). Overall, 83% (91/109) of patients had good recovery or moderate disability (GOS I and II) at the time of final follow-up. A statistically significant correlation was demonstrated between Hunt-Hess grade at presentation and final GOS outcome score ($\chi^2=41.4, P<0.0005$). All 26 patients presenting in Hunt-Hess grade I had a final score of GOS I. Of the 24 patients presenting in Hunt-Hess grade II, 46% (11/24) recovered to GOS I, 21% (5/24) improved to GOS II, 8% (2/24) recovered to GOS IV (4%), and 21% (5/24) deteriorated to GOS V status. Of the 8 patients with Hunt-Hess grade V at presentation, 25% (2/8) improved to GOS I, 13% (1/8) to GOS II, 1 to GOS III, while 50% (4/8) deteriorated to GOS V. Overall, of the patients presenting in Hunt-Hess grades I to III, 88% achieved a GOS I outcome score on final follow-up.

We used the QOL to assess the status of treated patients at final follow-up. A statistically significant relationship between Hunt-Hess grade at presentation and final QOL score was demonstrated ($\chi^2=54.6, P<0.00001$) (Figure 9B). A similar analysis of the modified Rankin outcome at latest follow-up established a significant correlation with Hunt-Hess grade at time of treatment ($\chi^2=71.1, P<0.00001$). Other variables at presentation were analyzed for their potential contribution to patient outcomes. Specifically, the presence of vasospasm was found to be inversely correlated with final clinical outcome as measured by GOS score ($\chi^2=15.6, P<0.008$). In contrast, patient age, sex, the presence of recanalization, the need for subsequent retreatment, and the location of the aneurysm were not significantly correlated with patient clinical outcome.
<table>
<thead>
<tr>
<th>Age/Sex</th>
<th>Aneurysm Location</th>
<th>SAH HH Grade</th>
<th>Nature of Complication</th>
<th>Symptoms</th>
<th>Treatment</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>67/F</td>
<td>Giant basilar trunk aneurysm</td>
<td>III</td>
<td>Delayed rehemorrhage in recanalized aneurysm (70%) 3 y after treatment Vertebral artery dissection</td>
<td>Coma</td>
<td>Medical None</td>
<td>Death Asymptomatic</td>
</tr>
<tr>
<td>52/F</td>
<td>Superior cerebellar aneurysm</td>
<td>III</td>
<td>Delayed PCA vasospasm/occlusion (day 9)</td>
<td>Blindness, Anton’s syndrome</td>
<td>Superselective papaverine and urokinase infusion</td>
<td>Partial recovery of left visual field</td>
</tr>
<tr>
<td>34/F</td>
<td>Intracranial fusiform vertebral artery aneurysm</td>
<td>III</td>
<td>Ventromedullary infarct after consecutive craniotomy (unsuccessful) and embolization</td>
<td>Left hemiparesis</td>
<td>Hypervolemia</td>
<td>Improved to mild hemiparesis</td>
</tr>
<tr>
<td>67/F</td>
<td>Superior cerebellar aneurysm</td>
<td>IV</td>
<td>Pontine hemorrhage, not adjacent to aneurysm and without a subarachnoid component</td>
<td>Obtundation, hydrocephalus</td>
<td>External ventricular drain</td>
<td>Significantly improved</td>
</tr>
<tr>
<td>44/M</td>
<td>Basilar bifurcation aneurysm</td>
<td>II</td>
<td>Intraprocedural aneurysm perforation</td>
<td>Hydrocephalus</td>
<td>Reversal of anticoagulant, completed coil embolization, ventricular drain</td>
<td>No permanent morbidity</td>
</tr>
<tr>
<td>45/F</td>
<td>Vertebrobasilar junction aneurysm</td>
<td>IV</td>
<td>Distal branch occlusion</td>
<td>Asymptomatic</td>
<td>Heparin 24 h, follow-up angiography</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
<tr>
<td>34/F</td>
<td>Fusiform PCA (P2-segment) fetal-type PCA</td>
<td>III</td>
<td>Retrograde thrombosis from PCA after parent vessel occlusion of P2 segment</td>
<td>Focal partial right MCA thrombosis, hemispheric ischemia</td>
<td>Superselective urokinase infusion</td>
<td>Successful complete recanalization without infarct, no permanent morbidity</td>
</tr>
<tr>
<td>47/F</td>
<td>Superior cerebellar aneurysm</td>
<td>I</td>
<td>Nonocclusive thrombus at coil interface</td>
<td>Asymptomatic</td>
<td>Heparin 24 h, follow-up angiography</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
<tr>
<td>39/F</td>
<td>Vertebrobasilar junction</td>
<td>III</td>
<td>Nonocclusive thrombus at coil interface</td>
<td>Asymptomatic</td>
<td>Heparin 24 h, follow-up angiography</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
<tr>
<td>55/F</td>
<td>Basilar bifurcation aneurysm</td>
<td>III</td>
<td>Nonocclusive thrombus at coil interface</td>
<td>Asymptomatic</td>
<td>Systemic abciximab (Gp IIb/IIIa)</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
<tr>
<td>62/F</td>
<td>Intracranial wide-necked vertebral artery</td>
<td>III</td>
<td>Coil encroachment on parent artery, leading to delayed vertebral artery occlusion</td>
<td>Asymptomatic</td>
<td>No treatment</td>
<td>No permanent morbidity</td>
</tr>
<tr>
<td>57/F</td>
<td>Basilar bifurcation aneurysm</td>
<td>II</td>
<td>Coil encroachment on PCA</td>
<td>Asymptomatic</td>
<td>Heparin 24 h, follow-up angiography</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
<tr>
<td>49/F</td>
<td>Posterior inferior cerebellar aneurysm</td>
<td>I</td>
<td>Coil encroachment on PCA</td>
<td>Asymptomatic</td>
<td>Heparin 24 h, follow-up angiography Snare redirection of coil end into aneurysm</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
<tr>
<td>34/F</td>
<td>Wide-necked mid-basilar</td>
<td>II</td>
<td>Coil unraveling</td>
<td>Asymptomatic</td>
<td>Coil successfully snared</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
<tr>
<td>64/F</td>
<td>Basilar bifurcation aneurysm</td>
<td>III</td>
<td>Coil unraveling</td>
<td>Asymptomatic</td>
<td>Coil successfully snared</td>
<td>Angiographic resolution, no permanent morbidity</td>
</tr>
</tbody>
</table>

HH indicates Hunt-Hess; PCA, posterior cerebral artery; MCA, middle cerebral artery; and Gp, glycoprotein.
Complications Associated With Endovascular Therapy

Aneurysm Rupture
One patient suffered late rebleeding (0.9%, 1/109 patients). This patient was a Hunt-Hess grade III with a ruptured giant fusiform distal basilar artery aneurysm that was treated with a staged embolization. A 90% occlusion was achieved but was complicated by an asymptomatic dissection of the left vertebral artery that progressed to a complete occlusion. Despite a good neurological recovery, a follow-up angiogram 21 months later showed 15% recanalization, but no further treatment was attempted because of inability to access the aneurysm. The patient suffered a recurrent SAH 3 years after initial treatment. An angiogram after the rehemorrhage showed a stable 75% occlusion. The patient died from complications related to recurrent hemorrhage.

Procedure-Related Mortality and Morbidity
There were no cases of procedure-related mortality in the series. Overall, there were 3 complications leading to permanent morbidity, for a rate of 2.8% (3/109 cases) (Table 1). Eight procedure-related complications were encountered that did not lead to a neurological deficit and were transient, for a rate of 7.3% (8/109 cases). These included 1 case of aneurysmal rupture, 1 case of asymptomatic branch occlusion successfully treated with superselective infusion of urokinase, 3 cases of transient nonocclusive thrombus, and 4 cases of herniation of a portion of a GDC into the parent vessel. We encountered technical problems during coil placement in 2 patients that necessitated coil removal by use of a microsnare device (Microvena).

Medical Complications
Patients in this cohort suffered concurrent medical complications, some of which were related to SAH. One patient suffered a myocardial infarction and aspiration pneumonia after treatment. Another patient developed a pulmonary embolus, which was treated to an uneventful recovery with anticoagulation. One patient with a Hunt-Hess grade V SAH suffered a repeated hemorrhage before treatment and subsequently developed severe vasospasm that was aggressively treated. The patient also developed pancreatitis, candida sinusitis, and severe fungemia. Three patients developed gastrointestinal bleeding, possibly due to stress ulcers.

Mortality
Sixteen treated patients died (16/109, 15%) during the course of this study. Nine of the sixteen (56%) presented initially in Hunt-Hess grade IV or V. This subset of patients had poor initial neurological condition, refractory vasospasm with subsequent infarction, and comorbid medical conditions (pneumonia, sepsis, congestive heart failure, and pulmonary edema). None of these patients showed improvement in their
TABLE 2. Continued

<table>
<thead>
<tr>
<th>HH III/IV (Excellent)</th>
<th>Indirect Mortality</th>
<th>Direct Mortality</th>
<th>Morbidity</th>
<th>Rebleed</th>
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<tbody>
<tr>
<td>59%</td>
<td>15%</td>
<td>0%</td>
<td>2.80%</td>
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<td>100%</td>
<td>8.8%</td>
<td>2.9%</td>
<td>3%</td>
<td>0%</td>
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<td>5%</td>
<td>N/A</td>
<td>5%</td>
<td>0%</td>
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<td>39%</td>
<td>6.6%</td>
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<td>N/A</td>
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<td>5%</td>
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<td>19.4%</td>
<td>6.4%</td>
<td>9.10%</td>
<td>2.9%**</td>
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<td>3%</td>
<td>2%</td>
<td>0.70%</td>
</tr>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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</tr>
<tr>
<td>N/A</td>
<td>3%</td>
<td>1.8%</td>
<td>3.60%</td>
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<td>18%</td>
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<td>2.2%</td>
</tr>
<tr>
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<td>N/A</td>
<td>2%</td>
<td>6%</td>
<td>%</td>
</tr>
<tr>
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<td>9.5%</td>
<td>0%</td>
</tr>
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<td>69%</td>
<td>N/A</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
</tbody>
</table>

neurological examination or outcome scores after endovascular treatment and before death.

Four patients who initially presented with Hunt-Hess grade II hemorrhages died. The first patient suffered from a rare anemia and developed a coagulopathy after a blood transfusion leading to a fatal hemorrhage from a previously unruptured pericallosal aneurysm. The second patient developed a massive gastrointestinal hemorrhage associated with severe cirrhosis, which led to hypotensive shock. The third patient with Wyburn-Mason’s syndrome with an arteriovenous malformation underwent successful coil therapy of a superior cerebellar feeding artery aneurysm but suffered a massive intracerebral hemorrhage from the arteriovenous malformation and died 30 days later. The fourth patient died as a result of overwhelming congestive heart failure, pulmonary edema, and pneumonia. Two patients died of myocardial infarctions during the follow-up period after discharge from the hospital.

Discussion
The primary goal of endovascular therapy is the prevention of repeated hemorrhage and its devastating consequences. The clinical experience from a series of ruptured aneurysms treated conservatively has demonstrated a 37% risk of rebleeding at 4 weeks and an overall mortality rate from repeated hemorrhage and its sequelae of 34% to 42%. In the context of this poor natural history, the results presented here for ruptured intracranial posterior circulation aneurysms indicate that GDC embolization confers a protective effect. We encountered no recurrent SAH in the acute phase after endovascular embolization. Furthermore, no aneurysm that was occluded to >75% by angiographic criteria rebled during the entire follow-up period.

The recurrent SAH rate and mortality from aneurysm repeated rupture in this series are 0.92% (1/109 patients). This corresponds to a yearly rebleeding rate of 0.85%/y, a rate similar to those reported in other endovascular series (Table 2), which range from 0%/y to 3%/y (Kuether et al, 1.4%; Eskridge et al, 3%; Pierot et al, 0%). Tsutsumi et al measured the rate of recurrent SAH at 1.4% to 1.8% in a group of 220 patients treated with surgical clipping during a follow-up period ranging from 3 to 21 years. The cumulative risk for recurrent SAH was estimated to be 0.5%, 2.2%, and 5.5% at 5, 10, and 15 years postoperatively, respectively. All the aneurysms in the surgical series were thought to have been completely clipped at surgery, in distinction to our series, in which the aneurysm that rebled was known to have been incompletely treated from the outset.

Clinical Outcomes
The initial clinical grade of the patient at presentation strongly predicted patient outcome. In this series, 94% of good-grade patients (Hunt-Hess I or II) had good recovery leading to a GOS I outcome at final follow-up. Intermediate-grade patients (Hunt-Hess III) predictably had a lower percentage of GOS I outcome (78%). This finding is consistent with other series that have reported lower percentages of good outcome for grade III patients: 55%, 57%, and 100%. In poor-grade patients (Hunt-Hess IV and V), fewer patients recovered to a good final outcome: only 46% of Hunt-Hess grade IV cases and only 25% of Hunt-Hess grade V patients achieved GOS I outcomes. All measured indices, including GOS, modified Rankin, and QOL, showed improved outcomes after GDC embolization when adjusted for the initial neurological condition. Late deterioration resulted from medical problems (7.3%, 8/109), vasospasm (8.3%, 9/109), and delayed complications (1.8%, 2/109). Our overall final excellent/good clinical outcome (GOS I/II) of 83% (91/109) is comparable to the 69% to 91% (average of 77%) GOS I/II outcomes seen in other series (Table 2). In the current single center study, 74% (81/109) of all treated patients recovered to a final GOS of I, compared with 69% of the ruptured subset of the multicenter series of 150 basilar bifurcation aneurysms. Comparison with other published series of endovascular treatment not limited to the subset of ruptured posterior circulation lesions reveals comparable outcome statistics. These series (Table 2) show GOS I outcome in 44% to 100% of good-grade patients, with a mean of 79%.

Angiographic Outcome
Small aneurysms with narrow necks and saccular shape demonstrated excellent initial and final occlusion rates. Overall, 88% of the treated non–parent vessel occlusion aneurysms were occluded in the 90% to 100% range, while all parent vessel occlusion–treated aneurysms (n=28) showed complete angiographic occlusion at the end of the treatment. In comparison, the multicenter study of 150 basilar apex aneurysms noted 75% of aneurysms at 90% to 100% occlusion after GDC embolization. Other series of posterior circulation aneurysms treated with GDC embolization (Table 2) report complete and near-complete (99% to 100%) angiographic occlusion in a mean of 62% of patients (range, 42% to 85%), compared with 54% in our series. In surgical series, Peerless et al reported an 87.4% rate of total occlusion by clipping, with a neck remnant seen in 5.8% and residual
aneurysm body or fundus in 6.8%. Recently, the series of Samson et al\textsuperscript{14} reported residual aneurysm after surgical clipping in 6% of cases by postoperative angiography. Complex aneurysm geometry was responsible for less than complete occlusion in almost all cases. In the present series, fully 39% of treated aneurysms harbored a wide neck (>4 mm), and 38% measured >10 mm in largest diameter. The difficulty in attaining complete obliteration of these complex aneurysms is shared with surgical series, which have similarly reported greater difficulty in complete occlusion by clipping in this group.\textsuperscript{34,35} Incomplete aneurysm occlusion by endovascular coil placement may still offer a measure of protection from rehemorrhage, as shown by the low repeated rupture rate in this and other series, although the threshold of occlusion needed to achieve such protection is unclear.

Histopathological examination of human aneurysms treated with GDC has shown that incompletely treated aneurysms develop an organized thrombus along the periphery of the aneurysm, possibly reinforcing the wall.\textsuperscript{36,37} Frank recanalization and aneurysm growth were noted in some wide-necked aneurysms with poor initial occlusion, a phenomenon similar to that recently reported by Mericle et al.\textsuperscript{38} Recent experimental modifications of the GDC, such as ion implantation and surface coating\textsuperscript{39} with collagen or growth factors,\textsuperscript{40} have led to improved endothelial proliferation on the coil surface and better aneurysm occlusion in animal studies. The possible future incorporation of these advances may eventually yield better intermediate and long-term angiographic occlusion in wide-necked and large aneurysms treated from an endovascular route.

Complications

There were no cases of procedure-related mortality in our series, compared with rates ranging from 0% to 6.4% in other endovascular series. The permanent morbidity rate of 2.8% compares favorably with other series ranging from 2% to 5% (Table 2). The permanent combined morbidity and mortality in our series was 3.7% (morbidity, mortality, and death from repeated hemorrhage). Other endovascular series have reported combined morbidity and mortality rates between 5% and 16.9%. A recent meta-analysis\textsuperscript{41} of 48 eligible endovascular studies totaling 1383 patients reported permanent complications in 46 of 1256 patients (3.7%; 95% CI, 2.7% to 4.9%).

Comparison With Surgical and Endovascular Series

Recent reports have compared endovascular and surgical treatment. Gruber et al\textsuperscript{22} performed a retrospective study of 41 patients with basilar apex aneurysms. Of the 11 who underwent GDC embolization after SAH, 91% had a GOS score of I or II compared with 73% for the 15 patients who underwent surgery in the same setting. Overall, patients who underwent GDC embolization had significantly better outcome ($P<0.001$) than patients who underwent surgery, even when poor-grade patients were excluded in that report. The second study by Vanninen et al\textsuperscript{33} described a prospective randomized trial of surgery versus endovascular therapy in 109 patients. Clinical outcome at 3 months showed 83% of coil-treated patients with posterior circulation aneurysm with GOS I and II scores compared with 60% of surgical patients. This study, which is limited by the small number of cases, failed to detect a statistically significant difference in final outcome. Leber et al\textsuperscript{23} performed a retrospective study comparing endovascular and surgical treatment of 248 aneurysms and concluded that the clinical outcomes showed no significant difference between the 2 methods in terms of safety and efficacy. This series analyzed 297 aneurysms, 162 treated surgically and 134 treated by endovascular techniques. Although these 3 studies have significant limitations, they suggest that short-term clinical outcome of patients treated with GDC embolization are at least equivalent to surgery. In the present study, restricted to posterior circulation aneurysms that in most surgical series have fewer favorable outcomes, we were able to demonstrate good outcomes (GOS I or II) in 94% of good-grade patients (Hunt-Hess I and II). This is comparable to the clinical outcome of similar cohorts in these 3 surgical/endovascular studies (Table 2) (GOS scores of 91%, 83%, and 91%, respectively). The 3 studies also reported the morbidity/mortality rates of the surgical versus endovascular approaches. Leber et al\textsuperscript{23} demonstrated a 6.2% mortality rate after surgery and 4.5% after endovascular treatment.

The surgical management of posterior circulation aneurysms has evolved significantly over the past 30 years.\textsuperscript{2,35,43,44} The international cooperative study described by Kassel et al\textsuperscript{45,46} included 266 patients treated for vertebrobasilar aneurysms. This series reported an overall death rate of 31.2%, good recovery in 52.6%, and a 7.9% incidence of severely disabled/vegetative outcome. Other surgical clipping series\textsuperscript{2,35,43,44} report mortality of 6% to 11% and morbidity of 10%. The most recent published surgical series by Samson et al\textsuperscript{44} describes the results of 303 aneurysms of the basilar apex, one third of which were unruptured. At 6-month follow-up, 81% of patients were judged to be neurologically intact or to have mild nonlimiting deficits (GOS I and II). Residual aneurysm was identified by follow-up angiography in 6% of patients. No patient suffered recurrent SAH during a mean follow-up of approximately 8 years. Other large series have shown similar outcome data, with GOS I and II outcome ranging from 82% to 85%.\textsuperscript{45,44,47–49} Any direct retrospective comparison of endovascular and surgical results is greatly hampered by differences in clinical condition at presentation, proportion of ruptured aneurysms, and acuity of treatment after SAH, since a longer wait before treatment selects better-grade patients). For example, our study had a higher
proportion of poor-grade patients compared with that of Samson et al.34 (29% Hunt-Hess IV and V versus 13%). The dependence of risk and complications on aneurysm location in surgical clipping and relative independence in endovascular treatment limits any direct comparison of results obtained with surgical and endovascular therapy. The criteria for difficulty and associated risk in treatment of an aneurysm are different. Whereas anatomic location and the required surgical exploration and exposure contribute to the morbidity of clipping, the angiographic determinants, such as neck size and aneurysm morphology, primarily affect the risk of endovascular therapy. The present study is probably characterized by a referral bias since a significant proportion of patients in the early phases of the study period were referred for coil therapy either because they were believed to be poor candidates for or had failed open surgical clipping. This partly accounts for the high proportion of fusiform aneurysms treated by parent vessel occlusion.

Despite the inherent limitations in comparing surgical and endovascular studies, the retrospective nature of this study, and potential selection and referral bias, our results of 0% direct mortality, 2.8% overall mortality, and 83% overall excellent/good outcome (GOS I and II) compare favorably with published surgical results of ruptured posterior circulation aneurysms.1,2,21,25,34,35,43,45–47 Our findings confirm that GDC embolization is effective in preventing repeated hemorrhage of ruptured posterior circulation aneurysms, and they also highlight the need for surveillance angiography in partially treated lesions. Future studies will be needed to determine the extended long-term outcome and efficacy of this endovascular therapy.

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