Available online at www.sciencedirect.com
ScienceDirect
Surgical Neurology 70 (2008) 368 – 377
SURGICAL NEUROLOGY
www.surgicalneurology-online.com

Aneurysm

Endovascular therapy of distal anterior cerebral artery aneurysms—an effective treatment option

Peter Waldenberger, MD[a], Johannes Petersen, MD[a], Andreas Chemelli, MD[a], Claudia Schenk, cand med[a], Ingrid Gruber, MD[b], Alexander Strasak, PhD[c], Wilhelm Eisner, MD[d], Ronny Beer, MD[e], Bernhard Glodny, MD[a,*]

Departments of [a]Radiology, [b]Vascular Surgery, [c]Medical Statistics, Informatics, and Health Economics, [d]Neurosurgery and [e]Neurology Innsbruck Medical University, Computer Sciences and Health Management, Innsbruck 6020, Austria

Received 12 April 2007; accepted 24 July 2007

Abstract

Background: Surgical treatment of APAs is associated with relatively high morbidity and mortality. The aim of this study was to illustrate the technical achievements of endovascular procedures in the distal anterior cerebral artery area, technical difficulties and how they can be overcome, and the outcome of endovascular treatment of APAs.

Methods: Between 1997 and 2006, of 49 patients with APAs at our institution, 29 were treated endovascularly (4.1% of all endovascularly treated aneurysms; F:M = 3.8; mean age, 52.8 ± 11.5 years), and 12 were treated surgically. Twenty-one (72.4%) of the endovascularly treated patients had a subarachnoid hemorrhage. The mean observation period was 25 ± 22.8 months.

Results: In 27 (93.1%) cases, complete occlusion of the aneurysm was achieved. The intervention led to 5 (17.2%) cases of minor complications with no neurologic deficits: 2 thromboembolisms, 1 local thrombus, 1 occlusion, and 1 recurrent hemorrhage. Mortality related to the intervention was 3.4%. There was no morbidity associated with the elective procedures. The dome-to-neck ratio is the main predictor of reperfusion. The most important factor impairing the outcome in terms of the GOS status is the presence of an intraparenchymal hematoma, followed by thrombembolic complications.

Conclusion: Endovascular treatment of APAs is feasible, safe, and effective. Mortality and morbidity are comparable with surgical therapy. An intraparenchymal hematoma has a severe negative influence on the patient's condition after rehabilitation. In these cases, surgical intervention should be considered. In case of incomplete occlusion of the aneurysm, prompt reintervention is required.

Keywords: Intracranial aneurysm; Pericallosal artery; Endovascular therapy; Subarachnoid hemorrhage; Embolization; Stent; Neuroform

Abbreviations: 3D-RA, 3-dimensional rotational angiography; APA, aneurysm of the pericallosal artery; CI, confidence interval; CT, computed tomographic; DCS, detach coil system; DSA, digital subtraction angiography; F, French; GCS, Glasgow Coma Scale; GDC, Guglielmi detachable coils; GOS, Glasgow Outcome Scale; H and H, Hunt and Hess; ISAT, International Subarachnoid Aneurysm Trial (ISAT collaborative group); MRI, magnetic resonance imaging; MRS, modified Rankin scale by Lindley; PA, pericallosal artery; WFNS, World Federation of Neurological Surgeons scale.

* Corresponding author. Tel.: +43 512 504 22761; fax: +43 512 504 22758.

E-mail address: bernhard.glodny@i-med.ac.at (B. Glodny).

0090-3019/$ – see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.surneu.2007.07.058

1. Introduction

Aneurysms in the terminal segment of the anterior cerebral artery, the PA, represent about 4.5% of all intracranial aneurysms [17]. In the ISAT, they represent, with 95 ruptures in 2143 random patients, only 4.4% of the ruptured intracranial aneurysms [27].

This is thus a relatively small patient group, but it exhibits several peculiarities; operative therapy is difficult because of interhemispheric adhesions, and there is not much room for surgical manipulation [17,26,8,41]. Additional aneurysms [29,40,8] and intraparenchymal hematomas often occur [38-41]. It is also noteworthy that the posttherapy rerupture rate in the distal anterior cerebral artery area is higher than in all other vascular areas, both after clipping and after coiling [1]. The mean perioperative mortality from 18 series with 382 aneurysms was 9.7% [17]. The 3 largest studies report a mortality of 23.3%, 5.9%, and 9.2% [39,29,14], and only 3 studies report a mortality of 0% [19,41,35]. The perioperative morbidity varies between 5% and 45% [8].

Attempts at endovascular therapy were initially futile because of technical difficulties—pericallosal aneurysms are difficult to reach because of their distal position and difficult to coil because of their small size [31]. Recently, however, it has been shown that APAs have become accessible to endovascular treatment because of improved equipment used [26,20]. Because there have thus far been only a few studies done on a relatively small number of patients, the aim of this study was to illustrate the technical achievements of endovascular procedures in the distal anterior cerebral artery area, technical difficulties and how they can be overcome, and the outcome of endovascular treatment of pericallosal aneurysms.

2. Methods

2.1. Patients

From January 1997 to May 2006, a total of 49 aneurysms of the anterior circulation area at the transition from segment A2 to A3 were diagnosed in 45 patients at our institution. Of the 45 patients, 29 underwent primary endovascular therapy. This decision was made by the surgeons. This corresponds to 4.1% of all endovascularly treated patients at our center. Twelve (26.7%) patients underwent surgery. Of the remaining 4 patients, 1 died before therapy could begin; the aneurysms of the other 3 patients have not yet been treated. The criterion for deciding on a particular therapy was the availability of endovascular treatment, which was initially offered by only 1 neuroradiologist. If endovascular therapy was not available, the patient was treated surgically.

The 29 endovascularly treated patients included 23 women and 6 men with a mean age of 52.8 ± 11.5 years. The APAs of a total of 28 patients were coiled. A fusiform aneurysm of another patient was stented primarily. All 28 APAs that were coiled were bifurcation aneurysms of the PA at the bifurcation of the callosal marginal artery. Twenty-one patients had developed subarachnoidal bleeding from the APA: 4 of them presented with H and H grade I, 3 with grade II, 7 with grade III, 4 with grade IV, and 3 with grade V. Eight interventions were elective. The aneurysms in these patients were found incidentally during angiography or CT examinations done for other reasons. Treatment of all patients was done in consensus with the neurosurgeon consulted.

The retrospective evaluation of data was carried out in adherence to the Declaration of Helsinki. Institutional ethical approval was waived because the study had no influence on treatment, and our institutional ethical review board did not require its approval for this study. In the cases in which it was possible, written consent was received for all measures carried out and for the data analysis for research purposes.

2.2. Aneurysms

Twenty aneurysms were located on the left side, 9 on the right. The median size of the aneurysms was 4.8 mm (mean, 5.4 ± 3 mm; range, 1.5-12 mm) by 4 mm (mean, 4.1 ± 1.9 mm; range, 1.5-8 mm). Eleven (37.9%) aneurysms were larger than 5 mm, and 2 (6.9%) aneurysms were larger than 10 mm. There were no dissecting, traumatic, or mycotic aneurysms. No branches were involved. Sizes and attributes of the individual aneurysms are shown in Table 1.

2.3. Procedure description

Endovascular treatment was carried out before 2000 on a monoplane angiography unit (Philips Integris V3000, Philips Medical Systems, Best, the Netherlands), thereafter, on a biplane angiography unit (Philips Integris V5000, Philips Medical Systems), in all cases after prior therapy planning based on DSA and 3D-RA with a mechanical injection of contrast medium (18 mL; flow, 3 mL/s; 6 seconds; 180° rotation).

A number of unusual steps and materials differed from standard coil embolization procedures. A stable 6F guiding catheter (Envoy, Cordis Neurovascular Inc, Miami, Fla, or Softip, Boston Scientific, Fremont, Calif) was sometimes placed more distally than usual in the internal carotid artery to achieve greater stability of the microcatheter if necessary. Assisted by different fine 0.0010- and 0.0014-in microguidewires (Silver Speed 10, Micro Therapeutics Inc, Irvine, Calif; Essence, Boston Scientific; Transend-Ex, Boston Scientific), a microcatheter (straight-tip Prowler 10 and Prowler 14 microcatheters, Cordis Neurovascular Inc, and Excelsior SL 10 microcatheter, Boston Scientific) was inserted into the distal segment of the anterior cerebral artery. After retrieving the microguidewire, the manually J-shaped preformed microcatheter was placed in the aneurysm neck, in most cases by simple slow backtracking, using fluoroscopy in 2 planes simultaneously. In this way, the tip of the microcatheter can glide into the aneurysm neck and can then be advanced to the working position. The 28 saccular aneurysms were embolized by placing soft or ultrasoft detachable microcoils under fluoroscopy (Table 1 and Fig. 1A and B). Table 1 shows the specifications and quantities of the detachable platinum coils or the specifications and dimensions of the Neuroform 2 stent (Boston Scientific) used. To prevent rehemorrhaging, the maximum possible number of coils was inserted into each aneurysm.

In case of subarachnoidal bleeding, the intervention was always done as soon as possible, using general anesthesia and usually with heparinization for 24 hours. An intraparenchymal hematoma, which occurred in 12 (41.4%) cases, was viewed as a relative contraindication for heparinization,

Table 1
Specifications and quantities of detachable platinum coils

Patient	Maximum diameter of aneurysm (mm)	Neck size	Dome-to-neck ratio	Direction of aneurysmal dome	Specification of coils	No. of coils	Dimensions of coils (mm/cm) and J-coils (cm)
1 (F, 41)	2			Cranial anterior	Neuroform 2 stent (Boston Scientific)		2.5/15 (stent)
2 (F, 52)	8	1	2	Right side	GDC (Boston Scientific)	3	5/15, 4/10, 3/6
3 (F, 51)	8	0.4	8.2	Anterior	DCS (Cordis, Cook, Bjaeverskov, Denmark)	6	6/15, 6/9, 4/10, 3, 6
4 (F, 66)	12	4.3	1.2	Anterior	GDC (Boston Scientific), Micrus microcoils	11	8/16, 7/15, 6/10, 5/10, 4/10, 4/6, 3/4, 6/12, 3/5, 5, 2/4
5 (F, 72)	5	5.7	1.4	Cranial anterior	GDC (Boston Scientific)	2	3/8, 2/4
6 (M, 49)	5	2.2	1.7	Anterior	GDC (Boston Scientific)	4	5/12, 4/8, 3/6, 2/3
7 (F, 60)	12	3.6	1.4	Caudal anterior	GDC (Boston Scientific)	6	8/20, 5/15, 3/10, 2/6
8 (F, 55)	4	7.1	1.0	Cranial anterior	GDC (Boston Scientific), DCS (Cordis), Micrus microcoils	2	2.5/6, 2/3
9 (F, 38)	10	2.6	1.0	Anterior	GDC (Boston Scientific)	8	7/25, 7/10, 6/10, 6/20, 4/10, 4/8, 3/8
10 (F, 43)	7	2.5	2.9	Cranial anterior	GDC (Boston Scientific)	5	7/15, 4/8, 2.5/4, 2/3
11 (F, 34)	2	1.8	2.3	Cranial anterior	GDC (Boston Scientific)	2	2/4, 2/1
12 (F, 34)	2.5	1	2.2	Anterior	GDC (Boston Scientific)	2	2/4, 2/1
13 (F, 54)	8	1.1	1.8	Cranial anterior	GDC (Boston Scientific)	3	6/20, 4/10, 3/6
14 (F, 50)	3	3	2.4	Cranial anterior	DCS (Cordis)	3	3/3, 2/2, 2/1.5
15 (F, 51)	2	2	1.5	Anterior	GDC (Boston Scientific)	1	2/2
16 (M, 37)	1.5	1.1	1.9	Cranial anterior	GDC (Boston Scientific)	1	2/2
17 (F, 60)	8	1	1.5	Cranial anterior	GDC (Boston Scientific), Micrus microcoils	8	8/16, 7/14, 7/15, 5/10, 4/8, 3/10, 2/4
18 (F, 48)	4	3	2.7	Cranial anterior	GDC (Boston Scientific)	2	4/8, 2/4
19 (M, 47)	6	2.2	1.8	Cranial anterior	DCS (Cordis)	4	5/15, 5/5, 4/3, 3/3
20 (F, 74)	5	4.0	1.2	Cranial	GDC (Boston Scientific)	2	4/8, 2/4
21 (M, 67)	3	2	2	Anterior	GDC (Boston Scientific)	2	2/4, 2/1
22 (F, 65)	3	1.5	1.4	Cranial anterior	GDC (Boston Scientific), Micrus microcoils	6	2/2, 2/3, 2/4, 3/8, 2/2.5
23 (F, 49)	6	1.9	1.2	Cranial	GDC (Boston Scientific)	2	6/15, 3/12
24 (M, 56)	4	2	3	Cranial anterior	GDC (Boston Scientific)	1	2/4
25 (F, 54)	3	4	1	Cranial anterior	GDC (Boston Scientific)	1	3/6
26 (F, 50)	8	2.4	1.3	Cranial anterior	GDC (Boston Scientific)	3	2/4, 2/2
27 (M, 76)	5	3.9	1.9	Cranial anterior	GDC (Boston Scientific)	2	4/10, 3/8
28 (F, 57)	3	1.9	2.1	Caudal anterior	GDC (Boston Scientific)	1	3/6
29 (F, 40)	4.5	1.2	2.5	Fusiform aneurysm	GDC (Boston Scientific)	1	2/4

to retain the possibility of removing the hematoma. However, heparin was contained in the catheter pressure infusion systems, and these patients received up to 5000 IU of heparin during the intervention as well. The indications for long-term aspirin therapy (100 mg, n = 8 patients) were vasospasm with flow limitation during the intervention, formation of a thrombus at the end of the coil or thromboembolic events, and coil herniation into the parent artery.

2.4. Follow-up and evaluation of treatment

Follow-up angiography examinations were done after 6 and 12 months, thereafter annually. The angiograms were reviewed by 2 experienced radiologists who had not been involved in the treatment of the patients. In case of residual perfusion or reperfusion of the aneurysm, recoiling with an angiographic follow-up according to the same schedule was done, depending on the initial finding or the dimensions. If the results of the angiography and MRI follow-ups were consistent with each other 24 months after the intervention, further annual MRI follow-ups ensued. The degree of the initial occlusion of the aneurysm was scored as follows: complete (99%-100%), subtotal (95%-99%) with a neck remnant, or incomplete with only a loose or partial aneurysm packing or partial opacification [6,7]. For objectivity, the size of the residual perfusion or reperfusion was given in millimeters. The median follow-up period was 21.5 months (mean, 25 ± 22.8 months; range, 1-83 months). Follow-up on 23 patients was done at our center (long term-follow up, >2 years in 10 patients). Six patients were not available for follow-up and were lost from the study.

2.5. Compiled parameters and statistics

For acquiring data on the initial condition of the patients, the treatment itself, and the outcome and characteristics of the aneurysms, the following qualitative and quantitative factors were used: patient age and sex, initial H and H grade, presence of an intraparenchymal hematoma, size and location of the aneurysm, dome-to-neck ratio, direction of the aneurysms, number of originating vessels, number and dimension of the coils, degree of occlusion, residual perfusion and reperfusion, concomitant medications, associated aneurysms, GCS before acute treatment, GOS after

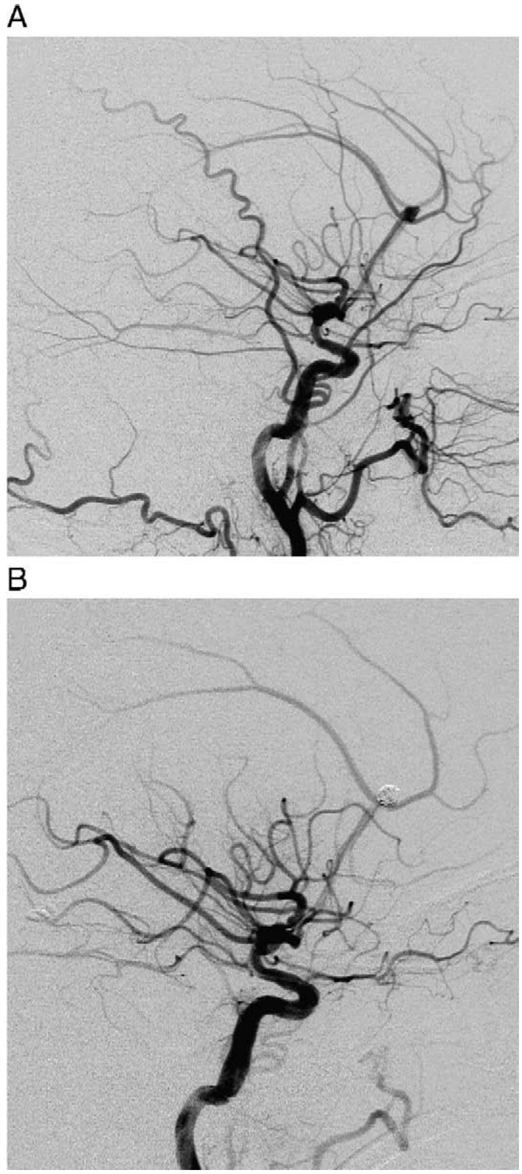

Fig. 1. A and B: Digital subtraction angiography of an APA at the bifurcation of the pericallosal marginal artery. Access with the microcatheter (Fig. 1A) and embolization by placing microcoils (Fig. 1B).

acute treatment and after rehabilitation, the MRS, and the WFNS scale. With regard to the anatomical and clinical result of treatment, odds ratios with 95% CIs were estimated from multivariate logistic regression models, including variables on initial patient condition using GSC and H and H scores, properties of the aneurysms, and procedure-related variables. Different regression models were fitted by first including all mentioned variables as covariates and then by using a forward, stepwise, variable selection procedure, excluding variables with probability values of more than 0.10. All calculations were done with the aid of the Excel program from Microsoft (Seattle, Wash), GraphPad Prism Software Version 4 from GraphPad Software (San Diego, Calif), and SPSS 14.0 (SPSS Inc, Chicago, Ill).

3. Results

3.1. Aneurysms

The mean size of the ruptured aneurysms was 5.4 ± 3.1 mm, whereas the mean size of the aneurysms that did not rupture was 5.1 ± 2.8 mm. Eleven (52.4%) ruptured aneurysms were smaller than 5 mm. No branch originated from any of the aneurysms. Seven aneurysms showed 1 daughter aneurysm, and another 7 had 2 daughter aneurysms. Table 1 shows the size of the aneurysms, neck size, dome-to-neck ratio, direction of the aneurysm dome, associated aneurysms, specifications, and number and dimensions of the coils used. Fig. 2 demonstrates a typical APA.

3.2. Feasibility of treatment

Various technical measures and technical precautions were taken to overcome special problems.

1. If the aneurysm could not be reached using standard procedures because of its distal location and distally increasing instability of the microcatheter, the guiding catheter was placed further distal into the internal carotid artery. Care was taken not to interfere with the flow of the carotid artery and PA. Using this means, all aneurysms could be reached with the microcatheter (n = 8).
2. If the guiding catheter/microcatheter combination still appeared to be too unstable, a 6F Envoy guiding catheter was used as the inner component of a standard coaxial guiding system (eg, 8F Casasco catheter, Balt, Montmorency, France) (n = 1). To avoid perforation of the particularly small and fragile aneurysms, the microcatheter was first advanced past the aneurysm into the distal PA using the guidewire. Then the wire was withdrawn until its tip was inside the microcatheter. After this, the preformed J-shaped catheter tip inserted before the intervention was withdrawn. It then usually glides into the aneurysm neck and can then be advanced into the working position. As an additional precautionary measure, the finest atraumatic wire available was chosen (Silver Speed 10, Micro Therapeutics Inc). Microcatheters with extremely fine tips were given preference (straight-tip Prowler 10, Cordis Neurovascular Inc).
3. To achieve the best possible control of the microcatheter, coiling was always done under simultaneous fluoroscopy in 2 planes.
4. To avoid uncontrolled changes of the position of the catheter tip during the coiling procedure, soft or ultrasoft coils were used (Table 1).

Using these measures, all aneurysms could be reached with the microcatheter system. In 27 (93.1%) of 29 patients, primary occlusion of the APA was successful. In each of 2 partially thrombotic aneurysms, only part of the aneurysm could be occluded (approximately two thirds of the aneurysm)

Fig. 2. Patient with an APA along with an aneurysm of the right middle cerebral artery.

because progressive thrombotization occurred during the intervention. This issue could not be overcome by any means.

3.3. Illustrative case

Fig. 3A shows the convoluted and elongated internal carotid artery of a 43-year-old patient, whose APA had hemorrhaged. Because of 2 curves in the carotid artery, there were 2 changes in direction of more than 180° of the microcatheter/wire system that caused instability of the microcatheter tip as the coil passed through microcatheter, and there was a risk that the aneurysm would be perforated or that the catheter tip would slip out of the aneurysm (Fig. 3B and C). In this case, the microcatheter tip was stabilized by using ultrasoft coils.

3.4. Immediate postinterventional results

Immediately after intervention, the occlusion of the aneurysm was considered complete in 27 of 29 cases. In 2 cases, the occlusion was incomplete.

Five (17.2%) patients had the following minor complications during intervention:

1. one proximal occlusion of the A3 segment with retrograde perfusion with no subsequent infarction;

Fig. 3. A, B, and C: A 43-year-old patient with hemorrhaged aneurysm. Convoluted and elongated internal carotid artery and clearly elongated internal carotid artery. The microcatheter tip could be stabilized by using ultrasoft coils.

2. one small apposition thrombus from the aneurysm neck into the vessel, which was subsequently dissolved by intra-arterial lysis;
3. one discrete recurrent bleeding from the aneurysm because of its complete occlusion in a patient who was completely healed, with no neurologic deficit, at the 12-month follow-up;
4. one clinically and neurologically irrelevant infarction of the adjacent area 24 hours postintervention; and
5. one thromboembolic event in the PA during the procedure with sufficient retrograde perfusion and no infarction.

There were no major complications. No minor or major complications occurred during any of the elective procedures.

3.5. Short-term postinterventional results

Within the first 30 days after intervention, the following major complications occurred:

1. One intracranial hemorrhage of unclear etiology due to bleeding from the anterior choroidal artery into the lateral ventricle 3 weeks after the procedure. This occurred in a 56-year-old man with an initial H and H grade of III and a GOS score of III during acute treatment and who remained impaired in the further course and required assistance, with a GOS score of III.
2. One secondary hemorrhage due to incomplete embolization caused by a partial thrombosis of the aneurysm. This occurred in a 60-year-old woman with one of the largest aneurysms (12 mm) of all patients. The patient died.

3.6. Medium-term postinterventional results and reinterventions

Five patients exhibited a slight reperfusion of the aneurysm neck at the 6-month checkup. This was handled as follows:

1. In 1 patient, a further checkup was performed after an observation period of 12 months because of the small size of the reperfused aneurysm neck. There was no change. The size of the reperfused segment was 1 × 1 mm.
2. In another patient, a follow-up was planned (reperfused neck segment, 1 × 1 mm).
3. In 1 patient, recoiling was done after 22 months, leading to complete occlusion (reperfused neck segment, 2.5 × 1.9 mm; Fig. 4).
4. In 2 patients, recoiling was done immediately after the 6-month checkup, also leading to complete occlusion without any complications (reperfused neck segments, 2 × 2 and 3 × 1.5 mm).

In 1 patient, the well-known residual perfusion (3 × 3 mm) of the aneurysm due to incomplete occlusion because of partial thrombotization was seen at the 6-month checkup. Contrast enhancement of the aneurysm showed that the thrombus was dissolved and recoiling possible; however, during this intervention, fulminant hemorrhaging set in, which finally led to the patient's death.

3.7. Properties predicting the anatomical and clinical outcome

Regarding incomplete occlusion, no predictors or risk factors could be identified because only 2 aneurysms had been occluded incompletely. The dome-to-neck ratio and the width of the aneurysm neck are positive but insignificant predictors of reperfusion after 6 months (Table 2). All other variables in terms of initial patient condition,

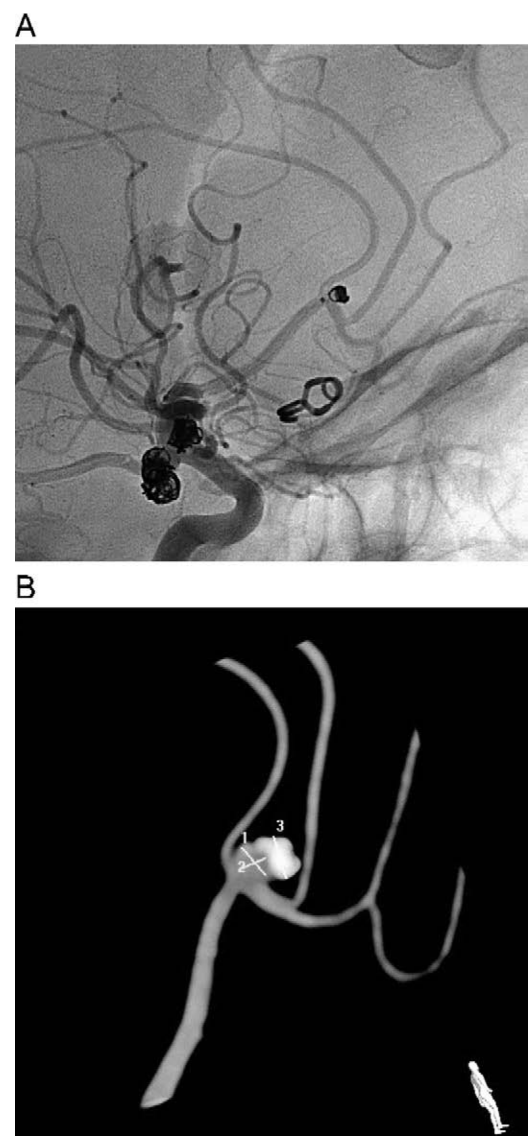

Fig. 4. A and B: Angiography (Fig. 3A) and 3D-RA (Fig. 3B): Reperfusion of a neck segment of an APA in a patient with multiple aneurysms (ICA on the right side, coiled; MCA on the right side, coiled; MCA on the left side, clipped). The microcatheter is placed in the PA.

Table 2
Predictors of reperfusion

Predictor	Odds ratio	CI	Significance (*P*)
Dome-to-neck ratio	10.1	0.2-2085.6	.198
Width of aneurysm neck	4.8	0.21-109.9	.329

medication, and properties of the aneurysms were irrelevant. There were no clearly distinguishable predictors of minor or major complications.

The most important factor impairing the outcome in terms of the GOS status after the intervention was the presence of an intraparenchymal hematoma, followed by thrombembolic complications and the initial GCS score. The presence of associated aneurysms and all other variables were irrelevant (Table 3). Regarding survival, there was 1 predictor of a poor outcome: the initial condition of the patient, expressed as a poor GCS score (odds ratio, 0.774; 95% CI, 0.609-0.983; $P = .036$).

3.8. Outcome

During the follow-ups after the 6-month checkups, no new reperfusion of aneurysms was observed. One patient died because of secondary hemorrhaging from an incomplete occlusion within the first 30 days, and 1 patient died because of secondary hemorrhaging from an incomplete occlusion during a reintervention 7 months after the initial hemorrhage. Mortality related to the intervention was thus 3.4%.

At the end of the observation period, the following figures were determined for outcome (Table 4). The patients who underwent elective treatment all had an MRS score of 1 or a WFNS grade of I (100%). Thirteen (44.8%) patients had no symptoms or symptoms that did not interfere with daily life (MRS score, 0 or 1; WFNS grade, I or II). One (3.5%) patient was assigned an MRS score of 2/WFNS score of III. Three (10.3%) patients had an MRS score of 3 or WFNS score of III. Six (20.7%) patients had died (MRS score, 6). Six patients could not be followed up.

4. Discussion

The results of this study show that APAs are accessible and treatable endovascularly and provide an approach to potential technical difficulties. Mortality is related to the initial condition of the patient, predicted by poor initial H and H or GCS scores. The mortality of the procedure itself is 3.4%; morbidity is 17.2%. An elective procedure is associated with neither morbidity nor mortality. The condition of the patients after rehabilitation depends basically on the initial GCS and H and H scores as well as on the initial presence or absence of an intraparenchymal hematoma.

The only risk factor for reperfusion of the aneurysm is the dome-to-neck ratio. Any reperfusion occurred within the first 6 months after the intervention. Thereafter, the aneurysms treated were stable, and no reperfusion occurred.

At our center, we strive for the fastest possible intervention in case of any hemorrhage, irrespective of the clinical condition of the patient, even including patients in poor to very poor initial condition. We do not postpone treatment for any patient, not even for those in poor initial condition. The reasoning behind this is that rehemorrhaging is associated with a greatly increased rate of long-term disability for the patient, if he survives the new event at all, because the mortality rate is then about 50% [2]. In particular, patients with an initial poor GCS, WFNS, or H and H score seem to experience an increased rate of rehemorrhaging [10,12,16,23], and rehemorrhaging often occurs within the first 24 hours after the initial hemorrhage [2,10]. Although statistically speaking, a poor initial condition is associated with a poor outcome, an individual case can never be predicted with certainty beforehand, and there is a group of patients who are capable of independent living later on [22].

Table 3
Predictors of the outcome of the patients in terms of the GOS status after intervention

Predictor	Odds ratio	CI	Significance (*P*)
Intraparenchymal hematoma	102.4	1.6-6686.0	.030
Thrombembolic complications	56.2	0.4-8825.1	.116
Initial GCS score	2.1	1.0-4.4	.049

Table 4
Initial conditions of patients and outcome postintervention and after rehabilitation

Patient	Initial condition/ H and H	GOS score postintervention	GOS score after rehabilitation
1 (F, 40)	0	5	5
2 (F, 40)	0	5	5
3 (F, 52)	0	5	5
4 (F, 51)	0		
5 (F, 66)	V	1	Died
6 (F, 72)	III	1	Died
7 (M, 49)	I-II	1	Died
8 (F, 60)	IV	1	Died
9 (F, 55)	III		
10 (F, 38)	III	3	3
11 (F, 43)	V	1	Died
12 (F, 34)	I	5	5
13 (F, 34)	I-II	5	5
14 (F, 54)	I	3	4
15 (F, 50)	0	5	5
16 (F, 51)	IV		
17 (M, 37)	0	5	5
18 (F, 60)	0	5	5
19 (F, 48)	II	5	5
20 (M, 47)	0	0	Died
21 (F, 74)	II-III	2	
22 (M, 67)	IV-V	2	
23 (F, 65)	IV		
24 (F, 49)	V	5	5
25 (M, 56)	III	3	3
26 (F, 54)	I	5	5
27 (F, 50)	I	5	5
28 (M, 76)	III	3	3
29 (F, 57)	II-III	5/1	5/1 (died)

Our study included a woman who was unconscious with and H and H grade of V on admission but who has now resumed normal activity for 2 years with no neurologic deficits. This policy explains most deaths that occurred in our study—these were patients who already had a poor primary prognosis due to poor GCS and H and H scores.

Our study also includes peculiarities of APAs. They are, consistent with earlier information [14,8,29,43] and despite a probable inclusion of selection bias because of the retrospective design of our study, often associated with other aneurysms. In our study, only 2 of these aneurysms hemorrhaged, but in principle, all of these aneurysms can be the source of a subarachnoid hemorrhage, and thus, all require treatment, which, in our center, is usually carried out simultaneously with the treatment of APAs, if possible, or in staged procedures. On the one hand, these additional aneurysms could contribute to the high morbidity and mortality in patients with APAs as seen in literature, but on the other hand, the accumulation of aneurysms in these patients could also be an indication of an underlying vascular wall weakness, which causes these aneurysms to be especially fragile [8]. In any case, in our study, the presence of additional aneurysms was not associated with a tendency to deterioration of the anatomical or clinical outcome.

The particular fragility of APAs is also confirmed by our data: 52.4% of the aneurysms that hemorrhaged were smaller than 5 mm, and the mean size of the hemorrhaged aneurysms was, at 5.4 mm, also smaller than would be generally anticipated for ruptured intracranial aneurysms [30,34]. In ruptured aneurysms, the extent of bleeding of smaller aneurysms is more pronounced than for larger aneurysms [34]. This could be an explanation of the fact that in our study, relatively many patients had an initially high H and H score and were in poor initial condition. Whereas in the ISAT study [27], 37% of the patients were in WFNS stage II or higher, and only 12% of the patients were in WFNS stage III or higher initially, in our study, 14 (48.3%) patients had an H and H grade of III or higher, and 7 (24.1%) patients had an H and H grade of IV or higher. To the extent that the 2 classification systems are comparable, the portion of patients who were already primarily unconscious in our study is very high, although the extremely peripheral location of APAs would initially appear to be a favorable factor for prognosis [32]. The observation that the ruptured as well as the nonruptured APAs are quite small confirms the results of earlier studies [8,9,14,29,35,40]. It is assumed that this is so because they rupture before reaching the size of aneurysms in other areas [8,4,14]. Although we also did not carry out a longitudinal study of the patients, our findings are consistent with this hypothesis. In our study, there was also a case of an azygos anterior cerebral artery with an aneurysm. However, this isolated observation does not support the hypothesis of a possible nonrandom high coincidence [8,3,15,18,28,21]. Twelve (41.4%) patients had initially experienced an intraparenchymal hematoma due to a ruptured aneurysm. This is an unusually high incidence and is a peculiarity of ruptured APAs, although this value is clearly lower than the data known from literature, which indicate an incidence of 48% to 73% [38-40,42]. Statistically highly significant, such an intracranial hematoma is associated with a poor prognosis.

Thus far, there have been only a few reports on the endovascular therapy of APAs. In an initial study [31] of 8 aneurysms in 1996, only 2 could be successfully coiled, because of technical difficulties. The aneurysms were too small and too peripherally located for endovascular treatment. In 2002, Menovsky et al [26] reported the complete coiling of 11 of 12 APAs and the “nearly complete” coiling of a twelfth aneurysm with no morbidity and no mortality. It is remarkable that only patients with H and H grades II to IV were treated. This contradicts the observation that normally, about 20% of ruptured intracranial aneurysms present in stage I [11]; therefore, bias due to the small number of cases in the study must be assumed. No information was provided as to how many ruptured aneurysms were treated surgically instead of by endovascular means. It was thus impossible to rule out selection bias toward aneurysms that were easy to treat endovascularly. In contrast to this, Keston et al [20] report high morbidity in a study of 18 patients: 3 (18%) of the 17 treatable patients had a rerupture of the aneurysm caused by the insertion of the catheter or placing a coil that was too large. One aneurysm was not accessible to endovascular treatment because vessels branched off from it, and 2 (12%) aneurysms could not be accessed by a microcatheter. All together, only 50% of the aneurysms could be completely occluded, and accordingly, rebleeding occurred in 1 patient 2 years after the initial coiling. All parameters mentioned are above average in comparison with other studies on aneurysms in other supratentorial regions [33,27].

In our study, every one of the far distal aneurysms could eventually be reached with the microcatheter by selecting a guiding catheter that, depending on need, could be placed further distal into the carotid artery than normal. Care was taken not to impair the blood flow to avoid a further increase of the already existing risk of thromboembolism [26]. In addition, Menovsky et al [26] reported the risk of thromboembolism with consecutive infarction or localized thrombus formation, the problem of vascular spasm up to occlusion, and rehemorrhaging during the procedure before complete occlusion. However, these complications do not occur more often than in other vascular areas as compared with data from literature [33]. The danger of rehemorrhaging during the procedure was minimized by probing the aneurysm without using a guidewire. The problem of instability of the soft microcatheter system together with a very fine wire, as described by Keston et al [20], was solved by using soft or ultrasoft coils—in all cases, the system was sufficiently stable for the procedure of occlusion of the aneurysm using these coils. Only 6.9% of the aneurysms of the PA could not be completely occluded—at any rate not more than in other studies [37,5], although the initial small size of the aneurysms presented a special technical difficulty. However, both patients in whom complete occlusion was not successful experienced recurrent hemorrhaging that eventually led to their deaths. In patients whose aneurysm cannot be completely occluded initially, prompt further treatment after a short interval is thus urgently indicated to prevent rebleeding because incomplete occlusion does not seem to change the well-known extremely poor quoad vitam prognosis of APAs, with a mortality of 80% in their natural course [36]. For these aneurysms, the possibility of stent placement should be examined [13], or surgical intervention should be considered. If the aneurysm can be completely occluded, it is possible that during the first 6 months, coil compaction could lead to slight reperfusion of the aneurysm. The only identifiable risk factor for this incident, which can be treated by recoiling, is a large dome-to-neck ratio of the aneurysm. In this respect, there is no difference from other vascular areas [37]. After more than 6 months, reperfusion of the aneurysm no longer occurs, so that it appears to be justifiable, assuming that after 2 years, the angiographic and MRI findings are consistent with each other, to follow up the endovascularly treated APAs with MRI examinations alone. After more than 6 months of observation, no new factors appeared, and the long-term results were stable. However, long-term follow-up should always be aimed for because recurrent hemorrhaging despite complete occlusion of the aneurysm and despite the absence of reperfusion affects anterior circulation (anterior communicating artery, middle cerebral artery, PA) almost exclusively for as-yet-unknown reasons [1]. However, no such case occurred in our study.

The direct comparison of endovascular with surgical treatment of aneurysms of the PA is difficult because of the heterogeneous nature of surgical therapy. Three neurosurgical studies with medium or small case numbers of 23, 16, and 11 patients [35,41,24] indicate a mortality rate of 0%, whereas the mean mortality from 18 studies including 382 patients before 1998 was 9.7% [17]. This mortality appears to have decreased somewhat since then but still amounts to between 5.5% and 6.9% [25,8]. Minimally invasive approaches will surely give rise to further progress. Data on intraoperative morbidity are rare. However, it can be assumed that it is generally higher than the mortality rate, and the data also show large fluctuations and lie between 0% [35] and 5% to 50% [38,4,24,19,39,41,43]. One disadvantage of surgical treatment is certainly that most associated aneurysms cannot be reached simultaneously from 1 approach. One of the greatest advantages of surgical therapy is that an intraparenchymal hematoma, which greatly influences the outcome as measured by the GOS score after rehabilitation but is not treatable endovascularly, can be treated simultaneously with the surgical treatment of the aneurysm. The presence of an intraparenchymal hematoma must thus be considered a criterion for open surgery and (eventuell "against endovascular treatment" Weglassen) against endovascular treatment and for open surgery.

Overall, endovascular therapy is comparable with surgical therapy with respect to its mortality of 3.5%, if the case of the fatal rerupture during reintervention for incomplete aneurysmal occlusion is included, and with respect to the morbidity of 17.2%. In elective procedures, endovascular therapy, with 0% morbidity and mortality, may be superior to surgical treatment.

5. Conclusion

Endovascular treatment of APAs is feasible, safe, and effective. Today, the special technical problems can today be overcome by the selection and use of a suitable microcatheter/wire combination and of soft or ultrasoft coils. Endovascular therapy is comparable with surgical therapy with respect to its mortality of 3.4% and with respect to the morbidity of 17.2%. A large dome-to-neck ratio is the main risk factor for reperfusion of the aneurysm. Mortality depends on the patient's initial condition, expressed by a poor H and H and GCS score, but not on other variables. An existing intraparenchymal hematoma has a severe negative influence on the patient's condition after rehabilitation. In these cases, surgical intervention should be considered. In case of incomplete occlusion of the aneurysm, prompt reintervention is required.

References

[1] Asgari S, Wanke I, Schoch B. Recurrent hemorrhage after initially complete occlusion of intracranial aneurysms. Neurosurg Rev 2003;26:269-74.
[2] Bambakidis NC, Selman WR. Subarachnoid hemorrhage. In: Suarez JI, editor. Critical care neurology and neurosurgery. Tatowa, New Jersey: Humana Press; 2004. p. 365-77.
[3] Baptista AG. Studies of the arteries of the brain. II. The anterior cerebral artery: some anatomic features and their clinical implications. Neurology 1963;13:825-35.
[4] Becker DH, Newton TH. Distal anterior cerebral artery aneurysm. Neurosurgery 1979;4:495-503.
[5] Brilstra EH, Rinkel GJ, van der Graaf Y. Treatment of intracranial aneurysms by embolization with coils: a systematic review. Stroke 1999;30:470-6.
[6] Cognard C, Pierot L, Boulin A. Intracranial aneurysms: endovascular treatment with mechanical detachable spirals in 60 aneurysms. Radiology 1997;202:783-92.
[7] Cognard C, Weill A, Castaings L. Intracranial berry aneurysms: angiographic and clinical results after endovascular treatment. Radiology 1998;206:499-510.
[8] de Sousa AA, Dantas FL, de Cardoso GT. Distal anterior cerebral artery aneurysms. Surg Neurol 1999;52:128-35.
[9] Drake CG. Giant intracranial aneurysms: experience with surgical treatment in 174 patients. Clin Neurosurg 1979;26:12-95.
[10] Fujii Y, Takeuchi S, Sasaki O. Ultra-early rebleeding in spontaneous subarachnoid hemorrhage. J Neurosurg 1996;84:35-42.
[11] Gallas S, Pasco A, Cottier JP. A multicenter study of 705 ruptured intracranial aneurysms treated with Guglielmi detachable coils. AJNR Am J Neuroradiol 2005;26:1723-31.
[12] Gruber A, Dietrich W, Czech T. Recurrent aneurysmal subarachnoid haemorrhage: bleeding pattern and incidence of posthaemorrhagic ischaemic infarction. Br J Neurosurg 1997;11:121-6.
[13] Gupta R, Horowitz MB, Gilman S. Neuroform stent-assisted coil embolization of a ruptured A1 segment anterior cerebral artery aneurysm. J Neuroimaging 2006;16:117-9.

[14] Hernesniemi J, Tapaninaho A, Vapalahti M. Saccular aneurysms of the distal anterior cerebral artery and its branches. Neurosurgery 1992;31: 994-8.
[15] Huber P, Braun J, Hirschmann D. Incidence of berry aneurysms of the unpaired pericallosal artery: angiographic study. Neuroradiology 1980; 19:143-7.
[16] Inagawa T, Kamiya K, Ogasawara H. Rebleeding of ruptured intracranial aneurysms in the acute stage. Surg Neurol 1987;28:93-9.
[17] Inci S, Erbengi A, Ozgen T. Aneurysms of the distal anterior cerebral artery: report of 14 cases and a review of the literature. Surg Neurol 1998;50:130-9.
[18] Katz RW, Horoupian DS, Zingesser L. Aneurysm of azygous anterior cerebral artery. A case report. J Neurosurg 1978;48:804-8.
[19] Kawamura S, Suzuki A, Sayama I. Ruptured aneurysms of the distal anterior cerebral artery. Jpn J Stroke 1988;10:298-305.
[20] Keston P, White PM, Horribine L. The endovascular management of pericallosal artery aneurysms. J Neuroradiol 2004;31:384-90.
[21] Kondo A, Koyama T, Ishikawa J. Ruptured aneurysm of an azygos anterior cerebral artery. Neuroradiology 1979;17:227-9.
[22] Laidlaw JD, Siu KH. Poor-grade aneurysmal subarachnoid hemorrhage: outcome after treatment with urgent surgery. Neurosurgery 2003;53:1275-80.
[23] Le Roux PD, Elliott JP, Newell DW. Predicting outcome in poor-grade patients with subarachnoid hemorrhage: a retrospective review of 159 aggressively managed cases. J Neurosurg 1996;85: 39-49.
[24] Mann KS, Yue CP, Wong G. Aneurysms of the pericallosal-callosomarginal junction. Surg Neurol 1984;21:261-6.
[25] Martinez F, Spagnuolo E, Calvo A. Aneurysms of the distal anterior cerebral artery. Neurocirugia (Astur) 2005;16:333-44.
[26] Menovsky T, van Rooij WJ, Sluzewski M. Coiling of ruptured pericallosal artery aneurysms. Neurosurgery 2002;50:11-4.
[27] Molyneux A, Kerr R, Stratton I. International Subarachnoid Aneurysm Trial (ISAT) Collaborative Group. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. Lancet 2002;360:1267-74.
[28] Niizuma H, Kwak R, Uchida K. Aneurysms of the azygos anterior cerebral artery. Surg Neurol 1981;15:225-8.
[29] Ohno K, Monma S, Suzuki R. Saccular aneurysms of the distal anterior cerebral artery. Neurosurgery 1990;27:907-12.
[30] Osawa M, Hongo K, Tanaka Y. Results of direct surgery for aneurysmal subarachnoid haemorrhage: outcome of 2055 patients who underwent direct aneurysm surgery and profile of ruptured intracranial aneurysms. Acta Neurochir (Vienna) 2001;143:655-63.
[31] Pierot L, Boulin A, Castaings L. Endovascular treatment of pericallosal artery aneurysms. Neurol Res 1996;18:49-53.
[32] Rosen DS, Macdonald RL. Subarachnoid hemorrhage grading scales: a systematic review. Neurocrit Care 2005;2:110-8.
[33] Ross IB, Dhillon GS. Complications of endovascular treatment of cerebral aneurysms. Surg Neurol 2005;64:12-8.
[34] Russell SM, Lin K, Hahn SA. Smaller cerebral aneurysms producing more extensive subarachnoid hemorrhage following rupture: a radiological investigation and discussion of theoretical determinants. J Neurosurg 2003;99:248-53.
[35] Sindou M, Pelissou-Guyotat I, Mertens P. Pericallosal aneurysms. Surg Neurol 1988;30:434-40.
[36] Skultety FM, Nishioka H. The results of intracranial surgery in the treatment of aneurysms. J Neurosurg 1966;25:683-705.
[37] Sluzewski M, van Rooij WJ, Rinkel GJ. Endovascular treatment of ruptured intracranial aneurysms with detachable coils: long-term clinical and serial angiographic results. Radiology 2003;227: 720-4.
[38] Snyckers FD, Drake CG. Aneurysms of the distal anterior cerebral artery. A report on 24 verified cases. S Afr Med J 1973;47: 1787-91.
[39] Thomas DG, Paterson A. Results of surgical treatment of pericallosal aneurysms. J Neurol Neurosurg Psychiatry 1975;38:826.
[40] Wisoff JH, Flamm ES. Aneurysms of the distal anterior cerebral artery and associated vascular anomalies. Neurosurgery 1987;20: 735-41.
[41] Yasargil M. Clinical considerations, surgery of the intracranial aneurysms and results. In: Yasargil M, editor. Microneurosurgery; 1984. p. 65–229. Stuttgart, Thieme.
[42] Yasargil MG, Carter LP. Saccular aneurysms of the distal anterior cerebral artery. J Neurosurg 1974;40:218-23.
[43] Yoshimoto T, Uchida K, Suzuki J. Surgical treatment of distal anterior cerebral artery aneurysms. J Neurosurg 1979;50:40-4.