ORIGINAL ARTICLE

The Interdisciplinary Treatment of Unruptured Intracranial Aneurysms

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SUMMARY

Introduction: The purpose of this article is to present the results of microsurgical clipping or endovascular coil obliteration of unruptured intracranial aneurysms (UIA), in a single cerebrovascular center with regard to successful obliteration and periprocedural complications.

Methods: Data concerning patients with UIA were recorded in the neurovascular database of the neurosurgical department at the University of Frankfurt. The outcome of treatment was assessed with the modified Rankin Scale.

Results: 126 patients were treated by open surgery and 74 patients by endovascular coil obliteration. After treatment, the rate of new, mostly transient neurological deficits was 5%, and there were no deaths related to any treatment in this series. The outcome was good in 124 (98.4%) of the surgically treated patients and 73 (98.6%) of the endovascularly treated patients, and only 3 patients (1.5%) had a treatment-related unfavorable outcome. 98% of the treated aneurysms were satisfactorily obliterated. Seven endovascularly treated patients required retreatment because of coil compaction leading to recanalization of the aneurysm.

Conclusions: The majority of patients with unruptured intracranial aneurysms, even complex ones, can be treated by microsurgery or endovascular aneurysm obliteration with very good clinical results and a very low percentage of unfavorable outcomes. With careful patient selection and individualized assignment of the best form of treatment to each patient, we were able to achieve a low overall complication rate and a very high rate of obliteration in our specialized neurovascular center.

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Key words: unruptured intracranial aneurysm, clipping, coiling, complication, morbidity

The use of non-invasive neuroradiological techniques to evaluate non-specific symptoms is leading to an increase in incidental intracranial findings. Magnetic resonance imaging (MRI) screening showed 1.8% of the population to have unruptured intracranial aneurysms (UIA) (1), often diagnosed as an incidental finding. Deciding on the further procedure and the need for primary prophylaxis of subarachnoid bleeding is a challenge for all the disciplines involved in these patients' management. Treating UIA is only productive, however, if the expected morbidity risk associated with rupture relevantly exceeds the risk of treatment. The first important step is therefore to identify suitable patients. Available treatment modalities are microsurgical clipping and endovascular coil obliteration (*e-table 1*, *e-table 2*, *e-table 3*). The literature data, however, do not allow conclusions to be drawn as to whether either of these procedures is superior in principle. While views about which therapeutic approach is optimal are often controversial, the decision should be taken as a consensus agreement by the specialized disciplines involved in the patient's management. The purpose of this article was not to compare the two forms of treatment but to evaluate the results of the interdisciplinary treatment of a consecutive series of patients with unruptured aneurysms at a neurovascular center.

Methods

Since June 1999, all patients diagnosed with an intracranial aneurysm at the Neurocenter of Johann Wolfgang Goethe University in Frankfurt/Main, Germany (Department of Neurosurgery, Department of Neurology, and Institute for Neuroradiology) have been entered in the neurovascular database of the Department of Neurosurgery. The database includes both patients with subarachnoid bleeding (SAB) from a ruptured aneurysm and with UIA. Up to February 2007, altogether 1078 patients were entered in the database, of whom 790 suffered SAB from a ruptured aneurysm and were not analyzed further in this study. 288 patients (26.7%) had a total of 362 UIA. 200 (69.4%) of these patients received treatment. Reasons for conservative management in 88 patients (117 UIA) were either a very poor clinical state following SAB from another, ruptured aneurysm, small aneurysm size more suitable for follow-up observation, or the patient's wish not to be treated.

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FIGURE 1

Number of unruptured intracranial aneurysms treated at the Neurocenter of Johann Wolfgang Goethe University Hospital, classified according to microsurgical clipping and endovascular coiling with reference to treatment year (June 1999 to February 2007). The small numbers of endovascular treatments in 2000 and 2001 are due to the installation of a new angiography unit.

During follow-up, the number of UIA treated with both types of intervention at our center steadily increased (*figure 1*). Before establishing a treatment strategy, four-vessel digital subtraction angiography (DSA), including 3-D reconstruction was performed in each patient. No standard selection criteria were applied to decide the treatment modality, rather, every aneurysm was discussed jointly by an interdisciplinary team of experienced neurovascular neurosurgeons and neuroradiologists. The aneurysm criteria (size, morphology, configuration, site, relation to carrier vessel) as well as the patient criteria (age, life expectancy, comorbidity) and the patient's preference were the deciding factors for the type of treatment selected (*table 1*). There were no relevant differences between the two forms of treatment as regards the severity of existing comorbidities. When the optimal treatment had been selected in the interdisciplinary consultation, the result was discussed with the patient and the treatment with the anticipated lowest periprocedural risk and most stable longterm occlusion was presented as a definitive recommendation. The treatment algorithm is based on the recommendations for the management of unruptured aneurysms of the German Society of Neurosurgery (2) which are derived from the data of the International Study of Unruptured Intracranial Aneurysms (ISUIA studies) (3, 4) and the guidelines of the medical societies. In both disciplines, the treatment was carried out by colleagues with many years of experience. The data were deliberately evaluated using purely descriptive methods since the intention was to demonstrate that these are complementary treatment modalities which only provide the best results when patients are specifically selected for each procedure.

Periprocedural management

Craniotomy for clipping the aneurysm was performed in a manner suited to the localization in a standardized microsurgical procedure. The endovascular treatment was also performed under general anesthesia. To document treatment associated complications such as bleeding or infarctions, cranial computed tomography was routinely performed after 24 to 48 hours. In the event of thromboembolic complications, magnetic resonance imaging was also performed.

The success of aneurysm obliteration in the endovascularly treated patients was documented at the end of the neuroradiological intervention. In all operated patients, control angiography was performed between day 7 and day 10. Obliteration was assessed as follows: complete occlusion (no residual filling of the aneurysm and neck of aneurysm), small residue (occlusion with small residue at aneurysm neck) or residual aneurysm (residual filling of the aneurysm) (5). In the first few years, all patients with endovascularly treated UIA underwent digital subtraction angiography (DSA) over the course of 6 months. Over the last few years follow-up magnetic resonance angiography (MRA) has been performed after 6 months. In addition, MRA was recommended after 2 and 5 years.

The follow-up clinical examination was performed between 3 and 6 months after the treatment and patient outcome was recorded using the modified Rankin Scale (mRS) (6, 7) which describes the patient's clinical condition based on specific criteria.

Results

The clinical symptoms and the reason for performing DSA are shown in *table 2*. It is notable that unspecific clinical symptoms such as headache, dizziness or other complaints that prompted the use of MRI or CT diagnostic procedures which disclosed the presence of an unruptured aneurysm were much more common than specific focal neurological abnormalities. The patient specific data (age, gender and patients with multiple aneurysms) as well as aneurysm specific characteristics are shown in *table 3*. There were no conspicuous differences as regards the size of the treated aneurysms. Patients with multiple aneurysms were more often treated microsurgically. *Table 4* presents the type of treatment according to the localization of the aneurysms. This clearly shows that all so-called transitional aneurysms arising from the cavernous sinus and extending intradurally were treated endovascularly. Aneurysms of the posterior circulation (vertebro-basilar system) as well as paraclinoid aneurysms were more frequently treated endovascularly. In contrast, almost all aneurysms of the middle cerebral artery were treated microsurgically. There were no appreciable differences for the other sites.

Complete clip occlusion was achieved in 90.3% (149 of 165 UIA) (*e-figure 1*). In 11 (6.7%) aneurysms the clip was intentionally placed at a short distance from the carrier vessel or the efferent branches to avoid stenosing the vessel. This was especially the case for complex

TABLE 1

Patient and aneurysm specific criteria used to make the decision for treatment (clipping or coiling) or conservative therapy in an interdisciplinary consultation

Criteria	Prophylactic treatment		Primary conservative treatment
	Clipping	Coiling	
Risk factors	Increased familial incidence of aneurysms Polycystic renal disease Symptomatic aneurysms		No risk factors
Size/localization	>7 mm anterior circulation		<7 mm anterior circulation
	MCA aneurysms	Vertebrobasilar circulation, transitional ACI aneurysms	
	For all other sites, individualized decision on therapeutic procedure		
Previous SAB	Good recovery after SAB		Persisting considerable deficits and poor general condition
Age	<60 years* ¹	<65 years* ¹	<65 years* ¹
Aneurysm morphology	Broad based neck, unfavorable aneurysm dome-to-neck ratio	Well defined neck, dense coil packing possible as precondition for good long-term result	
Angioarchitecture	Efferent vascular branches from base of aneurysm	No efferent vascular branches from base of aneurysm	
Treatment techniques	Additional reconstruction techniques for endovascular treatment (stent implantation or balloon remodeling)	Extended cranial base access sites for microsurgical treatment	
Multiple aneurysms	Primary surgical treatment	Endovascular treatment, if risk of intraoperative access creation is too high	

* Recommendations for treatment. The treatment modalities depend not only on the purely numerical age, but also the "biological" age (overall condition) of the patient and are therefore individually variable.
SAB, subarachnoid bleeding; ACI, internal carotid artery; MCA, middle cerebral artery

TABLE 2

Clinical symptoms and imaging techniques resulting in the diagnosis of an UIA

	Treatment	
	Microsurgery n = 126	Endovascular n = 74
Previous SAB from another aneurysm	28 (22.2%)	14 (18.9%)
Headache	20 (15.9%)	10 (13.5%)
Cranial nerve disorders	12 (9.5%)	10 (13.5%)
Dizziness	11 (8.7%)	10 (13.5%)
Ischemia including TIA	9 (7.1%)	4 (5.4%)
Visual disturbances	5 (4.0%)	8 (10.8%)
Seizures	3 (2.4%)	1 (1.4%)
Cerebral tumors	3 (2.4%)	2 (2.7%)
Positive family history	3 (2.4%)	0 (0%)
Degenerative CNS diseases	0 (0%)	1 (1.4%)
Other	4 (3.2%)	4 (5.4%)
MRI	22 (17.3%)	5 (6.7%)
CT	6 (4.8%)	5 (6.6%)

UIA, unruptured intracranial aneurysm; SAB, subarachnoid bleeding; TIA, transient ischemic attack

TABLE 3

Patient and aneurysm specific data of treated patients with UIA

	Treatment	
	Microsurgery n = 126	Endovascular n = 74
Age (years, mean $\pm$ SD)	44.4 $\pm$ 9.9	49.2 $\pm$ 11.8
Women	92 (73.1%)	50 (67.6%)
Number of patients with multiple aneurysms	40 (31.7%)	13 (17.6%)
Total number of UIA	165	80
Maximum diameter of aneurysm in mm	7.27 $\pm$ 5.7	8.0 $\pm$ 7.0
Size of aneurysms in mm		
<7	88 (53.3%)	39 (48.7%)
7–12	65 (39.4%)	33 (41.2%)
13–24	8 (4.8%)	3 (3.7%)
≥ 25	4 (2.4%)	5 (6.2%)

Indication for treatment of patients with aneurysms <7 mm were second aneurysms after SAB, multiple aneurysms treated together with a larger aneurysm, irregularly configured aneurysms, and patient's explicit wish for treatment. SAB, subarachnoid bleeding; SD, standard deviation; UIA, unruptured intracranial aneurysms

aneurysms with partial calcification in which the entire base of the aneurysm had to be reconstructed with different clips. In 5 cases the aneurysm was wrapped. Of the microsurgically treated aneurysms with a small residue and the wrapped aneurysms, 8 (50%) underwent repeat angiography over the course of 6 months and showed no changes.

The endovascular treatment was performed for 58 aneurysms by placing and anchoring platinum coils in the aneurysm. Nine patients additionally required the implantation of a vascular stent, and 8 patients required coiling with the balloon reconstruction technique in order to achieve adequate occlusion of the aneurysm and prevent the coil becoming dislocated into the carrier vessel. Occlusion of the carrier vessel was performed in 4 patients after an occlusion test. 47 of the 80 endovas-

cularly treated aneurysms (58.8%) were occluded completely (*e-figure 2*). In 33 (41.2%) a minimal residue was detectable at the base. Sufficient occlusion was achieved for all aneurysms such that no residual perfusion within the aneurysmal sac was detectable (*e-table 2*). For the endovascularly treated aneurysms, follow-up angiographic evaluation revealed recanalization of the aneurysm with partial filling in 7 patients, necessitating repeat endovascular treatment. Three of these patients initially had complete occlusion, and in 4 patients a small residue was visible. In 3 further patients with a small residue after coiling, spontaneous obliteration of the residue occurred during the further course. The treatment objective of bleeding prophylaxis was achieved in all patients with the exception of one female patient with a complex basilar aneurysm which was treated with a

TABLE 4

Site of unruptured intracranial aneurysms

Aneurysm site	Treatment	
	Microsurgery n = 126	Endovascular n = 74
Intracavernous (transitional)	0 (0.0%)	5 (6.25%)
Paraclinoid internal carotid artery	15 (9.09%)	17 (21.25%)
Internal carotid artery at the origin of the posterior communicating artery	22 (13.3%)	8 (10.0%)
Internal carotid artery (bifurcation)	14 (8.5%)	9 (18.75%)
Anterior communicating artery and anterior cerebral artery	32 (19.4%)	16 (20.0%)
Middle cerebral artery	76 (46.1%)	2 (2.5%)
Tip of basilar artery	2 (1.2%)	8 (10.0%)
Vertebrobasilar system	4 (2.4%)	10 (12.5%)

TABLE 5

Treatment-associated complications

	Treatment	
	Microsurgery n = 126	Endovascular n = 74
Total complications	22 (13.3%)	12 (15.0%)
Thromboembolic complications	0 (0%)	6 (7.5%)
Cerebral infarction	10 (6.2%)	3 (3.7%)
with clinical symptoms	4 (2.4%)	3 (3.7%)
Intracerebral bleeding/periprocedural SAB	6 (3.6%)	1 (1.2%)
with clinical symptoms	2 (1.2%)	1 (1.2%)
Other complications	5 (3.0%)	5 (6.2%)
Myocardial infarction	1	0 (0%)
Pneumonia	1	0
CSF fistula	2	0
Wound healing disorder	1	0
Visual disturbances	1	0
Inguinal hematoma	0	1
Iliac artery dissection	0	2
Intracranial artery dissection	0	1
Cranial nerve disorder	0	1

SAB, subarachnoid bleeding; CSF, cerebrospinal fluid

flow modifying stent. After 12 months, this patient suffered SAB from the previously treated aneurysm.

Complications during the course of treatment (*table 5*) were not essentially different in the two treatment groups. There were no treatment related mortalities. De novo neurological deficits were due mainly to cerebral ischemia or minor periprocedural bleeding. The rate of symptomatic ischemia after clipping and coiling was 2.4% and 3.7%, respectively. Periprocedural thromboembolic complications after endovascular therapy were treated by the intra-arterial use of antiplatelet medications (glycoprotein IIb/IIIa receptor antagonists) in half of the thromboembolisms without ischemic deficits.

After surgical therapy, 2 patients (1.2%) developed symptomatic bleeding. One aneurysm ruptured during the endovascular procedure, but without rupture related morbidity in the long-term course. The course of treatment was very good to good in the great majority of patients. Regardless of the treatment modality, 98.8% of all treated aneurysms (n = 245) and 98.5% of all patients (n = 200) had a postprocedural mRS ≤ 2 (*table 6*).

Discussion

Two basic questions arise regarding the treatment of patients with unruptured intracranial aneurysms. Is the treatment of this aneurysm indicated in this specific patient and, which is the most suitable treatment in this particular case to achieve permanent aneurysm occlusion with the lowest periprocedural risk? Even after publication of the prospective ISUIA data (4), the evidence situation for establishing the indication for treatment and selecting the suitable treatment modality remains modest due to the presence of selection bias and cannot be improved by the results reported here. The aim of this study was to present an overview of the results of treat-

ment in a large patient sample at a specialized neurovascular center in which the two treatment modalities are available on the basis of an interdisciplinary consensus and used in a complementary manner.

The decision whether to treat or observe a patient must be based on a consideration of both patient and aneurysm specific factors. The basic requirement is to weigh the risks associated with aneurysm rupture with potentially fatal SAB against the risks of treatment (*e-table 3*). Besides the localization and size of the aneurysm, age and previous SAB are important criteria for establishing the indication for treatment. In accordance with the guidelines of the medical societies, treatment is justified for asymptomatic aneurysms of the anterior circulation from a size of 7 mm onwards, and also for symptomatic intradural aneurysms or previous SAB from a different aneurysm. Asymptomatic aneurysms of the posterior circulation – including aneurysms of the carotid artery at the origin of the posterior communicating artery – also justify an intervention. As a general principle, the indication for treatment should always be considered in relation to the patient's age and state of health (*figure 2*). A relative indication for treatment may also be present for incidental aneurysms <7 mm in diameter if there is a family history of aneurysmal disease or if the aneurysm has increased in size or changed its configuration in the follow-up examination.

In our patient series none of the patients died of the treatment and the treatment associated morbidity with poor outcome (mRS = 3–5) was only 1.2% (2 of 165 clipped aneurysms and 1 of 80 endovascularly treated aneurysms). The treatment results presented here are therefore better than those in the ISUIA studies (3, 4) and show good consistency with the results of other series (8–19). An analysis of the results over the time course shows that compared to the first segment of the

TABLE 6

Patient outcome after treatment of unruptured intracranial aneurysms

mRS	Treatment		Total n = 245 (%)
	Microsurgery n = 126* ¹	Endovascular n = 80	
0 = no impairment	64 (38.8%)	28 (35.0%)	98.8* ¹ , * ²
1 = no significant impairment	72 (43.6%)	36 (45.0%)	
2 = slight impairment	22 (13.3%)	13 (16.2%)	
3 = moderate impairment	0 (0%)* ¹	1 (1.2%)* ²	1.2* ¹ , * ²
4 = marked impairment	2 (1.2%)	0 (0%)	
5 = severe impairment	0 (0%)	0 (0%)	
6 = patient died	0 (0%)	0 (0%)	

*¹ 5 patients with surgical treatment and (5 patients) and an mRS of 4 (2 patients) due to a previous SAB (6 patients) and a cerebral infarction (1 patient) before treatment. The microsurgical and endovascular treatment of the unruptured aneurysm was uncomplicated and without additional impairment for the patients. An mRS of 3 was therefore not included in the outcome analysis. mRS, modified Rankin Scale; SAB, subarachnoid bleeding

series with recently published data (20), no relevant morbidity occurred within the last 20 months. The use of new surgical techniques (intraoperative indocyanine green angiography [21–23], continuous intraoperative monitoring [24], vascular navigation [25]) and new endovascular techniques (e1–e4) is leading to an improvement in safety in the treatment of UIA.

The ISUIA studies provide no information regarding the rate of completely obliterated aneurysms. In the series presented here, complete occlusion without small neck residue was successful in 58.8% of the endovascularly and 90.3% of the surgically treated patients. Because of the relatively short follow-up time, the results of the endovascular treatment are only preliminary and require further evaluation in terms of the effectiveness of bleeding prophylaxis in the long-term course. The surgically treated aneurysms with a small neck residue were large, in some cases calcified aneurysms in which either the carrier vessel or afferent vascular branches were involved in the aneurysm. Wrapping, an alternative mode of treatment for unclippable aneurysms, was performed in 5 patients (3% of the UIA) (e5). Although a small residue was left at the base of the aneurysm in reconstruction of the vessels and clip occlusion of a complex aneurysm in order to prevent ischemic deficits, this was found to be stable in the follow-up examinations.

Our data also show that certain aneurysm sites primarily favor one form of treatment. For example, all aneurysms that begin in the cavernous sinus and extending intradurally (transitional aneurysms) and the majority of aneurysms in the region supplied by the vertebrobasilar artery were treated by the endovascular technique. The paraclinoid aneurysms were also more frequently treated surgically. Almost all aneurysms of the middle cerebral artery were treated surgically. The experience that aneurysms of the middle cerebral artery are better treated

surgically is consistent with the treatment results obtained at other centers (e6, e7).

In conclusion, it should be mentioned that without randomization naturally no direct comparison was possible between neurosurgical and endovascular treatment of unruptured aneurysms. A competitive comparison of this kind between two treatment modalities is no longer up to date, and the two therapeutic approaches should be regarded as complementary. The two interventions also generate similar costs and are adequately covered by the Diagnosis Related Groups (DRG) remuneration system and coils by additional payments. Although such comparative cost calculations were not performed directly for the treatment of UIA, it was shown that there was no significant difference in costs for patients with ruptured aneurysm and SAB (e8). A discussion of costs of treatment versus costs of conservative therapy is very difficult to conduct and can only be poorly substantiated in view of the lack of data.

In patients with small unruptured aneurysms of the anterior circulation, the treatment outcome in the ISUIA study (4) was independent of the treatment modality. This fact underlines the importance of a careful, interdisciplinary consideration of the suitable therapeutic approach taking into account patient age, aneurysm size and configuration and comorbidity. Patients with large, complex aneurysms – defined by vessels originating at the base – will have to continue being treated microsurgically, with a significantly higher level of technical difficulty and correspondingly greater demands on the microsurgical skills of the surgeon. The data presented here show that even with these aneurysms, surgical therapy offering a very good outcome and a low rate of complications is possible at a specialized center. The most important point, however, is that a non-competitive discussion of each individual aneurysm by a team of

experienced neurosurgeons and neuroradiologists is indispensable for establishing whether there is an indication for treatment in a specific case and which procedure is the safest and most promising.

Conclusion

Unruptured intracranial aneurysms can be treated surgically or endovascularly with low morbidity and a very good clinical and angiographic outcome. Complex and partially calcified aneurysms with involvement of a carrier vessel or vascular branches are more suitable for surgical treatment. The treatment of patients with unruptured aneurysms should be carried out at specialized centers handling large numbers of cases and with corresponding endovascular and neurosurgical experience. It should be carried out only after an interdisciplinary case discussion and a joint decision regarding the optimal treatment modality and taking into consideration all the risks.

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Conflict of interest statement

The authors declare that no conflict of interest exists according to the guidelines of the International Committee of Medical Journal Editors.

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FIGURE 2

Flow chart for treatment of patients with unruptured intracranial aneurysms (modified from Diener et al.: Leitlinien für Diagnostik und Therapie in der Neurologie [e9]).

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ORIGINAL ARTICLE

The Interdisciplinary Treatment of Unruptured Intracranial Aneurysms

Volker Seifert*, Rüdiger Gerlach*, Andreas Raabe, Erdem Güresir, Jürgen Beck, Andrea Szelényi, Matthias Setzer, Hartmut Vatter, Richard Du Mesnil de Rochemont, Friedhelm Zanella, Matthias Sitzler, Joachim Berkefeld

E-TABLE 1

Definition of treatment modalities and treatment associated mortality and morbidity

	Clipping	Coiling
Definition	After craniotomy and microsurgical dissection of the aneurysm, occlusion of the aneurysm sac from outside with a clip which after placement prevents inflow of blood into the aneurysm. Often several clips have to be used to achieve obliteration of the aneurysm or reconstruction of the vessel without constricting the carrier vessel.	Endovascular therapeutic procedure in which after puncture of a large artery (usually the femoral artery) one or more catheters are advanced into the circle of Willis and coils (small wire spirals) are placed in the aneurysm to occlude it from inside. With certain aneurysms, this treatment is only possible using a stent or a balloon. This is intended to prevent dislocation of the coils into the vessel.
Periprocedural mortality according to ISUIA data (1 year)	2.7%*	3.4%*
Periprocedural morbidity according to ISUIA data (1 year)	9.9%*	6.4%*

* The data refer to the patients who had no SAB from another aneurysm.
ISUIA, International Study of Unruptured Intracranial Aneurysms; SAB, subarachnoid bleeding

E-TABLE 2

Detailed UIA outcome data

Number of aneurysms	Treatment	
	Microsurgery n = 165	Endovascular n = 80
Complete occlusion	149 (90.3%)	47 (58.8%)
Minimal aneurysm residue at the base	11 (6.7%)	33 (41.2%)
Wrapping	5 (3.0%)	
No change over course	8 (50%)*	26 (78.8%)
Spontaneous obliteration of residue		3 (9.1%)
Coil compaction		4 (12.1%)
Repeated treatment for initially incomplete obliteration	0	7 (8.75%)
Repeated treatment for initially complete obliteration		4
		3

* In 8 patients with intentionally remaining small neck residue, for aneurysms in status post wrapping the angiographic controls are still awaited.
UIA, unruptured intracranial aneurysms.

E-TABLE 3

Annual rupture risk depending on the site and size of the UIA according to ISUIA data

	<7 mm		7-12 mm	13-24 mm	>25 mm
	No SAB	SAB from other aneurysm			
Intracavernous ICA	0%	0%	0%	0.6%	6.4%
Anterior circulation	0%	0.3%	0.5%	2.9%	8%
Vertebrobasilar circulation including the aneurysms at the origin of the posterior communicating artery	0.5%	0.7%	2.9%	3.7%	10%

UIA, unruptured intracranial aneurysm; ISUIA, International Study of Unruptured Intracranial Aneurysms; SAB, subarachnoid bleeding; ICA, internal carotid artery

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E-FIGURE 1:

Image of a giant aneurysm of the left internal carotid artery (A1–3, preoperative angiography) and after microsurgical clipping (B1–3, postoperative angiography). Middle: 3-D reconstruction and right: vascular image after subtraction of cranial bone.

E-FIGURE 2:

Image of a giant aneurysm of the right internal carotid artery. A1) 3-D reconstruction before endovascular treatment; A2) digital subtraction angiography of the right internal carotid artery before and A3) after complete obliteration of the aneurysm with coils. B1) 3-D reconstruction of the complete occluded aneurysm after 6 months; B2) before and B3) after subtraction of the cranial bone.