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ORIGINAL ARTICLE

Periprocedural morbidity and mortality by endovascular treatment of cerebral aneurysms with GDC: a retrospective 12-year experience of a single center

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Abstract Despite increasing experience and improved material, endovascular treatment of cerebral aneurysms still has risks linked to the technique itself and to the specificity of the pathology treated. The purpose of this report is to examine procedural technical and clinical negative events, even minimal ones, occurring in this type of treatment. We considered 557 procedures carried out from January 1994 to December 2005 in 533 patients harboring 550 aneurysms. Of the patients, 448 presented with SAH and 85 with unruptured aneurysms. All procedures were performed under general anesthesia. The GDC-10 system was routinely used. Additional devices like the balloon remodeling technique, Trispan and stents were also occasionally used. Every procedural complication occurring during or soon after treatment was registered. Endovascular treatment was completed in 539 out of 557 procedures. There were 18 failures (3.3%). Occlusion of the aneurysm was judged complete in 343 (64%), near complete in 184 (34%) and incomplete in 12 (2%). Procedural complications occurred in 72 (13%) of the cases. The most frequent negative events were thromboembolisms (6.6%) and ruptures (3.9%). Other types (coil migration, transient occlusions of the parent vessel, dissections and early rebleeding) were rarer (2.5%). In the majority of cases there were no clinical consequences. Procedural morbidity and mortality were 1.1 and 1.8%, respectively. Considering the 449 procedures performed in ruptured and the 90 in the unruptured aneurysms separately, morbidity and mortality were 1.1 and 2.2% in the former group and 1.1 and 0% in the latter. Many factors influence the risk of complications. Being progressively aware of this and with increasing experience, the frequency can be limited. Negative events linked to the procedure have more significant serious clinical consequences in patients admitted in a critical clinical condition after SAH, because of the already present changes involving the brain parenchyma and cerebral circulation.

Keywords Intracranial aneurysms · Detachable coils · Procedural morbidity and mortality

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Introduction

The introduction of Guglielmi detachable coils (GDC) in 1991 [13] changed the therapeutic approach to cerebral aneurysms. The positive results obtained with this technique explain its rapid and progressively broadened use. Today in many centers endovascular treatment is the first choice for at least 60–70% of all ruptured aneurysms.

Along with the positive results, however, all neurovascular teams involved in this kind of therapy have experienced progressively different types of negative events strictly linked to this technique.

We reviewed all kinds of technical and clinical complications we registered from the beginning of our experience. The purpose of this study was to determine the frequency and types of complications, which factors could be responsible for these negative events and which kind of patients are more at risk.

Patients and methods

Between January 1994 and December 2005, 533 patients harboring 550 aneurysms were treated with GDC embolization; 350 (66%) were female and 183 (34%) male. The ages ranged between 21 to 84 years (mean 57.4 years). In the same period we admitted 1,563 patients harboring saccular intracranial aneurysms, and 974 were surgically treated. Fifty-six patients were not treated because of bad clinical conditions or other reasons.

The attitude towards endovascular treatment has changed slowly in our department. In the first period of our experience (1994–2000), only 25% of the aneurysms were considered for endovascular treatment. In the last few years (2001–2005), 64% of the patients have been treated with this technique.

Four hundred forty-eight patients out of 533 presented with subarachnoid hemorrhage (SAH), and 85 had unruptured aneurysms. Among the patients with SAH 170 (38%) were Hunt-Hess grade 1–2, 170 (38%) Hunt-Hess 3 and 108 (24%) Hunt-Hess 4–5. Sixteen patients had more than one aneurysm. Fourteen with a ruptured aneurysm had a second unruptured one. Two patients with unruptured aneurysms had two and three lesions, respectively. Twenty-one patients treated endovascularly for an unruptured aneurysm had already been operated on for a ruptured aneurysm.

Aneurysm location and volume

The majority of the aneurysms were located in the internal carotid artery (ICA, including carotid opthalmic, paraclinoid and bifurcation), in the anterior communicating artery (ACoA), in the posterior communicating artery (PCoA) and in the basilar artery (Bas). All aneurysms are listed in Table 1.

Four hundred thirty-six were <10 mm in diameter, 98 were within 10 and 20 mm and 16 were larger than 20 mm.

Technique

Five hundred fifty-seven procedures were carried out. Among them there were 517 patients with a single aneurysm treated in a single session. Fifteen patients with two aneurysms were treated in a unique and in two sessions in ten and five cases, respectively. One patient harboring three aneurysms was treated in two sessions.

Table 1 Aneurysm location

Location	Number of aneurysms	Percent
ICA	150	27%
ACoA	147	26.7%
PCoA	93	16%
Basilar	60	10%
MCA	43	7.8%
Prox. PCA	2	0.33%
Distal PCA	6	1%
Choroid ant. art.	2	0.33%
Pericallosal art.	7	1.2%
PICA	16	2.8%
Vert.-PICA junction	13	2.3%
Vert. art.	9	1.6%
SCA	2	0.33%

Retreatment was performed in 14 patients for GDC compaction, once in 12 patients and twice in two cases. In two other cases retreatment was performed for rebleeding.

The decision for endovascular treatment was taken in all cases together by the therapeutic neuroradiologist and the neurovascular surgeon. Two neuroradiologists were involved in the procedure.

All procedures were performed under general anesthesia. Systemic anticoagulation with heparin was used in all cases, from the beginning of the treatment in unruptured aneurysms. In ruptured aneurysms, which were treated in the majority of cases within 24–48 h after SAH, heparin was first given when at least a partial occlusion of the aneurysm was achieved.

The GDC-10 system was routinely used (Boston Scientific-Target Inc. Freemont, CA). All types of GDC coils depending on the size and morphology of the aneurysm were used including matrix, 3D coils and more GDC 360. Additional devices like the balloon remodeling technique [25] and Trispan were applied two times each. Stents (six neuroform and two cardiovascular) were used eight times. Two neuroforms were used in the acute phase after SAH for aneurysms localized in the vertebrobasilar and middle basilar artery, respectively, and six times in unruptured internal carotid arteries. In the latter, therapy with aspirin (100 mg) and Ticlopidine (500 mg) was performed 2 days before treatment.

We routinely used long introducers (45–65 cm). In the last few years in cases of patients with very tortuous vessels a very long introducer catheter (F7) has been positioned in the subclavian or common carotid arteries. A guiding catheter (F 5–7) is advanced through it in the vertebral or internal carotid arteries. In our experience this system allows easier progression and more stability of the microcatheter.

Occlusion of the aneurysm was defined as complete when the aneurysm was no longer injected, near complete when a small neck remnant or minimal injection through the coil mass was present and incomplete when the neck remnant was more relevant or loose packing of the sack was still present.

Occlusion of the aneurysm and parent vessel was intentionally performed in 20 patients (ICA: two cases; peripheral posterior cerebral artery: six cases; peripheral PICA: six cases; superior cerebellar artery: two cases; vertebral artery: three cases; peripheral middle cerebral artery: one case).

After the procedure the patient was held in the intensive care unit for the time necessary depending on his/her clinical condition and evolution. Anticoagulation therapy with low weight molecular heparin was continued for 48 h, followed by antiplatelet therapy for 3–4 weeks.

CT was performed 24 h after each treatment and in the days afterwards depending on the clinical evolution. An angio-MR was routinely performed as an initial control 3–4 months after treatment, followed by an angiogram in cases of recanalization. All negative events related to the procedure that were recognizable during or in the days after treatment were registered. Morbidity and mortality were analyzed 6 months after treatment.

Results

Endovascular treatment was completed in 539 procedures out of 557. In 18 aneurysms (16 ruptured and 2 unruptured —3.3%) the treatment failed (unfavorable morphology of the aneurysm; peripheral branch arising from it; tortuosity).

Occlusion of the aneurysm was complete in 343 (64%), near complete in 184 (34%) and incomplete in 12 (2%).

The reasons for non-complete occlusion of the aneurysm were: morphology of the aneurysm with a peripheral branch arising near the neck in 108 cases, morphology and dimension of the neck in 48 cases and impossibility to introduce more coils with minimal injection through the coil mass in 40 cases. In 20 cases the aneurysm and parent vessel were intentionally occluded.

Procedural complications

These occurred in 72 (13%) out of 539 cases. The most frequent complications were thromboembolism (6.6%) and rupture (3.9%). Other types (coil migration, transient occlusion of the parent vessel and dissection) were rarer (1.8%).

Cases of early rebleeding after the treatment (0.7%) have also been considered.

Thromboembolism

Thromboembolism occurred in 36 cases (6.6%); 29 out of 36 (80%) were females.

In four cases out of 43 this occurred during the treatment of MCA aneurysms, in 14 out of 147 ACoA aneurysms, in 5 out of 93 PCoA aneurysms, in 5 out of 60 basilar aneurysms and in 2 out of 29 PICA aneurysms (Table 2).

In 18 cases out of 36 it was in the vascular territory of the middle cerebral artery (MCA), which was not necessarily linked with the localization of the aneurysm. In nine cases it was in the anterior cerebral artery territory. Rarer localizations were in the territory of the posterior cerebral arteries (five cases) and in the cerebellum (four cases) (Table 2).

In 28 cases it was recognizable on the angiogram as an occlusion or slowing down of flow in one or more branches. In 23 patients a spontaneous recanalization occurred, which was in some cases probably facilitated by the systemic additional injection of heparin. There were no clinical consequences in these cases. Two patients treated for a PCoA aneurysm had a thromboembolism in the MCA territory, followed by a rapid spontaneous recanalization. These patients suffered a minimal stroke. In three other patients admitted in bad clinical condition (Hunt-Hess grade 4), two with a MCA aneurysm and the other with a ACoA aneurysm developed ischemia due to thromboembolism

Table 2 Relationship between the vascular territory involved in 36 cases of thromboembolism and the localization of the aneurysm

		Localization of aneurysms treated							
		MCA	ACoA	Pericall.	PCoA	ICA	BAS	PICA	Vascular territories total
Vascular territories occluded in cases of thromboembolism	MCA	4	6		3	5			18
	ACA		8	1					9
	PCA				2		3		5
	Cerebellum						2	2	4
	Aneurysms total	4	14	1	5	5	5	2	36

in the MCA and in the anterior cerebral artery territory, respectively. These three patients died.

In another eight cases thromboembolism was suspected on the basis of ischemic lesions visible on CT 24–72 h after treatment. These were asymptomatic or only responsible for a minor transient neurologic deficit in four patients.

Two patients (Hunt-Hess grade 4) died with a small ischemia in the thalamic area and in the temporal region after treatment, respectively, of PCoA and ICA aneurysms.

Two other patients developed ischemia in the territory of the anterior cerebral artery and in the thalamic area after treatment of ACoA and PCoA aneurysms, respectively. One patient remained severely disabled, and the other suffered a minor stroke.

In many of these cases thromboembolism has certainly been an additional negative event even if it was probably not the main cause responsible for the unfavorable clinical result.

In five case with thromboembolism recognizable during or at the end of the treatment, fibrinolysis with urokinase in three and with rt-PA in two cases was performed, allowing partial recanalization. In spite of this, two patients died, one with a hemorrhagic transformation of the ischemia. Three other patients recovered well.

Overall morbidity and mortality due to thromboembolism were 0.7% (three minor strokes and one severely disabled) and 0.9%, respectively (Table 3).

Aneurysm perforation

Perforation of the aneurysm occurred in 21 cases (3.9%). This was distributed throughout all vascular territories, with no significant differences (ICA: 4; ACoA: 6; PCoA: 3; basilar: 3; MCA: 3; VA-PICA junction: 2 cases) (Table 4).

All aneurysms were 5–8 mm in diameter. In all cases protamine was injected for heparin reversal, and the aneurysm could be occluded, thus stopping the hemorrhage. Three patients (0.5%), however (one basilar; one ICA-OpthA; one MCA aneurysm), died due to an acute increase of intracranial pressure (ICP) in two, with an additional hematoma in one (Table 3).

Table 4 Site of aneurysms perforated during treatment

Site	No. of perforated aneurysms
ICA	4
ACoA	6
PCoA	3
Basilar	3
MCA	3
VERT- PICA junct.	2
Tot	21

Ventricular shunts already present in two other patients (Hunt-Hess grade 4) were very useful to control ICP. The patients recovered well. In the remaining patients the mild hemorrhages rapidly controlled were asymptomatic and did not lead to any changes of the pre-existing clinical condition. Two perforations occurred in unruptured aneurysms without any clinical consequence.

The cause of rupture was either instability of the microcatheter that slipped suddenly because of its position close to the wall of the aneurysm, allowing easier perforation through the coils. In other cases coils protruded suddenly outside the aneurysm without any specific technical reason. Morbidity and mortality for this kind of complication were 0% and 0.5%, respectively (Table 3).

Transient occlusion

Transient occlusion of ICA occurred in two large carotid ophthalmic, in one large paraclinoid and in one giant carotido-opthalmic aneurysm.

Two patients presented with hemorrhage and two with aspecific headache. In the treatment of ruptured aneurysm only coils were used, while in another two unruptured aneurysms, the insertion of coils was preceded by the application of a neuroform.

Table 3 Periprocedural negative events in 557 procedures

		Clinical complications		
		Minor stroke	Severe stroke	Death
Technical complications	Failure 18 (3.3%)			
	Thromboembolism 36 (6.6%)	3 (0.5 %)	1 (0.18%)*	5 (0.9%)
	Rupture 21 (3.9%)	–	–	3 (0.5%)
	Transient occl. ICA 4 (0.7%)	1 (0.18%)	–	–
	Early rebleeding 4 (0.7%)	–	–	2 (0.3%)
	Coil migration 3 (0.5%)	–	–	–
	Dissection 3 (0.5%)	.	–	–

*In addition one severe stroke (0.18%) occurred in an intentional occlusion of the parent vessel.

In three cases (one with neuroform) when we were almost at the end of the procedure, with the aneurysm nearly completely occluded, the flow of ICA slowed down and was rapidly arrested. In the fourth case the same event happened after the uneventful application of a neuroform. In all cases there was a good collateral circulation via the controlateral ICA. A control angiogram 20 h later showed a complete recanalization. In the patient where only a neuroform was used the treatment was completed with coils. There were no serious clinical complications. One patient suffered a minor stroke characterized by a slight impairment in the movement of the fingers of the controlateral hand (Table 3).

Coil migration

Coil migration occurred in three cases. This event had no clinical consequences (Table 3).

Artery dissections

There were three dissections of the ICA. In one case the treatment was stopped, and the patient was later operated on. In two other cases coiling could be further performed. The small dissection in one of these cases was endovascularly treated with a stent 2 months later (Table 3).

Early rebleeding

There were four early rebleedings: two aneurysms involving the peripheral segment of the PICA, one carotid ophthalmic and one middle cerebral artery aneurysm. The first case with a peripheral PICA aneurysm occurred in a very old patient in whom the lesion was not completely occluded in the acute phase after SAH. The patient recovered slowly, but 3 weeks later the aneurysm rebled.

A retreatment was performed allowing the complete occlusion of the aneurysm. The patient recovered well. In the second patient with a peripheral PICA aneurysm the morphology of the malformation suggested a possible dissecting aneurysm (Fig. 1a) and so occlusion of the peripheral PICA was planned. During the treatment, however, a selective occlusion of the aneurysm was possible sparing the PICA (Fig. 1b). The patient recovered, but 3 months later he suffered a second bleeding. On admission the angiogram revealed a large regrowth of the aneurysm (Fig. 1c), which at this time was occluded along with peripheral PICA (Fig. 1d). The patient recovered completely. The third patient admitted in bad clinical condition (Hunt-Hess grade 4) had a large carotid ophthalmic aneurysm treated in the acute phase with an incomplete occlusion. The treatment was difficult due to the tortuous ICA and unfavorable morphology of the aneurysm. The patient slowly recovered. A retreatment was planned, but the aneurysm rebled 7 months later, and the patient died. The last case was a large ruptured middle cerebral aneurysm, treated in the acute phase with an incomplete occlusion. The patient recovered. A control angiogram was planned for endovascular retreatment or surgery. The aneurysm, however, rebled 1 month later, and the patient died. Mortality in this group of patients was 0.36%, morbidity 0 (Table 3).

Procedure including occlusion of the aneurysm and parent vessel

There were 20 cases in which this procedure was performed. In 19 patients there were no clinical consequences. One patient remained severely disabled. In this latter case we were dealing with a peripheral middle cerebral artery aneurysm that had already bled two to three times in the days before admission. The patient was in a deep coma (Hunt-Hess grade V), and the angiogram showed the aneurysm along with severe spasms. The decision was made to occlude the aneurysm along with the peripheral branch arising from it, followed by selective injection of nimodipine. The patient survived, however, with permanent neurologic deficit. Morbidity in this group of patients was 0.18%, without mortality (Table 3).

Procedural complications in unruptured aneurysms

There were 85 patients treated for unruptured aneurysms. One patient had two and another three aneurysms treated in one and two sessions, respectively. Six other patients already treated endovascularly for a ruptured aneurysm underwent a second treatment for an unruptured aneurysm later.

We did not consider separately unruptured aneurysms treated in the same session as the ruptured one. There were two failures, and so 90 procedures were the object of this study. We experienced five technical complications: one minimal thromboembolic episode in the territory of the middle cerebral artery, with rapid spontaneous recanalization, two ruptures and as already described above two transient occlusions of the ICA. There were no clinical complications in four patients. One patient with transient occlusion of the ICA suffered a minor stroke. Considering the 90 procedures, the morbidity was 1.1%. There was no mortality.

Procedural complications in old patients

There were 92 patients older than 70 treated for ruptured or clinically symptomatic aneurysms. There were seven failures (7.5%). The complications involving this group were

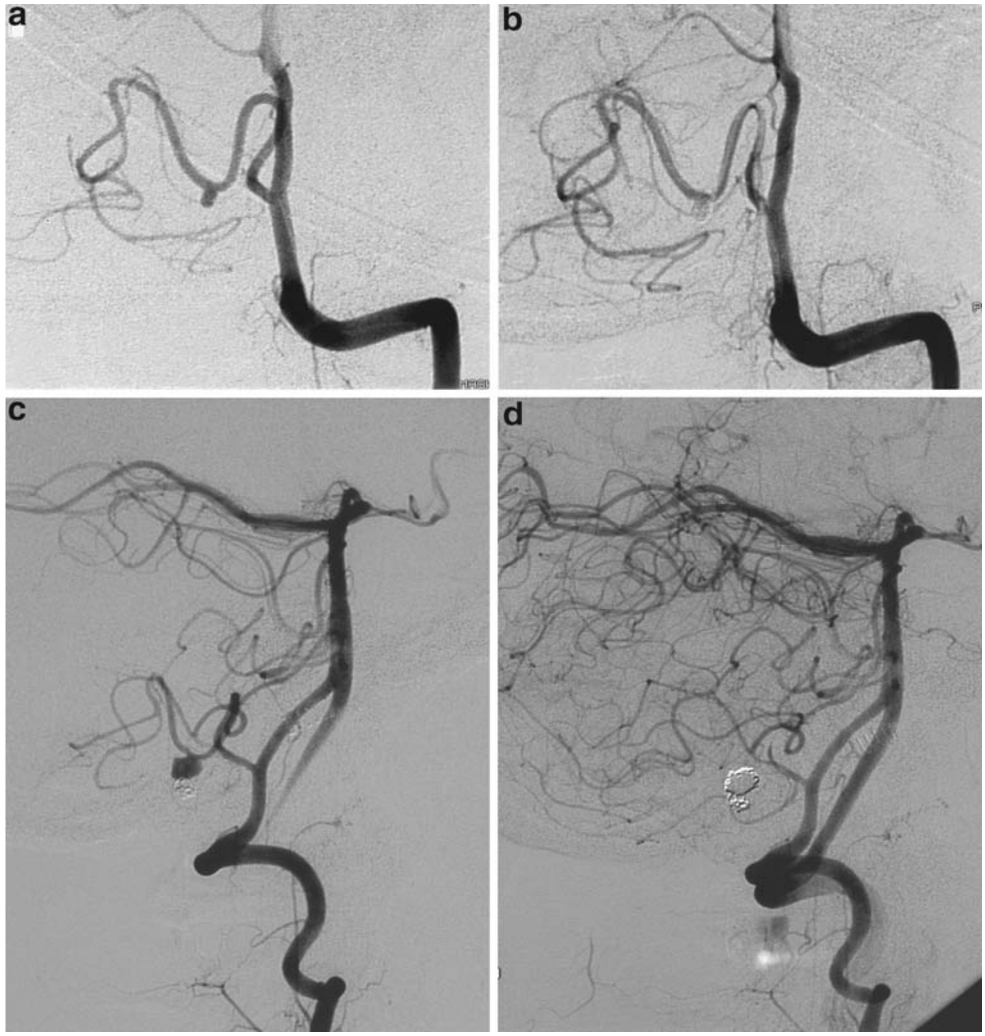

Fig. 1 Ruptured aneurysm of the retromedullary segment of PICA. **a** Vertebral angiogram pre-treatment. **b** Vertebral angiogram post-treatment. Regrowth and rebleeding 3 months later. **c** Vertebral angiogram before the second treatment. **d** Vertebral angiogram after the second treatment with occlusion of the aneurysm and the peripheral PICA

included in the whole series and have already been considered. Procedural morbidity and mortality were 1.1 and 0%, respectively.

Discussion

Several negative events can occur in GDC endovascular treatment of cerebral aneurysms. Among them thromboembolism remains the most frequent complication with a frequency reported in the literature ranging from 2.4 to 10% [6–8, 10, 11, 15, 16, 26–28, 33, 40]. In our series this occurred in 6.8%.

In this study the site of the aneurysm does not influence the risk of thromboembolism. More important seems to be the morphology of the aneurysm and its close relationship to the origin of the adjacent vessels. The higher frequency in the vascular territory of the middle cerebral artery, in the majority of cases not linked to aneurysms located in this area, is probably due to its large vascular area and the higher blood flow.

Large-giant aneurysms [6, 8, 30, 41] have been reported to increase the risk due to the large volume of the possible thrombotic material already pre-existing in the sac or formed in the coil mass, which can lead to an embolism. In our series, however, large-giant aneurysms per se were not the cause of thromboembolism.

Women have been considered to be at higher risk [8]. This seems to be confirmed in our study where 29 out of 36 (80%) thromboembolic events occurred in women.

Furthermore, in accordance with other authors [1, 6–8], we think that technical aspects like prolonged work trying to occlude the aneurysm completely and the use of additional devices (remodeling with ballons, Trispan and stents), which certainly can be useful in some cases, can however particularly in the acute phase after SAH increase the risk of thromboembolism.

MR examinations using diffusion-weighted techniques have been performed 1–2 days after endovascular treatments of aneurysms. These studies [3, 7, 32, 35, 36] have demonstrated the presence of several, in general asymptomatic microischemic lesions located prevalently, but not only, in the vascular territory of the treated aneurysm. The etiopathogenesis of these lesions is not completely understood. The aneurysm itself can be the source of microembolization as well as probably the previous diagnostic angiographies [2] and the followed endovascular treatment. Furthermore, as suggested by some authors [7], also other factors such as hypercoagulation as well as changes occurring in the acute phase of SAH like increased intracranial pressure and cardiac disfunctions, both leading to modifications of cerebral blood flow, probably play an important role. It is interesting that the reported lesions were more frequent in patients with SAH in comparison to the patients with unruptured aneurysms, and they seem to be in relationship with the gravity of SAH itself [7, 14].

We have not performed DWI after treatments, but it is remarkable that in our series, 34 out of 36 cases with thromboembolic events occurred in patients with SAH. Furthermore, the majority of cases with serious clinical complications belonged to the group of patients admitted in a critical clinical condition (Hunt-Hess grade 4–5), for whom any additional negative event, even if minor, can have more serious clinical consequences in comparison to patients in good clinical condition. Thromboembolism occurred only in two cases of unruptured aneurysms without clinical consequences.

Fortunately, in the majority of cases thromboembolism remains asymptomatic, frequently due to rapid spontaneous recanalization, or in other cases because the ischemic lesions are minimal or in silent areas. Anticoagulation therapy in prevention is important, and it is possible that its efficiency varies from case to case. When a thrombotic event occurs during treatment a selective fibrinolytic treatment can be useful. However, this can be the cause of rebleeding of the aneurysm or of hemorrhagic transformation of the ischemic lesion. Taking all these aspects into consideration, we are restrictive in using fibrinolytic drugs. We apply these only if one or more large proximal branches are occluded. In this context, the use of antiplatelet agents like abciximab seems to be more effective than fibrinolytic drugs since acute thrombus is rich in platelets [28, 37]. Some authors [28] have proposed the same antiplatelet therapy to prevent thromboembolism at the end of the treatment.

Aneurysm rupture This is certainly the most feared complication of coil treatment leading to death from an increase of ICP and/or intracerebral hematoma. In the more recent literature the perforation of an aneurysm is reported to be between 1.4 and 8% [1, 10–12, 15, 16, 18, 19, 24, 26–29, 34, 39–42]. In our series it occurred 21 times, corresponding to 3.9% of all procedures.

Fortunately, it does not necessarily always mean a bad prognosis for the patient. In the majority of the cases the hemorrhage can be rapidly and completely controlled with coils with a final good morphological and clinical result. The risk of perforation is higher in small aneurysms [28, 31, 34, 42] due to the limited free space where coils can be inserted between the tip of the microcatheter and the dome of the aneurysm. Also, unfavorable morphology of the aneurysm or the presence of very tortuous vessels can increase the risk of perforation due to instability of the microcatheter. Moving it gently to and fro while pushing the coils in particular in very small aneurysms can help to avoid this kind of complication.

The outcome has been correlated with the site of the aneurysm. Perforated aneurysms in the posterior circulation have been reported to have a worse prognosis [39]. For others [42], the pre-existent clinical condition is more important. Probably both elements along with other factors like the extent of the rupture, the rapid slow down of cerebral flow, the difficulties to occlude the aneurysm and the possibility to control ICP rapidly play an essential role in the outcome. In patients already in bad condition (Hunt-Hess grade 4 and 5), the preventive application of a ventricular shunt before endovascular treatment can be very useful.

Treatment of ICA aneurysms Especially if large or giant using coils alone or with additional stents has the possible risk of occluding the artery due to compression, spasm or formation of thrombus. This occurred in four of our cases. The occlusion was transient, and all patients had a favorable outcome, certainly due to a good collateral circulation. Since this risk exists, the presence of a good collateral flow should be examined before treatment.

Early rebleeding It is a rare complication occurring in the days/weeks after treatment for up to 10–12 months. It can be considered as an early postprocedural complication. In the literature its frequency ranges between 0.5 and 5% [5, 9, 11, 18, 19, 22, 28, 34, 38]. In the majority of cases we are dealing with aneurysms that are not completely occluded, but rebleeding has been reported also in aneurysms judged completely occluded on the angiogram [5, 22]. In one of our four cases, the aneurysm of the peripheral PICA appeared completely occluded at the end of the treatment, but it regrew 3 months later and rebled. It was probably a dissecting aneurysm for which the best treatment should have been, already in the acute phase, the occlusion of the aneurysm and of the parent vessel. This case, similarly to other cases reported in the literature, appearing completely occluded at the end of the treatment, shows the need of early control in all treated aneurysms.

Unruptured aneurysms The types of technical complications occurring in patients with unruptured aneurysms are similar to those present in cases of ruptured aneurysms. However, the frequency is lower and the clinical consequences are much less relevant. All changes involving brain parenchyma, cerebral metabolism and cerebral flow following SAH, along with the presence of an already ruptured wall, fail in unruptured aneurysms, and that probably explains the better results in the treatment of these aneurysms. In more recent literature [8, 15, 16, 26, 28, 33], the morbidity ranges from 1.4 to 4.3% and mortality from 0 to 2% [1, 15, 16, 26, 28, 33]. Our results with a morbidity of 1.1% out of 90 procedures for unruptured aneurysms are in keeping with those of the literature and confirm the relative safety of the treatment for this group of patients.

Endovascular treatment in old patients The risk of complications is not higher in old and very old patients. Positive morphological and clinical results [4, 23] are frequent and depend basically on the primary clinical condition after SAH and on the possibility to reach the aneurysm. A very long introducer can be very useful in overcoming the tortuosity of vessels frequently present in these patients.

Conclusions

Like any other intervention, endovascular treatment is burdened by complications that are strictly dependent on the pathology treated and on the technique used.

The neuroradiologists involved in this kind of therapy have become progressively aware of this. With increasing experience and improved materials, the frequency of these negative events can be lessened. As reported in the more recent literature, procedural morbidity ranges from 0.6 to 9% [1, 10, 11, 15–18, 20, 21, 26–28, 34] and mortality from 0.6 to 5% [1, 10, 11, 15, 16, 18, 26, 28, 34]. In our series we registered a procedural morbidity of 1.1% (four minor and two severe strokes) and a mortality of 1.4% (five patients due to thromboembolism and three following perforation). If we add two deaths due to early rebleeding (1 month and 7 months, respectively), the mortality increases to 1.8%. Considering the 449 procedures performed in ruptured and the 90 in the unruptured aneurysms separately, morbidity and mortality were 1.1 and 2.2% in the former group and 1.1 and 0% in the latter.

Many factors can influence the risk of complications. There is an evident difference in the treatment of ruptured and unruptured aneurysms. The risk of complications is much higher in ruptured aneurysms in comparison to ruptured ones. Furthermore, the clinical consequences are significantly related to the severity of SAH and the clinical condition. It was not our aim to discuss the indication of therapy of unruptured aneurysms. We only confirm that endovascular treatment can be relatively safely attempted in these cases.

Considering age and sex we can say that the frequency of complications does not increase in old patients; on the contrary there is a tendency to have more thromboembolic events in women.

More than the localization of an aneurysm is its morphology, its wide neck, its relationship to parent and adjacent vessels and its accessibility the elements that can influence the risk of negative events. Confronting unfavorable anatomical conditions, the surgical alternative should be considered.

Finally, there is no doubt that the aim of endovascular treatment is the complete occlusion of the aneurysm. We think, however, that in many cases, particularly in the acute phase after SAH, it is probably safer to accept a near complete occlusion rather than to try to achieve a perfect occlusion with overpacking or using more sophisticated devices that can increase the risk of complications.

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Comments

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At first glance this is a very promising paper dealing with endovascular management of cerebral aneurysms, demonstrating 12 years of experience and more than favorable results. However, at second glance, some points induce a critical analysis with questions arising that make the results and conclusions to some degree debatable.

The endovascular treatment of aneurysms by controlled detachment of platinum coils has a history of more than 15 years now. The breakthrough came with the results of the ISAT trial, leading to a shift from microsurgical clipping to endovascular “coiling” in a large number of patients.

Analyzing the ISAT study critically, the results of the endovascular therapy were not far different from the surgical results. In the endovascular group, the immediate and the 1-year outcome were superior, but the rebleeding rate was slightly higher. However, the ISAT results changed the therapeutic management, and in many countries and centers worldwide the endovascular treatment is now the first choice.

As we know from other randomized studies comparing different treatment modalities for vascular diseases (as, for example, the NASCET or ECASS studies for carotid surgery or the CAVATAS and SPACE study comparing stenting to surgery), the results under study conditions may differ from the daily clinical experience because a study produces to some degree an artificial situation. The included centers are often those of excellence with greater experience and high procedure numbers, and the patient selection is sometimes different from the patient population in normal life due to several factors such as exclusion and other selection criteria and the number of included centers. Therefore, the clinical and operative results can be different between study results and clinical routine findings. Because of the study design of ISAT, such selction artifacts were excluded as far as possible; nevertheless, there may be some slight differences.

All this, which can be discussed long and critically, led to the conclusion that a single-center experience over a long period can give very valuable clinical information on the value of a method, the learning curve, technical and personal aspects and other facts that cannot always be analyzed in a prospective randomized trial.

The authors present their results from 557 procedures over a period of 12 years performed by two neuroradiologists. The number of procedures was low in the first 7 years and increased markedly in the last 5 years as a result of ISAT and the further development of the technique with better coils and microcatheters. Four hundred forty-eight patients suffered from an SAH; 90 were incidental/unruptured. This means that more than 80% of all patients had an SAH. In this group about 50% were graded Hunt and Hess 3–5.

The distribution, size and location of the aneurysms did not differ from surgical series. The early complications (13%) were classified into transient and permanent and include mostly thromboembolism (6.6%) and rupture (3.9%). All other problems (such as coil migration, dissection, early rebleeding, etc.) were rare. The permanent complication rate was 1.1 and 1.8% for morbidity and mortality, respectively. However, this can only be regarded as the periprocedural negative events and not as the overall clinical morbidity and mortality of the patients related to the SAH.

For thromboembolic complications the authors analyzed the relationship between the vascular territory involved and the localization of the aneurysm. Risk factors for thromboembolism were a prolongated work and the use of additional devices or techniques (remodeling; stents). This is an interesting point and supports the clinical experience, “simple is often more safe.” The more technically difficult the procedure, the more complications may occur.

The four cases of early rebleeding were discussed as well as the treatment of patients of higher age and of those with unruptured aneurysms, all with favorable results.

It would have been interesting to see if and how there was a learning curve over the years influencing the rate of periprocedural complications.

Compared to surgical series, the nature and course of the disease and the complications differ in this endovascular series as well as the management of the complications. Thromboembolism was the most frequent adverse event and was responsible for the majority of complications in the early phase; however, many of them were described as clinically asymptomatic or reversible. Even the perforation of the aneurysm during the procedure occurring in 21 cases was not associated with a high morbidity or mortality.

Overall, with regard to the clinical state (SAH and HH grade), the authors present a series with extremely low morbidity and mortality.

However, the results should be discussed critically because the authors present and discuss the periprocedural complications and not the clinical outcome.

The majority of the patients suffered from an SAH, and 278 were Hunt and Hess Grade 3–5. Analyzing the current literature, the outcome of these patients includes a much higher morbidity and mortality than the authors have described for their series. Data from the neurosurgical literature demonstrate that patients HH grade 3–5 have morbidity and mortality rates up to 50% (especially in HH grade 5) due to vasospasm and all known problems of an SAH.

To my experience, in a comatose patient HH grade 5, a thromboembolic complication cannot always be regarded as asymptomatic. Thus, it may be debatable to classify an adverse event as asymptomatic if the patient cannot be examined for the possible defect. Keeping this in mind, the complication rate might be higher than the authors have calculated. Therefore, the true complication rate may be higher than the given numbers and lower than the early rate of 13%.

To conclude, the paper demonstrates that the nature of negative events due to endovascular management differs significantly from those of surgical procedures and gives a good overview of the development of the method in a single center.