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ORIGINAL RESEARCH

Procedural Complications of Coiling of Ruptured Intracranial Aneurysms: Incidence and Risk Factors in a Consecutive Series of 681 Patients

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BACKGROUND AND PURPOSE: To report the incidence of procedural complications of coiling of ruptured intracranial aneurysms leading to permanent disability or death in a consecutive series of 681 patients and to identify risk factors for these events.

PATIENTS AND METHODS: Between January 1995 and July 2005, 681 consecutive patients with ruptured intracranial aneurysms were treated with detachable coils. Procedural complications (aneurysm rupture or thromboembolic) of coiling leading to death or neurologic disability at the time of hospital discharge were recorded. For patients with procedural complications, odds ratios (OR) with corresponding 95% confidence intervals (CI) were calculated for the following patient and aneurysm characteristics: patient age and sex, use of a supporting balloon, aneurysm location, timing of treatment, clinical condition at the time of treatment, and aneurysm size.

RESULTS: Procedural complications occurred in 40 of 681 patients (5.87%; 95% CI, 4.2% to 7.9%), leading to death in 18 patients (procedural mortality, 2.6%; 95% CI, 1.6% to 4.2%) and to disability in 22 patients (procedural morbidity, 3.2%; 95% CI, 2.0% to 4.9%). There were 8 procedural ruptures and 32 thromboembolic complications. The use of a temporary supporting balloon was the only significant risk factor (OR, 5.1; 95% CI, 2.3 to 15.3%) for the occurrence of procedural complications.

CONCLUSION: Procedural complication rate of coiling of ruptured aneurysms leading to disability or death is 5.9%. In this series, the use of a temporary supporting balloon in the treatment of wide-necked aneurysms was the only risk factor for the occurrence of complications.

Endovascular coiling of ruptured intracranial aneurysms has become an accepted treatment with good clinical results and adequate protection against rebleeding.[1-5] Adverse outcome after aneurysmal subarachnoid hemorrhage (SAH) may be the result of the initial impact of the hemorrhage, the occurrence of early rebleeding after treatment, and delayed events such as vasospasm and hydrocephalus. Moreover, complications during the endovascular treatment itself can result in poor patient outcome. Complications of endovascular coiling consist of procedural perforation by the microcatheter, microguidewire, or coil and thromboembolic complications. Thromboembolic complications may be caused by clotting inside the guiding catheter, clot formation on the coil mesh, or clotting in parent vessels caused by induced vasospasm or malpositioned coils.

In this study, we report the incidence of procedural complications of coiling of ruptured intracranial aneurysms leading to permanent disability or death in a consecutive series of 681 patients. In addition, we tried to find risk factors associated with the occurrence of procedural complications.

Patients and Methods

Patients

Between January 1995 and July 2005, 681 consecutive patients with a ruptured intracranial aneurysm were treated with detachable coils. There were 215 men and 466 women with a mean age of 53.2 years (median, 52 years; range, 19–83 years). Clinical grading according to the Hunt and Hess scale (HH)[6] at the time of treatment was: HH I–II, 438 patients; HH III, 122 patients; and HH IV–V, 121 patients. Mean size of the 681 ruptured aneurysms was 8.0 mm (median, 7; range, 2–35 mm). There were 518 small aneurysms (≤10 mm), 154 large aneurysms (11–25 mm), and 9 giant aneurysms (≥25 mm). Timing of treatment after SAH was ≤3 days in 317 patients, between 4 and 11 days in 234 patients, and ≥11 days in 130 patients. Locations of the aneurysms are listed in Table 1.

Coiling Procedure

Coiling of aneurysms was performed on a biplane angiographic unit (Integris BN 3000; Philips Medical Systems, Best, the Netherlands) with the patient under general anesthesia and systemic heparinization. Heparin was continued intravenously or subcutaneously for 48 hours after the procedure, followed by oral low-dose aspirin for 3 months. Coiling was performed with Guglielmi detachable coils (Boston Scientific, Fremont, Calif) or Trufill DCS/Orbit coils (Cordis, Miami, Fla). Some large aneurysms were coiled with very long mechanically detachable coils (Detach-18; Cook Inc, Copenhagen, Denmark). The aim of coiling was to obtain an attenuated packing of the aneurysm, until not a single coil could be placed.

Forty-nine wide-necked aneurysms (7.2%) were coiled with the aid of a temporary supporting balloon. During the study period, several occlusion balloons were used for this purpose: Balt no I balloon glued on a Magic 1.8 microcatheter (Balt, Montmorency, France), Endeavor nondetachable balloon (Boston Scientific, Fremont, Calif), Solstice Balloon Occlusion System (Medtronic MIS, Sunnyvale, Calif), and Sentry 15-mm balloon (Boston Scientific, Fremont, Calif).

In the occurrence of aneurysm perforation during coiling, heparin was reversed instantaneously and coiling was continued until the bleeding stopped. In the occurrence of thromboembolic complications, usually a selective bolus injection of 100,000–250,000 U of

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Table 1: Location of 681 ruptured aneurysms treated with detachable coils

Posterior circulation ($N = 181$)	
Basilar tip	109
Superior cerebellar artery	23
Posterior inferior cerebellar artery	26
Vertebral artery	8
Basilar trunk	8
Posterior cerebral artery	6
Anterior inferior cerebellar artery	1
Anterior circulation ($N = 500$)	
Anterior communicating artery	244
Posterior communicating artery	123
Carotid tip	25
Carotid ophthalmic artery	15
Anterior choreoideal artery	13
Carotid hypophyseal artery	1
Middle cerebral artery	49
Pericallosal artery	29
Carotid cavernous sinus	1

urokinase was administered in the involved vessel, followed from 2002 onward by intravenous infusion of a glycoprotein IIb/IIIa antagonist (tirofiban; Agrastat, Merck & Co., Whitehouse Station, NJ), titrated to 2 to 3 times normal values of activated thromboplastin time.

Procedural Complications

Procedural complications (aneurysm rupture or thromboembolic) of coiling leading to death or neurologic disability at the time of hospital discharge were prospectively recorded in our data base during a weekly joint meeting with neuroradiologists, neurosurgeons, and neurologists. For comatose patients, thromboembolic complications were considered to have caused neurologic deficit if this was either clinically evident or if there were infarctions on subsequent CT scans in the territory of the involved vessel. Procedural rupture in comatose patients who subsequently died was considered procedural mortality. Outcome of surviving patients with procedural complications was assessed according to the Glasgow Outcome Scale (GOS)[7] at the joint outpatient clinic at 6 weeks. All procedural aneurysm ruptures, independent of clinical consequences, were recorded.

Statistical Analysis

For patients with procedural complications, odds ratios (OR) with corresponding 95% confidence intervals (CI) were calculated using univariate logistic regression analysis for the following patient and aneurysm characteristics: sex, age ≥60 years, age ≥70 years, use of a supporting balloon, aneurysm location (posterior circulation, middle cerebral artery, anterior cerebral artery, or carotid artery), timing of treatment (≤3 days, between 4 and 11 days, and ≥11 days), clinical condition at the time of treatment (HH I–II, HH III, or HH IV–V), and aneurysm size (≤5 mm, >10 mm, and >15 mm). Separate univariate logistic regression analyses were performed for the same patient and aneurysm characteristics for thromboembolic complications and procedural ruptures.

Results

Procedural Complications

Procedural complications occurred in 40 of 681 patients (5.87%; 95% CI, 4.2–7.9%), leading to death in 18 patients (procedural mortality, 2.6%; 95% CI, 1.6% to 4.2%) and to disability in 22 patients (procedural morbidity, 3.2%; 95% CI, 2.0% to 4.9%). There were 8 procedural ruptures and 32 thromboembolic complications. Five of 8 procedural ruptures and 13 of 32 thromboembolic complications led to mortality (Table 2). Of 22 patients with procedural morbidity, 10 had a nondisabling neurologic deficit and were independent (GOS 4) and 12 were dependent (GOS 3) at 6 weeks after coiling. There were no patients in vegetative state (GOS 2). Overall procedural complications leading to death or dependency were 30 of 681 (4.4%; 95% CI, 3.0% to 6.2%).

Overall rupture during coiling occurred in 31 patients (4.6%) and was without clinical sequelae in 23 (74%). These 23 patients with procedural rupture without clinical consequences were not included in statistical analysis of procedural complications.

In the 49 patients with wide-necked aneurysms treated with a supportive balloon, 10 complications leading to disability or death occurred (20.4%): procedural ruptures in 2 and thromboembolic complications in 8 patients.

Table 2: Morbidity and mortality for 8 procedural ruptures and 32 thromboembolic events in 681 patients

	Procedural Rupture	Thrombo-embolic Event
Morbidity	3	19
Mortality	5	13
Total	8	32

Table 3: Odds ratios for different patient and aneurysm characteristics for the occurrence of all procedural complications leading to disability or death in 681 patients

Variable	Odds Ratio	95% Confidence Interval
Men	0.71	0.34–1.48
Timing after SAH		
≤3 d	0.75	0.39–1.44
Between 4 and 11 d	0.81	0.40–1.62
≥11 d	1.90	0.94–3.84
Aneurysm location		
Posterior circulation	0.67	0.30–1.48
Anterior cerebral artery	1.00	0.52–1.92
Middle cerebral artery	1.47	0.50–4.32
Carotid artery	1.23	0.61–2.47
Supportive balloon	5.10	2.31–11.32
Clinical condition at the time of treatment		
HH I–II	0.67	0.35–1.28
HH III	1.49	0.78–2.84
HH IV–V	0.79	0.32–1.93
Aneurysm size (mm)		
<5	0.76	0.39–1.51
<10	0.59	0.31–1.13
≥10	1.58	0.79–3.13
>15	1.55	0.58–4.12

Note:—SAH indicates subarachnoid hemorrhage; HH, Hunt and Hess scale.

Statistical Analysis

Results of univariate logistic regression for the different variables for occurrence of all complications are listed in Table 3, for occurrence of thromboembolic complications in Table 4, and for occurrence of procedural rupture in Table 5.

The use of a temporary supporting balloon was the only

Table 4: Odds ratios for different patient and aneurysm characteristics for the occurrence of thromboembolic complications leading to disability or death in 681 patients

Variable	Odds Ratio	95% Confidence Interval
Men	0.98	0.46–2.11
Timing after SAH		
≤3 d	0.68	0.33–1.41
Between 4 and 11 d	1.15	0.55–2.40
≥11	1.44	0.63–3.28
Aneurysm location		
Posterior circulation	0.27	0.08–0.90
Anterior cerebral artery	1.35	0.66–2.74
Middle cerebral artery	1.36	0.40–4.62
Carotid artery	1.51	0.71–3.20
Supportive balloon	4.94	2.10–11.69
Clinical condition at the time of treatment		
HH I–II	0.71	0.35–1.45
HH III	1.41	0.69–2.88
HH IV–V	0.64	0.22–1.85
Aneurysm size (mm)		
≤5	0.44	0.19–1.02
<10	0.49	0.24–1.01
≥10	2.28	1.10–4.72
>15	0.44	0.76–5.51

Note:—SAH indicates subarachoid hemorrhage; HH, Hunt and Hess scale.

Table 5: Odds ratios for different patient and aneurysm characteristics for the occurrence of procedural ruptures leading to disability or death in 681 patients

Variable	Odds Ratio	95% Confidence Interval
Men		
Timing after SAH		
≤3 d	1.15	0.29–4.64
Between 4 and 11 d	0	
≥11 d	4.34	1.07–17.60
Aneurysm location		
Posterior circulation	4.67	1.10–19.74
Anterior cerebral artery	0.21	0.03–1.74
Middle cerebral artery	1.86	0.22–15.43
Carotid artery	0.40	0.05–3.28
Supportive balloon	4.44	0.87–22.60
Clinical condition at the time of treatment		
HH I–II	0.56	0.14–2.25
HH III	1.79	0.44–7.23
HH IV–V	1.52	0.30–7.62
Aneurysm size (mm)		
≤5	4.92	0.99–24.55
<10	1.36	0.27–6.80
≥10	0	
>15	0	

Note:—SAH indicates subarachnoid hemorrhage; HH, Hunt and Hess scale.

significant risk factor (OR, 5.10; 95% CI, 2.31% to 11.32%) for the occurrence of any procedural complication.

Thromboembolic complications occurred significantly more often when a supportive balloon was used (OR, 4.94; 95% CI, 2.10 to 11.69) and in aneurysms >10 mm (OR, 2.28; 95% CI, 1.10 to 4.72). Thromboembolic complications occurred significantly less often in posterior circulation aneurysms (OR, 0.27; 95% CI, 0.08 to 0.90). There was a strong trend for fewer thromboembolic complications in aneurysms <10 mm (OR, 0.49; 95% CI, 0.24 to 1.01).

Procedural ruptures significantly more often occurred in posterior circulation aneurysms (OR, 4.67; 95% CI, 1.10 to 19.74) and when timing of treatment after SAH was ≥11 days (OR, 4.34; 95% CI, 1.07 to 17.60). There was a strong trend for more procedural ruptures in aneurysms ≤5 mm (OR, 4.92; 95% CI, 0.99 to 24.55).

Discussion

We found that procedural complications of coiling of ruptured intracranial aneurysms leading to permanent disability or death occurred in 5.9% of patients; mortality or dependency was 4.4%. Thromboembolic complications accounted for 80% and procedural rupture for 20% of complications.

The overall complication rate is in concordance with previous studies: Brilstra et al[2] reported, in a meta-analysis of 1256 patients, a 3.7% procedural complication rate leading to permanent deficits. In a meta-analysis limited to posterior circulation aneurysms, Lozier et al[8] found 1.4% procedural mortality and 5.1% procedural morbidity. Henkes et al[9] reported a procedural mortality of 1.5% and morbidity of 5.0% in 1034 coiled ruptured aneurysms.

Risk Factors for All Complications

The only risk factor for the occurrence of complications was the use of a temporary occlusion balloon to assist in coiling of wide-necked aneurysms. This may be explained by the following 3 reasons: first, the technique requires the introduction of an additional balloon microcatheter, with inherent higher risk of thromboembolic events as was shown by Soeda et al[10,11] in a study using diffusion-weighted MR imaging. Second, the (thrombogenic) coil mesh in a wide-necked aneurysm has a large surface area in contact with blood. Third, there is a higher tendency for procedural rupture when the microcatheter is fixed by the balloon and coils are deployed.[12] An increased rate of complications with use of a temporary occlusion balloon or stent was also reported by Henkes et al[9] but not by others.[13-16]

Procedural Aneurysm Perforations

Aneurysm perforations occurred in 4.4% of patients. Mortality of procedural rupture was 0.7%, and morbidity was 0.4%. Procedural ruptures significantly more often occurred in posterior circulation aneurysms and when timing of treatment after SAH was ≥11 days. There was a strong trend for more procedural ruptures in aneurysms ≤5 mm. Small aneurysm size is a well-known risk factor for procedural rupture.[12] We do not have an explanation for the fact that ruptures were more frequent in posterior circulation aneurysms and when timing of treatment after SAH was ≥11 days.

Incidence of procedural rupture was similar to that reported by others: in a meta-analysis of 1248 ruptured aneurysms by Cloft et al,[17] the procedural rupture rate was 4.1%, leading to mortality in 1.8% and morbidity in 0.2%. Henkes et al[9] reported a procedural rupture rate of 5.0% in 1034 ruptured aneurysms. Most aneurysm perforations remain without clinical sequelae. Countermeasures such as reversal of anticoagulation and securing the perforation site with additional coils seem to be effective in preventing disability or death in most cases.

Thromboembolic Complications

Thromboembolic complications occurred in 4.7%, accounting for a mortality of 1.9% and a morbidity of 2.8%. Risk factors for the occurrence of thromboembolic complications were the use of a supportive balloon and aneurysm size >10 mm. The use of a supportive balloon, the only risk factor for all complications, is thus due mainly to thromboembolic events. Large aneurysms usually have a wide neck and are more frequently treated with a supportive balloon. Moreover, thrombi may originate in and dislodge from the sac during coiling of large aneurysms, and procedure time is likely to be longer. Conversely, we found significantly fewer thromboembolic complications of coiling of small aneurysms. Thromboembolic complications occurred significantly less often in posterior circulation aneurysms. We do not have a solid explanation for this finding. It is possible that the access to posterior circulation aneurysms is less difficult and time-consuming then for anterior circulation aneurysms.

The thromboembolic complication rate is comparable with that reported in other studies: Henkes et al[9] found a thromboembolic complication rate of 4.7% in 1034 ruptured aneurysms. The rate of thromboembolic stroke was 6% in a series of 118 patients by Ross.[18] In the occurrence of clot formation, local intra-arterial fibrinolysis with urokinase, abciximab, or recombinant tissue plasminogen activator may help to recanalize the occluded artery,[19,20] but even complete recanalization may not prevent a major neurologic deficit. Aneurysmal rebleeding due to intraarterial fibrinolysis has been observed in this setting and has a poor prognosis.[20]

In the present study, patient age, clinical condition, timing of treatment, and aneurysm size and location had no influence on the occurrence of procedural complications. The interval between endovascular treatment and SAH did not affect periprocedural morbidity rates in a study of 327 patients by Baltsavias et al.[21] Sedat et al[22] reported that thromboembolic events during embolization of a ruptured aneurysm were more frequent in elderly people than in younger patients (9.6% versus 1.4%), but this could not be confirmed by Lubicz et al,[23] who found a permanent morbidity as a result of thromboembolic complications of 2.9% in 68 patients older than 65 years.

The absence of risk factors for procedural complications, besides the use of a temporary balloon, is in contrast with neurosurgical clipping of intracranial aneurysms, where advanced age, large and giant aneurysm size, and aneurysm location in the posterior circulation are well-known risk factors for surgical mortality and morbidity.[24,25] In addition, decreased level of consciousness on admission and early treatment adversely influence surgical outcome.[26]

For clinical practice, the absence of risk factors for coiling implies that all patients with a ruptured aneurysm suitable for endovascular treatment with coils may proceed to treatment as soon as possible after admission, regardless of timing after SAH, clinical condition, patient age, or aneurysm size and location.

In conclusion, the procedural complication rate of coiling of ruptured aneurysms leading to disability or death is 5.9%. The use of a temporary supporting balloon in the treatment of wide-necked aneurysms is the only risk factor for the occurrence of complications.

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