Journal of Neuroradiology 46 (2019) 331–335

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

Original Article

Intracranial aneurysms treatment with Barricade coils: Safety and 1-year efficacy in a prospective, single-center series

Raoul Guerreiro-Simoes , Sébastien Soize , Matthias Gawlitza , Pierre-François Manceau , Laurent Pierot *

Department of neuroradiology, Hôpital Maison-Blanche, CHU de Reims, 45, rue Cognacq-Jay, 51092 Reims cedex, France

INFO ARTICLE

Historique de l'article :
Disponible sur Internet le 11 January 2019

Keywords :
Intracranial aneurysm
Embolisation
Coils

ABSTRACT

Background and purpose. – Barricade coils (Blockade/Balt, Montmorency, France) are bare platinum coils, electrically detached existing in different shapes, softnesses, and sizes. This series is analyzing the safety (procedural complications) and efficacy (anatomical results at 1-year) of these coils in a prospective, single-center series.

Materials and methods. – All patients with aneurysms treated with Barricade coils, without associated treatment (flow diverter, flow disrupter, or surgery) or parent artery occlusion were included. Peri-operative complications were evaluated. Anatomical results at 1-year were analyzed for patients that completed the 1-year digital subtraction angiographic follow-up and were independently evaluated by an expert neuroradiologist.

Results. – During the study period (October 2013–October 2017), 132 patients (female: 88/132, 66.7%; median age: 50 years) with 141 aneurysms treated with Blockade coils were included. Aneurysm rupture, thromboembolic complication, and technical problems occurred in 9 aneurysms (6.3%), 8 aneurysms (5.6%), and 8 aneurysms (5.6%), respectively. Clinical consequences were variable; morbidity was reported in 5 patients (3.8%) and mortality in 2 patients (1.5%). Post-operatively aneurysm occlusion was complete in 117 aneurysms (83.0%), neck remnant in 16 aneurysms (11.3%), and aneurysm remnant in 8 aneurysms (5.7%). At 1-year aneurysm occlusion was complete in 53 aneurysms (51.5%), neck remnant in 34 aneurysms (33.0%), and aneurysm remnant in 16 aneurysms (15.5%). Retreatment in the year following the initial treatment was reported in 10 aneurysms (9.7%).

Conclusion. – Treatment of ruptured, unruptured, and recanalized aneurysms with Barricade coils is associated with a good safety and 1-year efficacy.

Endovascular treatment (EVT) is the first line treatment for ruptured and unruptured intracranial aneurysms [1,2]. Despite the recent technical developments of EVT (flow diversion, flow disruption), coiling is still the endovascular modality that is more frequently used for both ruptured and unruptured aneurysms [3–11]. In ARETA study, coiling (including balloon-assisted coiling) was used in 97.8% of ruptured aneurysms and 73.5% of unruptured aneurysms [12].

Since the introduction of the first controlled-detachable coils and due to the relatively high rate of recanalization of coiled aneurysms (roughly 20%), coil technology has dramatically evolved with the appearance of new shapes, coils of variable softness (regular, soft, ultra-soft), enlarged range of sizes, and surface-modified coils [13]. These latter have been extensively evaluated showing the potential benefit of hydrocoils and the absence of benefit of PGLA-coils [14–18]. However the impact of the other evolutions of coils (shape, softness, size) on the rate of recanalization has not really been evaluated.

Barricade coils (Blockade/Balt, Montmorency, France) are new bare platinum coils, electrically detached existing in different shapes, softness's, and sizes [19]. Patients with ruptured and unruptured aneurysms treated with these coils were prospectively included in a database in a single center. This series is analysed in term of safety (procedural complications) and efficacy (anatomical results at 1 year).

* Corresponding author.
Adresse e-mail : lpierot@gmail.com (L. Pierot).

https://doi.org/10.1016/j.neurad.2018.12.003

Material and methods

Study setting

This study analyzed the prospectively collected registry of patients with an intracranial aneurysm ruptured or unruptured) treated using Blockade coils between October 2013 and October 2017. In line with French law, a submission to Ethics Committee is waived for retrospective studies as well as written informed consent.

For the purpose of this study, were included all patients fulfilling the following inclusion criteria:

- patients with aneurysms treated with Barricade coils,
- without associated treatment (flow diverter, flow disrupter, surgery),
- without parent artery occlusion.

Anatomical results at 1-year were obtained from patients that completed the 1-year digital subtraction angiographic follow-up.

Patients treated with balloon–assisted and stent-assisted coiling were included.

The Barricade coil system

The Barricade Coil System is intended for the endovascular embolization in the treatment of intracranial aneurysms and other neurovascular abnormalities. Barricade is a bare platinum coil line available in Framing, Filling and Finishing configurations. It is designed with a variable softness profile; as coils get smaller they get softer by utilizing different primary wind and filar sizes, the coils are designed to be softer in smaller sizes. The Framing coils provide an even loop distribution and stable basket for a wide range of aneurysm shapes. The finishing coils are of the softest finishing coils available.

Recorded data

Demographic data (age, sex), medical history data (smoking, arterial hypertension, multiple aneurysm carrier), and aneurysm characteristics (status, location, maximum diameter of the sac and neck) were collected.

In addition, the following data relative to endovascular treatment were collected: type of treatment (coiling alone, balloon-assisted, or stent-assisted coiling), immediate post-operative occlusion graded, and per-procedure complications (aneurysm rupture, thrombo-embolic complication and technical problems such as coil protrusion or coil migration).

The complications and their clinical impact were independently evaluated by a neuroradiologist (2 years experience) by screening medical charts (especially systematic follow-up consultations). The clinical evolution of the complication was classified in 4 groups: no deficit, transient deficit, permanent deficit (morbid complication), death (mortal complication).

Post-operative and 1-year anatomical results were independently evaluated by an experimented interventional neuroradiologist (more than 20 years' experience) using a 3-grade Montreal scale: complete occlusion, neck remnant, and aneurysm remnant. A direct comparison was also made between post-operative and 1-year occlusion with a 3-grade scale: improved, stable, and worsened.

During the 1-year follow-up period, aneurysm retreatments were collected.

Endovascular treatment

Indications and modalities of treatment of ruptured and unruptured aneurysms were discussed multidisciplinary by at least a neurosurgeon and a neuroradiologist.

All endovascular procedures were performed under general anesthesia on a biplane flat-panel angiography machine (Axiom Artis dBA; Siemens, Erlangen, Germany). All patients were treated by a femoral access with a 8 or 6-French sheath and with various guiding catheters. A 3D rotational DSA was obtained in all cases to better define the aneurysm neck and the parent vessel and for the determination of an optimal working projection. Intravenous heparin was administered at the beginning of the procedure while in patients with ruptured aneurysms heparin was given after deployment of the first coil. The goal was to achieve an activated clotting time twice the baseline value. In our center, the typical protocol consists of a loading dose of 80–100 IU/kg heparin followed by continuous intravenous infusion of 1000–1500 IU/h for the next 24 hours. In cases of unruptured aneurysms, patients scheduled for possible stent-assisted coiling were given clopidogrel (75 mg) 5 days before the procedure. Aspirin (250 mg) was given intravenously during the procedure on a case-by-case basis. The coils were delivered using various micro-catheters.

Thromboembolic events were diagnosed intra-operatively by angiography regardless of type (clotting near the neck of the aneurysm, clotting in the distal branches, and parent vessel occlusion). Post-operative thromboembolic events were diagnosed by MRI and/or digital subtraction angiogram performed in cases of sudden neurological compromise. Intraoperative rupture was diagnosed by the exit of the tip of the coil or the microcatheter outside the limit of the aneurysmal sac and/or extravasation of contrast media.

Statistical analyses

Distribution normality was assessed using the Kolmogorov-Smirnov test. Continuous variables were described as mean ± SD or median and interquartile range and were compared using either Student's *t*-test or Mann–Whitney U, as appropriate. Statistical tests were 2-sided and $P < 0.05$ was considered statistically significant. Analyses were performed using Medcalc software (Release 18.2, Ostend, Belgium).

Results

Patients

During the study period (October 2013 – October 2017), 163 patients with 172 intracranial aneurysms were treated with Barricade coils. Twenty-two patients with 31 aneurysms were excluded. Reasons for exclusion were as follows: treatment failure ($n = 1$), parent artery occlusion ($n = 7$), associated treatment ($n = 23$). Finally, 132 patients with 141 aneurysms treated with Blockade coils were included. Fig. 1 displays the study's flow chart. Baseline characteristics of the patients and their aneurysms are displayed in Table 1.

At 1-year, 36 patients with 38 aneurysms did not complete the scheduled angiographic follow-up, because of: death ($n = 22$ patients with 22 aneurysms), lost to follow-up ($n = 8$ patients with 9 aneurysms), follow-up with /angiography refusal ($n = 4$ patients with 5 aneurysms) and follow-up refusal ($n = 2$ patients with 2 aneurysms).

Causes for death were: consecutive to subarachnoid hemorrhage ($n = 20$ patients with 20 aneurysms), cardio-respiratory arrest at presentation and per-operative rupture ($n = 1$ patient with 1 aneurysm), and cancer ($n = 1$ patient with 1 aneurysm).

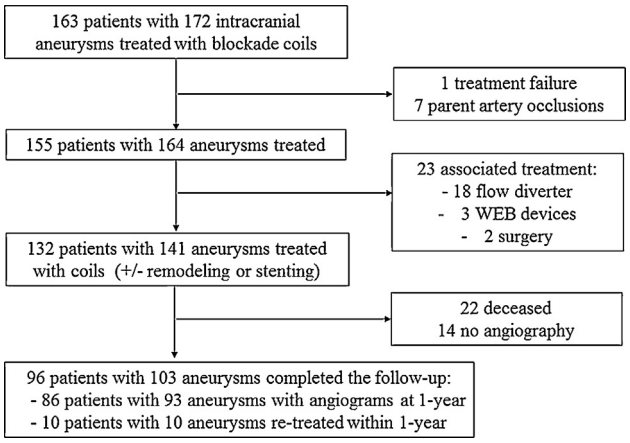

Fig. 1. Flow chart of the study.

Table 1
Baseline characteristics of patients and aneurysms.

Variables	
Demographics (*n*=132)	
Age, years	50 (43–61)
Female	88 (66.7%)
Medical history (*n*=132)	
Smoking[a]	
Active smoking	57 (48.7%)
Weaned smoking	14 (12.0%)
No smoking	46 (39.3%)
Hypertension[b]	
Controlled hypertension	23 (19.2%)
Uncontrolled hypertension	15 (12.5%)
Not hypertensive	82 (68.3%)
Carrier of multiple aneurysms	38 (28.8%)
Aneurysms characteristics (*n*=141)	
Status	
Ruptured aneurysms	84 (59.6%)
Unruptured aneurysms	43 (30.5%)
Aneurysm remnant	14 (9.9%)
Location	
supraclinoid ICA	45 (31.9%)
cavernous ICA	5 (3.5%)
ACA and ACom	52 (36.9%)
MCA	22 (15.6%)
BA	10 (7.1%)
Vertebral or PICA	6 (4.3%)
PCA	1 (0.7%)
Maximum sac diameter (in mm)	6.5 (4.6–9.0)
Neck (in mm)	3 (2.0–4.0)
Treatment (*n*=141)	
Coïls	92 (65.3%)
Coïls + Balloon	46 (32.6%)
Coïls + Stent	3 (2.1%)

Data relative to demographic and medical history was calculated on the 132 patients.
Data relative to aneurysm characteristics and treatment was calculated on 141 aneurysms.
ICA: internal carotid artery; ACA: anterior cerebral artery; ACom: anterior communicating artery; MCA: middle cerebral artery; BA: basilar artery; PICA: posterior inferior cerebellar artery; PCA: posterior cerebral artery.
[a] Data missing for 15 patients.
[b] Data missing for 12 patients.

Finally, complete data at 1-year was accessible for 96 patients with 103 aneurysms.

Per-operative complications and their clinical significance

Aneurysm rupture, thromboembolic complication, and technical problems occurred 9 aneurysms (6.3%), 8 aneurysms (5.6%), and 8 aneurysms (5.6%), respectively (Table 2).

Table 2
Per-procedure complications and clinical impact.

Per-procedure complications (*n*=141)	
Aneurysm rupture	9 (6.3%)
TE complications	8 (5.6%)
Technical problems	8 (5.6%)
Clinical impact (*n*=132)	
For aneurysm ruptures	
Transient deficit	1 (0.7%)
Permanent deficit	2 (1.5%)
Death	1 (0.7%)
For thromboembolic complications	
Transient deficit	0 (0%)
Permanent deficit	3 (2.3%)
Death	1 (0.7%)
Procedure-related morbi-mortality (*n*=132)	7 (5.3%)
Morbidity	5 (3.8%)
Mortality	2 (1.5%)

Data are presented as *n* (%).

Table 3
Immediate and 1-year angiographic results.

Treatment results	
Immediate post-operative occlusion (*n*=141)	
Complete occlusion	117 (83.0%)
Neck remnant	16 (11.3%)
Aneurysm remnant	8 (5.7%)
Occlusion at 1 year (*n*=103)	
Complete occlusion	53 (51.5%)
Neck remnant	34 (33.0%)
Aneurysm remnant	16 (15.5%)
Evolution at 1 year (*n*=103)	
Stable	60 (58.2%)
Worsening	42 (40.8%)
Improving	1 (1.0%)
Retreatment during the 1st year (*n*=103)	
Endovascular	7 (6.8%)
Surgery	3 (2.9%)

Data are presented as *n* (%).

Aneurysm rupture was associated with no clinical change in 5 patients (3.8%), transient neurological deficit in 1 patient (0.7%), permanent neurological deficit in 2 patients (1.5%), and death in 1 patient (0.7%).

Thromboembolic complication was associated with no clinical change in 4 patients (3.0%), transient neurological deficit in 0 patient (0.0%), permanent neurological deficit in 3 patients (2.3%), and death in 1 patient (0.7%).

Technical problems were coil protrusion ($n = 6$) or coil migration ($n = 2$).

Morbidity was reported in 5 patients (3.8%) and mortality in 2 patients (1.5%).

Immediate and 1-year angiographic result

Post-operatively, aneurysm occlusion was complete in 117 aneurysms (83.0%), neck remnant in 16 aneurysms (11.3%), and aneurysm remnant in 8 aneurysms (5.7%) (Table 3).

At 1-year aneurysm occlusion was complete in 53 aneurysms (51.5%), neck remnant in 34 aneurysms (33.0%), and aneurysm remnant in 16 aneurysms (15.5%).

Evolution of aneurysm occlusion between post-operative and 1-year DSA was worsening in 42 aneurysms (40.8%), stable in 60 aneurysms (58.2%), and improvement in 1 aneurysm (1.0%).

Table 4
Characteristics of the 10 patients retreated within 1 year.

Patient	Age	Sex	Status	Location	Size (mm)	Neck (mm)	Type	Treatment	Post-op occlusion	Delay (months)	Retreatment
1	52	M	Ruptured	ACom	10	1.8	Sacciform	C	A	8	C
2	34	F	Ruptured	Sup. ICA	16	8	Sacciform	C + B	C	10	C + FD
3	77	M	Remnant	MCA	29	N/A	Sacciform	C	C	11	Surgery
4	56	F	Ruptured	ACom	6.3	4	Sacciform	C + B	A	12	C
5	46	M	Ruptured	ACom	10	4	Sacciform	C + B	B	8	C + B
6	49	M	Ruptured	PCA	7.6	2	Dissecting	C	A	< 1	C
7	53	M	Ruptured	ACom	3.5	2	Dissecting	C + B	C	1	Surgery
8	56	F	Ruptured	MCA	16	2.4	Sacciform	C	C	7	Surgery
9	62	F	Unruptured	Cav. ICA	9.2	8	Sacciform	C + B	B	4	FD
10	80	F	Ruptured	Sup. ICA	12	7.5	Sacciform	C + B	A	12	C + B

ACom: anterior communicating artery; Cav ICA: cavernous internal carotid artery; MCA: middle cerebral artery; PCA: posterior cerebral artery; Sup ICA: supraclinoid internal carotid artery. Treatment: C: coils; C + B: coils + balloon. Post-operative occlusion: A: complete occlusion, B: neck remnant, C: aneurysm remnant. Retreatment: FD: flow diverter.

Table 5
Comparison between ruptured vs. unruptured and remnant aneurysms.

	Ruptured	Unruptured and remnant	*P*-value
Per-operative complications	*n* = 84	*n* = 57	
Aneurysm rupture	5 (5.9%)	4 (7.0%)	1
TE complication	7 (8.3%)	1 (1.7%)	0.14
Technical problem	5 (5.9%)	3 (5.2%)	1
1-year occlusion	*n* = 55	*n* = 48	
Complete occlusion	28 (50.9%)	25 (52.1%)	0.21
Neck remnant	18 (32.7%)	16 (33.3%)	0.37
Aneurysm remant	9 (16.4%)	7 (14.6%)	0.77
1-year evolution	*n* = 55	*n* = 48	
Stable	30 (54.5%)	30 (62.5%)	0.42
Worsening	24 (43.7%)	18 (7.5%)	0.70
Improving	1 (1.8%)	0 (0.0%)	1
Retreatment during 1st year	8 (14.5%)	2 (4.2%)	0.20

Data are presented as *n* (%).

Retreated patients

Retreatment in the year following the initial treatment was reported in 10 aneurysms (9.7%) (Table 4). Eight out of 10 retreated aneurysms were initially ruptured, 2 of them being dissecting aneurysms. Initial post-operative occlusion was complete occlusion in 4 aneurysms, neck remnant in 2 aneurysms, and aneurysm remnant in 4 aneurysms. Retreatment was clipping in 3 aneurysms, coiling in 3 aneurysms, balloon-assisted coiling in 2 cases, and flow diverter in 2 cases.

Comparison ruptured vs. unruptured + remnant

For the purpose of this comparison, unruptured aneurysms and aneurysm remnants were pooled (Table 5). The rate of intraoperative rupture was similar in both groups (ruptured: 5.9%; unruptured + remnants: 7.0%; $P = 1$), whereas there was a trend toward more thromboembolic complications in ruptured aneurysms than in unruptured aneurysms (8.3% and 1.7%, respectively, $P = 0.14$).

Post-operative and 1-year anatomical results were similar in both groups as well as evolution of aneurysm occlusion.

Discussion

Aneurysm treatment with Barricade coils is associated with an immediate safety and mid-term efficacy, which is similar to what is reported in large coil series [1,2]. If the rate of intraoperative rupture is slightly higher to what is reported in large series of unruptured aneurysms (2.0% in ATENA versus 7.0% in the present series) and ruptured aneurysms (3.7% in CLARITY versus 5.9% in the present series), the rate of thromboembolic complication is slightly lower in both ruptured (8.3% versus 13.3% in CLARITY) and unruptured aneurysms (1.7% versus 7.3% in ATENA) [1,2]. These variations are probably not related to significant changes in the perioperative medication protocols, as both antiplatelet treatment and heparin treatment were not changing in this group of patients with aneurysms treated with coils. The variations are probably explained by the relatively small size of the present series compared to large coiling series (for instance, 782 patients in CLARITY and 649 patients in ATENA).

In term of efficacy, the results are similar or better to what was reported in the large randomized studies comparing different types of coils. In the Cerecyte Coil Trial (CCT), the respective rates of post-operative complete aneurysm occlusion, neck remnant, and aneurysm remnant are 25.5%, 50.2%, and 11.7% in the bare coil group to be compared to 83.0%, 11.3%, and 5.7%, respectively in the present series [15]. Similar results are reported in the Matrix and Platinum Science (MAAPS) trial with post-operative complete aneurysm occlusion in 35.6%, neck remnant in 27.7%, and aneurysm remnant in 37.2% in the bare coil group [17], as well as in the German-French Randomized Endovascular Aneurysm Trial (GREAT), with post-operative complete aneurysm occlusion in 52%, neck remnant in 23%, and aneurysm remnant in 24% in the bare coil group [18].

At mid-term follow-up, the rates of complete occlusion, neck remnant, and aneurysm remnant in the bare platinum coil group of CCT was 25.2%, 56.4%, and 18.3%, respectively, compared to 51.5%, 33.0%, and 15.5%, respectively in the present series [15]. Also, the rate of complete occlusion, neck remnant, and aneurysm remnant were 39.9%, 27.8%, and 32.3% at 455 days in MAPS trial and 53%, 20%, and 27% at 18-months in GREAT [17,18]. Of note, the rate of aneurysm occlusion worsening between post-operative period and mid-term follow-up is similar in MAPS trial and the present series (34.3% and 40.8%, respectively).

As analyzed in the CCT paper, the rate of retreatment after initial aneurysm coiling is difficult to compare from one series to another, as it is quite heterogeneous from one center to another, from one geographical region to another, and probably from one physician to another. In the present series the rate of retreatment (9.7%) is higher compared to CCT (1.8%) and GREAT (6.0%) but similar to MAPS (10.5%) [15,17,18]. Unsurprisingly most aneurysms retreated in this series are ruptured aneurysms as the fear of the interventionists in that case is rebleeding. Moreover, 6 out 10 retreated aneurysms were post-procedurally only partially occluded (2 neck remnants and 4 aneurysm remnants). In some cases (very complex aneurysms, severe initial clinical presentation), the decision of the neuro-interventionist will be to do a coiling that will protect the patient against rebleeding without taking the risk of worsening

the patient and without achieving a perfect aneurysm occlusion. In these cases, a retreatment is relatively often mandatory at mid- or long-term.

Limitations

This series has several limitations:

- as it is a single-center series, this limit the generalization of the results;
- the number of patients and aneurysms treated is relatively limited. However the series is prospective and anatomical results were blindly and independently analyzed;
- we investigated immediate and mid-term anatomical results but long-term follow-up is not available yet.

Future reports about the long-term results will also be useful.

Conclusion

In this prospective, single-center series of patients with ruptured, unruptured, and recanalized aneurysms treated with Barricade coils, the safety seems to be in line with what is reported in large coiling series like ATENA and CLARITY. Anatomical results are similar or even better compared to the results reported in large randomized controlled trials like MAPS and CCT. Prospective, multicenter series are necessary to evaluate this coil and its future versions.

Disclosure of interest

LP is consultant for Balt, Microvention, Penumbra, Phenox, Vesalio.

The other authors declare that they have no competing interest.

Références

[1] Pierot L, Spelle L, Vitry F, ATENA investigators. Clinical outcome of patients harbouring unruptured intracranial aneurysms treated by endovascular approach: results of the ATENA trial. Stroke 2008;39:2497–504.
[2] Cognard C, Pierot L, Anxionnat R, Ricolfi F, Clarity Study group. Results of embolization used as the first treatment choice in a consecutive nonselected population of ruptured aneurysms: clinical results of the Clarity GDC study. Neurosurgery 2011;69:837–41.
[3] Pierot L, Wakhloo AK. Endovascular treatment of intracranial aneurysms: current status. Stroke 2013;44:2046–54.
[4] Pierot L, Biondi A. Endovascular techniques for the management of wide-neck bifurcation aneurysms: a critical review of the literature. J Neuroradiol 2016;43:167–75.
[5] Pierot L, Costalat V, Moret J, Szikora I, Klisch J, Herbreteau D, et al. Safety and efficacy of aneurysm treatment with WEB® : results of WEBCAST study. J Neurosurg 2016;124:1250–6.
[6] Pierot L, Moret J, Turjman F, Herbreteau D, Raoult H, Barreau X, et al. WEB treatment of intracranial aneurysms: clinical and anatomical results in the French Observatory. AJNR Am J Neuroradiol 2016;37:655–9.
[7] Pierot L, Spelle L, Molyneux A. Byrne. Clinical and anatomical follow-up in patients with aneurysms treated with WEB device: one-year follow-up report in the cumulated population of 2 prospective, multicenter series (WEBCAST, French Observatory). Neurosurgery 2016;78:133–41.
[8] Pierot L, Soize S, Molyneux A, Byrne J. Spelle. Evaluation of the Safety and Efficacy of Aneurysm Treatment with WEB™ device in the cumulative population of 3 prospective, multicenter series (WEBCAST, French Observatory, WEBCAST-2). J NeuroIntervent Surg 2018;10:553–9.
[9] Kallmes DF, Brinjikji W, Cekirge S, Fiorella D, Hanel RA, Jabbour P, et al. Safety and efficacy of the Pipeline embolization device for treatment of intracranial aneurysms: a pooled analysis of 3 large studies. J Neurosurg 2017;127:775–80.
[10] Pierot L, Spelle L, BeLrge J, Januel AC, Herbreteau D, Aggour M, et al. Safety of aneurysm treatment with Flow Redirection Endoluminal Device (FRED): report of the 6-months results of SAFE study. J NeuroIntervent Surg 2018;10:765–70.
[11] Pierot L, Spelle J, Berge J, Januel AC, Herbreteau D, Aggour M, et al. SAFE study (Safety and efficacy Analysis of FRED embolic device in aneurysm treatment): 1-year clinical and anatomical results. J NeuroIntervent Surg 2018 [Epub ahead of print].
[12] Gawlitza M, Soize S, Barbe C, le Clainche A, White P, Spelle L, et al. Aneurysm characteristics, study population and endovascular techniques for the treatment of intracranial aneurysms in a large, prospective multicenter cohort – results of the Analysis of Recanalization after Endovascular Treatment of intracranial Aneurysm (ARETA) study. AJNR Am J Neuroradiol 2018 [in press].
[13] Benaissa A, Barbe C, Pierot L. Analysis of recanalization after endovascular treatment of intracranial aneurysm (ARETA trial): presentation of a prospective multicenter study. J Neuroradiol 2015;42:80–5.
[14] White PM, Lewis SC, Gholkar A, Sellar RJ, Nahser H, Cognard C, et al. Hydrogel-coated coils versus bare platinum coils for the endovascular treatment of intracranial aneurysms (HELPS): a randomised controlled trial. Lancet 2011;377:1655–62.
[15] Molyneux AJ, Clarke A, Sneade M, Mehta Z, Coley S, Roy D, et al. Cerecyte Coil Trial : angiographic outcomes of a prospective randomized trial comparing endovascular coiling of cerebral aneurysms with either Cerecyte or bare platinum coils. Stroke 2012;43:2544–50.
[16] Pierot L, Cognard C, Ricolfi F, Anxionnat R. CLARITY investigators. Mid-term anatomic results after endovascular treatment of ruptured intracranial aneurysms with Guglielmi detachable coils and Matrix coils: analysis of the CLARITY series. Am J Neuroradiol 2012;33:469–73.
[17] McDougall CG, Johnston SC, Gholkar A, Barnwell SL, Vazquez Suarez JC, Masso Romero J, et al. Bioactive versus bare platinum coils in the treatment of intracranial aneurysms: The MAPS (Matrix and Platinum Science) trial. Am J Neuroradiol 2014;35:935–42.
[18] Taschner CA, Chapot R, Costalat V, Machi P, Courthéoux P, Barreau X, et al. Second generation hydrogel coils for the endovascular treatment of intracranial aneurysms. Stroke 2018;49:667–74.
[19] Zidan M, Gawlitza M, Metaxas G, Foussier C, Soize S, Pierot L. Endovascular treatment of intracranial aneurysms with Barricade coils: feasibility, procedural safety, and immediate post-operative anatomical results. J Neuroradiol 2016;43:353–7.