CONTINUING EDUCATION PROGRAM: FOCUS...

Endovascular treatment of ruptured intracranial aneurysms: Indications, techniques and results


Department of diagnostic and therapeutic neuroradiology, Neurology Hospital, Central Hospital, 29, avenue du Maréchal-de-Lattre-de-Tassigny, CO 60034, 54035 Nancy cedex, France

KEYWORDS
- Encephalon;
- Vascular accident;
- Emergency;
- Subarachnoid hemorrhage;
- Hematoma

Abstract
Rupture of an intracranial aneurysm is a diagnostic and therapeutic emergency. Occlusion of the aneurysm with coils is the first line treatment and should be performed promptly to avoid any further rupture, which carries a poor prognosis. Most aneurysms are accessible to this type of treatment. The risks of coiling, which are mostly thromboembolic and less commonly hemorrhagic due to peroperative rupture, are low. The use of stents or a flow diverter requires dual anti-aggregation which increases their risks so that their use are restricted to specific situations such as dissecting aneurysms. Endovascular treatment is effective in the long and short term prevention of recurrent hemorrhage provided that patients are followed up by imaging, which allows possible early recanalization to be detected early and treated if necessary.

© 2015 Éditions françaises de radiologie. Published by Elsevier Masson SAS. All rights reserved.

Rupture of an intracranial aneurysm is a diagnostic and therapeutic emergency, which requires multidisciplinary management involving neuroradiologists, neurosurgeons and neurology intensive care physicians [1]. Occlusion of the aneurysm is required because of the possibility of further rupture.
Occlusion of intracranial aneurysms with controlled detachment coils was developed in 1991 [2,3]. This technique has gradually overtaken surgical clipping as the first line management of a ruptured aneurysm in light of the results of the International Subarachnoid Aneurysm Trial (ISAT), which compared the two techniques [4].

The indications for surgery are primarily limited to the treatment of ruptured aneurysms causing compressive hematomas, which need to be evacuated. The other main indication, aneurysms which are not accessible to endovascular treatment, is uncommon. Technological advances such as 3D angiography and improvements in navigation and endovascular occlusion materials have broadened the possibilities of endovascular treatment (EVT) to most aneurysms.

Basic EVT uses controlled detachment coils. The use of stents or flow diverters requires dual anti-aggregation which is difficult to manage in the hemorrhagic phase and is therefore reserved for selective situations. Other more recent devices are in clinical assessment.

This review provides an update regarding the indications, techniques, risks and results of EVT for ruptured intracranial aneurysms.

**Indications**

An untreated ruptured aneurysm is at high risk of rebleeding [5,6]. This new rupture may occur very early even before the patient has arrived at the hospital, but it usually happens several days later. Risk increases over time and without intervention the cumulative risk at 4 weeks is 40% [6].

In addition, rebleeding is associated with a poor prognosis and high morbidity and mortality [6]. In the ISAT trial, 59% of patients who suffered an early rebleed died [4].

It is therefore important to occlude the aneurysm promptly. Because of the estimated risk of recurrence of 4.1% within 24 hours after the initial rupture, ultra-early treatment of a ruptured aneurysm has been proposed [7]. But on the other hand, the advantages of this strategy are controversial [8], particularly in view of the increased risk of complications during procedures performed in the middle of the night, and also because there is currently no consensus on ultra-early treatment. According to current guidelines, the aneurysm should be excluded promptly, within 72 hours and if possible within 48 hours.

The ISAT trial is the only randomized multicenter international trial that has compared surgery to endovascular coiling for ruptured intracranial aneurysms. Its results supported endovascular treatment and showed a significant reduction in the risk of dependency or death at 1 year [4], although the population in this study included a great majority of young patients in good clinical state (WFNS grades 1 or 2) [9], with anterior circulation aneurysms under 10 mm in size. The results of this study led to a large and unrestricted increase in endovascular treatment for ruptured intracranial aneurysms. These results have also been confirmed in other studies [10]. Currently, EVT is considered to be the first line treatment for intracranial aneurysms by most groups.

Some sub-populations of patients who have suffered a ruptured aneurysm raise specific problems and have been examined in additional studies. This applies particularly to elderly patients, aneurysms with severe clinical grades and compressive hematomas.

Endovascular treatment is possible with acceptable clinical results in the elderly. A meta-analysis published in 2013 [11] showed high morbidity and mortality (9% and 23% respectively), although this was related more to the severity of the subarachnoid hemorrhage and its complications than to complications of endovascular treatment itself with a 4% aneurysm rupture rate and 5% postoperative ischemic injuries. At 1 year, 66% of patients had recovered well or had only moderate handicap, allowing them to be independent in their activities of daily living. Occlusion at 1 year was complete or subtotal in 87% of cases.

Severe clinical grade when the patient is first managed (WFNS grade IV or V) [9], is an independent poor prognostic indicator and outcome is significantly poorer in grade V patients [12, 13]. Clinical outcome was good in 62% of grade IV patients and in only 25% of grade V patients in a series of 80 patients by Bracard et al. [12].

Ruptured aneurysm causing a compressive hematoma is usually treated surgically by clipping the aneurysm and evacuating the hematoma at the same time. Combined treatment with urgent coiling of the ruptured aneurysm followed by evacuation of the hematoma is an alternative treatment [14].

**Techniques**

EVT is performed under general anesthesia. Arterial access is usually through the right femoral artery although if endovascular navigation is difficult, other approaches can be used: humeral, radial or even direct puncture of the cervical internal carotid artery. The access is infused continuously using an introducer through which a guide catheter is passed and is positioned in the artery giving rise to the aneurysm. This artery has usually been identified initially from a CT angiogram performed at the time of diagnosis of the subarachnoid hemorrhage.

A microcatheter is then carried by the guide catheter and its tip introduced into the aneurysm using a microguide. The aneurysm is occluded by gradually filling it with decreasing sizes of coils with the aim of occluding the aneurysm as well as possible up to its neck without going beyond this (Fig. 1).

It is fundamental to treat the aneurysm following an angiographic view called "working view" which shows the neck distinctly. Development of 3D angiography in 1996 played an important role in the safety of an endovascular treatment by allowing a precise analysis of the morphology of the aneurysm, facilitating the identification of a working view and allowing the size of the aneurysm to be measured accurately [15]. The size of the first coil must be suited as well as possible to the size of the aneurysm in order to obtain a "frame", which is used as the support structure to gradually fill the aneurysm with other coils.

The quality of occlusion is assessed from an angiographic sequence at the end of treatment in the working view which best identifies the neck of the aneurysm. Occlusion is classified into 3 grades: total occlusion, subtotal occlusion or residual neck and partial occlusion or residual aneurysm,
Endovascular treatment of ruptured intracranial aneurysms

Figure 1. Endovascular treatment (EVT) with coiling of a ruptured aneurysm performed on day 1 of rupture: a: plain cerebral CT shows a subarachnoid hemorrhage (SAH) in the optic chiasma cistern extending to the motor cortex sulci associated with a ventricular hemorrhage and dilatation of the lateral ventricles which required an external shunt; b: frontal CT angiography reconstructions showing an aneurysm in the anterior communicating artery responsible for the SAH; c: 3D angiography of the left internal carotid artery provides an optimal view which clearly shows the neck of the aneurysm and which is used for EVT for the aneurysm. This is known as the working view; d: accurate measurements of the dimensions of the aneurysm are taken from the 3D angiogram. These measurements are used to select the size of the initial coil; e: the working view is reproduced on the angiography arch; f: a microcatheter is advanced under fluoroscopy guidance to the aneurysm. Its visible tip in the aneurysmal sac is used as a landmark to deploy the coils; g: end of treatment series after inserting 3 coils showing complete occlusion of the aneurysm; h: the same, unsubtracted series, shows "packing" of coils fitting well to the shape of the aneurysm.

total occlusion or a residual neck are deemed to be satisfactory.

The first controlled detachable coils developed in 1991 were the Guglielmi detachable coils (GDC) [2,3] and have contributed to the rise of endovascular treatment of intracranial aneurysms [16]. These very flexible spiral shaped coils are made of a platinum alloy, which is entirely compatible with MRI. A large multicenter series on over 700 ruptured aneurysms treated by GDC [17] showed that coiling was feasible in 96.9% of cases with a mortality rate of 1.4%. 
Figure 2. Endovascular treatment of a wide neck ruptured aneurysm of the basilar artery top using a "remodeling" technique: a: subarachnoid and intraventricular hemorrhage with ventricular dilatation on CT; b: reconstruction from the 3D angiogram: aneurysm at the top of the basilar artery with a wide neck extending to the origin of the posterior cerebral arteries; c: working view angiography; d: unsubtracted angiography after an introduction of a first coil using a "remodeling" technique. This technique involves positioning a protective balloon catheter across the aneurysm neck, and temporarily inflating the balloon whilst the coils are positioned avoiding them protruding outside of the aneurysm. The coils are carried by a second microcatheter placed in the aneurysm. In this case, the balloon...
and morbidity of 8.6%. The current coils which are based on the same principle have undergone several technological developments and the user now has a wide variety of sizes, 3D shapes and flexibilities which can adapt to all types of aneurysm. The smallest coils measure 1 mm in diameter and the largest are over 20 mm. New technological developments have sought to improve the effectiveness of these coils in terms of occlusion. Coils with a bioactive coating have been developed but have not been shown to be superior compared to "uncoated" coils [18]. On the other hand, the use of coils incorporating a hydrogel into their structure enabling them to dilate once introduced into the aneurysm, appears to reduce the risk of major recanalization [19]. Their utility in preventing recurrence of hemorrhage and in the long term prognosis, however, has not been demonstrated [19].

When the neck of the aneurysm is large, positioning coils within the aneurysm can be facilitated by temporary inflation using a balloon microcatheter across the neck. This technique, described by Moret et al. [20] under the name "remodeling" technique, is widely used to treat difficult aneurysms safely [21] (Fig. 2). In addition, if the aneurysm ruptures, rapid inflation of the balloon in front of the aneurysm can limit the bleeding from rupture and improve prognosis [22].

The use of stents as a complement to coils requires long term dual anti-aggregation because of the very much higher thrombogenic risk than that of coils alone. Use of these materials to treat ruptured aneurysms is associated with a higher risk of thromboembolic and hemorrhagic complications [23–25] and is therefore reserved for aneurysms with a very wide neck or with no neck at all, such as dissecting aneurysms and "blister like" aneurysms which cannot be treated by coils alone or surgery (Fig. 3).

"Flow diverters" (FD) are self-expanding stents developed more recently, the very tight mesh of which redirects flow allowing the aneurysm to be occluded without using additional coils. These FD achieve high occlusion rates but require long-term dual anti-aggregation which makes their use difficult in the acute hemorrhagic phase. They can be used in selected indications for ruptured aneurysms such as dissecting aneurysms and "blister like" aneurysms, which are very small aneurysms without necks and are extremely fragile [26,27]. When possible and in order to reduce the risks, these stents and FD should be used a few days after the acute phase, possibly in addition to initial partial hemostatic coiling carried out in the acute phase.

The "flow disrupters" are flexible intrasaccual tight mesh devices which have been developed recently. A few studies have shown that these are suitable for treating complex aneurysms of the bifurcation with a wide neck [28] including ruptured aneurysms [29] although there is not yet sufficient experience to assess their long term results.

Occlusion of the vessel containing the ruptured aneurysm is a treatment option in some rare situations such as dissecting aneurysms of an intracranial vertebral artery provided that the contralateral vertebral artery can on its own provide all of the vertebrobasilar circulation [30]. In this type of situation, such "deconstructive techniques" are an effective alternative to the "constructive" techniques preserving the carrier vessel using stents or FDs [31].

## Risks of EVT

The two main complications of EVT are thromboembolic complications and aneurysm rupture during treatment.

A meta-analysis published in 1999 [32] reported an ischemic complication rate of 8.5% with an aneurysm perforation rate of 2.4% causing long term complications in 3.7% of cases. More recently, a large multicenter prospective series [33] has reported a 13.3% thromboembolic complication rate and 3.7% periprocedural rupture rate. As the main risk is therefore thromboembolic these treatments are usually carried out under anticoagulation and/or with antiplatelet agents, although there is no consensus in literature [34].

## Results

In the ISAT trial [4], the occlusion rate assessed by the operator was complete in 66% of cases, a residual neck was found in 26% of cases and a residual aneurysm in 6%. A meta-analysis published in 2009 [35] found similar results with a 62.3% complete occlusion rate, 29.5% residual neck rate and 8.2% residual aneurysm. The CLARITY "clinical and anatomical results in the treatment of ruptured intracranial aneurysms" multicenter prospective trial on 773 treated aneurysms found slightly different figures: 47.4% complete occlusion, 41.9% residual neck and 10.7% residual aneurysm [36]. The lower proportion of complete occlusions is explained by the independent reviewers which designated a significant proportion of complete occlusions as assessed by the operator as residual necks after occlusion. The satisfactory occlusion result combining partial occlusions and residual necks remains, however, around 90% in these different studies.

One of the limitations of treating aneurysms is the risk of recanalization which is greater after endovascular treatment than after surgery [4,10]. Recanalization after coiling has many mechanisms [37]. The risk factors for this are in particular large aneurysms and wide neck, partial initial occlusion and length of follow up [38,39] (Fig. 2). Recanalization, however, may also occur in aneurysms completely occluded initially and develop later, several years after...
Figure 3. Endovascular treatment of a ruptured "blister" aneurysm of the right carotid siphon with a stent and coils; a: 3D angiography: small "blister" aneurysm without a neck in the usual site at the carotid siphon; b: insertion of coils and a stent in the deployment phase on this unsubtracted angiography view; c: repeat angiography in the working view at the end of treatment.

Figure 4. Late recurrence of a ruptured anterior communicating artery aneurysm treated 14 years previously by clipping following an initial rupture, without long term follow up: a: Postero-anterior right carotid angiography: recurrence of aneurysm seen between the 2 surgical clips; b: unsubtracted view showing the position of clips and the craniotomy flap; c: 3D angiography showing the residual aneurysm, neck and position of the clips; d: working view providing good visualization of the neck; e: complete occlusion of the aneurysm with 4 coils; f: final end of treatment angiogram.
initial treatment [38], justifying regular routine long term follow up.

Recanalization does not systematically require further treatment. The indications for treatment vary depending on the teams but are usually proposed for major recanalization or expanding residual aneurysm on reviews. These “retreatments” can be carried out using an endovascular approach or surgically. A systematic literature review found 11.4% recanalization rate and 7.2% retreatment rate in aneurysms treated with coils despite a 95.9% satisfactory initial occlusion rate [35]. The ISAT trial reported more retreatments after coiling than after surgery [40] although the retreatments had no adverse consequences on clinical prognosis [41].

The primary aim of treating ruptured aneurysms is to prevent the long term risk of rebleeding. The risk of recurrent hemorrhage is low after both surgery and endovascular treatment [41–45], although cases of late recurrent hemorrhage related to recanalization of the aneurysm treated initially or to rupture of de novo aneurysms occurring several years after initial treatment have been reported both following endovascular treatment and surgery [45] (Fig. 4). Regular imaging follow up can detect these recanalizations and de novo aneurysms at an early stage and thereby reduce the risk of a recurrent bleed.

Conclusion

Endovascular treatment is currently the first line treatment for ruptured intracranial aneurysms. The basic technique is coils occlusion, possibly assisted by a remodeling balloon. This technique is appropriate for most aneurysms. The use of stents and flow diverters in the hemorrhagic phase carries additional risks, particularly through the use of dual anti-aggregation and is therefore reserved for those rare aneurysms which cannot be treated by coiling alone. This applies particularly to dissecting aneurysms. Endovascular treatment is effective in the short and long term prevention of the risk of recurrent hemorrhage provided that the aneurysm occlusion is followed up by imaging. This allows investigation for possible recanalization which may require further treatment.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


Endovascular treatment of ruptured intracranial aneurysms

