Immediate intracranial aneurysm occlusion after embolization with detachable coils: a comparison between MR angiography and intra-arterial digital subtraction angiography

Occlusion immédiate des anévrismes intracrâniens traités par embolisation à l’aide de coils détachables : comparaison entre l’ARM et l’angiographie conventionnelle

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Intracranial aneurysm; Endovascular treatment; Detachable coils; MR angiography

Abstract

Background and purpose. — To prospectively compare the effectiveness of time-of-flight (TOF) and contrast-enhanced (CE) MR angiography (MRA) with that of digital subtraction angiography (DSA) to assess immediate intracranial aneurysm occlusion after selective embolization.

Methods. — From August 2006 to March 2007, 33 consecutive patients with 40 aneurysms were included. Thirty aneurysms were treated by endosaccular coils (group 1). Ten aneurysms were treated by stent placement and subsequent endosaccular coils (group 2). All patients underwent MRA within 24 h after treatment. One senior and one fellow radiologist independently reviewed the MR images, and another senior radiologist reviewed the DSA images.

Results. — DSA showed 22 complete occlusions, ten residual necks, and eight residual aneurysms. For residual neck detection, there was no difference between TOF-MRA (sensitivity, 80%–80%; specificity, 93.8%–100%, according to both readers) and CE-MRA (sensitivity, 80%–80%; specificity, 100%). For residual aneurysm detection, there was a significant difference between TOF-MRA (sensitivity, 50%–62.5%; specificity, 100%) and CE-MRA (sensitivity and specificity, 100%, according to both readers). In group 2, a residual aneurysm was missed by both readers with TOF-MRA in the same 3 aneurysms. Moreover, both readers judged CE-MRA better.
Immediate intracranial aneurysm occlusion after embolization

Introduction

Selective endovascular treatment (EVT) by means of detachable coils is widely used and accepted as an alternative to surgical clipping for patients with unruptured and ruptured intracranial aneurysms [15,16]. Furthermore, EVT is associated with lower rates of morbidity and mortality in selected cases. However, over the long term, neurointerventionalists face a major problem: aneurysm recanalization due to coil compaction. These recurrences occur in 8% to 33.6% of patients [4,27].

To evaluate the stability of aneurysm occlusion, patients must regularly be followed-up. Digital subtraction angiography (DSA) is currently the standard method for the detection and evaluation of intracranial aneurysms [22]. However, the method is invasive, time-consuming, relatively expensive and associated with a 0.5% risk of permanent neurological complications [7]. Magnetic resonance angiography (MRA), including three-dimensional time-of-flight (TOF) MRA and contrast-enhanced (CE) MRA, has increasingly been recognized as an efficient non-invasive imaging method for the detection and evaluation of intracranial aneurysms [2,3,5,6,8-11,17,18,23,24,26,30-33]. Moreover, these authors have shown that TOF-MRA and CE-MRA are useful for the follow-up of coiled aneurysms. Therefore, MRA might be used in the future as the only imaging examination for the follow-up of patients with aneurysms treated by endosaccular coils.

Nevertheless, to precisely follow-up coiled aneurysms with only the use of MRA, it is mandatory to know how MRA correlates with DSA findings immediately after treatment. The aim of our study was to prospectively compare the effectiveness of both TOF-MRA and CE-MRA with that of conventional DSA in the assessment of aneurysm occlusion immediately after EVT.

Patients and methods

Population

All adult patients (≥ 18 years of age) undergoing EVT for unruptured or ruptured intracranial aneurysms were considered eligible. In the case of subarachnoid hemorrhage (SAH), patients were classified according to the Hunt and Hess scale [14]; those who presented with grade III-V were excluded because of the discomfort and difficulty in per-
forming good-quality MRA at these acute stages in such patients.

From August 2006 to March 2007, 40 eligible patients were identified, seven of whom were excluded from the present study. Thus, the study consisted of 33 patients with 40 aneurysms that were treated by the endovascular approach. All patients gave their written informed consent to the examination, and the local ethical committee’s approval was obtained.

Altogether, there were 20 women and 13 men with a mean age of 49 years (range, 21 to 70 years). Five patients were treated for a ruptured aneurysm, and the remaining were treated for one or multiple asymptomatic unruptured aneurysms. Locations of the aneurysms were as follows: internal carotid artery in 18 cases; the anterior communicating artery in seven cases; the middle cerebral artery bifurcation in five cases; the basilar artery in five cases; the superior cerebellar-basilar arterial junction in two cases; the pericallosal artery in one case; the vertebrobasilar junction in one case; and the posterior and inferior cerebellar artery in one case.

EVT

EVT was performed on a biplane flat-panel digital subtraction unit (Allura Xper 20/10, Philips, Netherlands). In all patients, EVT was performed under general anesthesia and systemic heparinization. The adequacy of systemic anticoagulation was monitored by frequent measurements of the activated clotting time (ACT). A baseline ACT was obtained prior to the bolus infusion of heparin (30-50 IU/kg body weight), and hourly thereafter. The bolus infusion of heparin was followed by a continuous drip (1000-1500 IU/h), with the purpose of doubling the baseline ACT. At the end of the procedure, systemic heparinization was maintained for 24 h in most patients. All procedures were performed by the same interventional neuroradiologist (BL). All patients were treated by selective embolization with MicroPlex coils (MicroVention, Aliso Viejo, CA), or Guglielmi detachable coils (Target Therapeutics, Fremont, CA). The technique used for the endosaccular coiling procedure has already been published [12,13,29].

The endosaccular coiling was done with (n = 6) and without (n = 24) the help of the remoulding technique [20,25] in 30 aneurysms (group 1). The stent-assisted technique [1, 21], whereby a stent was placed across the aneurysm neck and followed by endosaccular coiling, was used in ten aneurysms (group 2). Only self-expandable nitinol stents were used (Léo stent, Balt, Montmorency, France; Enterprise stent, Cordis, Miami Lakes, FL).

After endovascular treatment, patients were transferred to the intensive care unit, where fluid balance, neurological status and blood pressure were carefully monitored.

Anatomical outcome

DSA

At the end of the endovascular procedure, all patients were evaluated by angiography to document aneurysm obliteration. Angiograms included selective injection of internal carotid or vertebral arteries with intracranial views (fron-
duration of 7 min, 44 sec). The 3-D MT TONE volume included the circle of Willis and intracerebral arteries from the cervical segment of the carotid artery.

Original MRA data were retrieved and reprocessed. All MR examinations were performed within 24 to 48 h after EVT.

**Image analysis**

Immediate postinterventional DSA controls served as reference images and were interpreted by the senior neuroradiologist (BL), who has 6 years of experience in vascular diagnostic neuroradiology.

TOF-MRA and CE-MRA images were independently and blindly reviewed by one senior neuroradiologist (NS = reader 1) who has a 9-year experience in vascular diagnostic neuroradiology, and one fellow in the last year of radiology fellowship (PE = reader 2). Pretreatment DSA images were shown to the MRA readers to orient them to the nature of the aneurysms.

Quality of the MR images was judged according to the following criteria: image contrast; artefact (coil, motion); vessel overlap. Image contrast was graded as low when the signal intensity in the enhanced arterial lumen was only slightly higher than the signal intensity in the background, as moderate when the signal intensity was clearly higher and as high when the signal intensity was optimal. Artefacts and vessel overlap were judged as minor when they did not prevent image interpretation, and as major when they degraded image quality. On the basis of the Raymond et al. classification [27,28], both MRA and DSA results were assigned to one of three categories: class 1 = complete obliteration; class 2 = residual neck; class 3 = residual aneurysm. In patients treated with the stent-assisted technique, patency of the parent artery was also assessed on both TOF-MRA and CE-MRA.

**Statistical analysis**

The first step of the analyses consisted of an evaluation of the level of interobserver agreement for sets of MR images by means of the κ statistic. The second step included comparisons between TOF-MRA and DSA, and CE-MRA and DSA for the detection of a residual neck or aneurysm, using the same statistical test. The κ values > 0.6 suggested good agreement, and values > 0.8 indicated excellent agreement; P values < 0.05 were regarded as significant.

**Results**

**DSA**

All angiograms were interpretable. In group 1, there were 17 complete obliterations (56.7%), ten residual necks (33.3%) and three residual aneurysms (10%). In group 2, there were five complete obliterations (50%) and five residual aneurysms (50%). Patency of the parent artery was demonstrated in all cases in group 2. No parent-artery stenosis was identified.

**MRA**

Quality of the TOF-MRA and CE-MRA images was considered high or moderate in all cases by both readers. In all cases, artefacts and/or vessel overlap were judged as minor by both readers as they did not prevent interpretation of the images.

**Intertechnical agreement**

Comparisons between TOF-MRA and DSA for immediate aneurysm-occlusion evaluation were good for both readers (κ = 0.732 and 0.774, respectively). Comparisons between CE-MRA and DSA for immediate aneurysm-occlusion evaluation were excellent (κ = 0.914 for both readers).

**Interobserver agreement**

When TOF-MRA was used to evaluate immediate aneurysm occlusion after EVT, the agreement between both readers was excellent (κ = 0.9). Likewise, when CE-MRA was used to evaluate immediate aneurysm occlusion after EVT, the agreement between both readers was also excellent (κ = 1).

**Detection of residual necks**

The overall diagnostic performance of TOF-MRA and CE-MRA for the detection of residual necks is summarized in Table 1.

According to both readers, there was no difference between the sensitivity of TOF-MRA (80%) and CE-MRA (80%) for the detection of residual necks (Fig. 1). For reader 1, specificity was of 93.8% for TOF-MRA versus 100% for CE-MRA; for reader 2, specificity was of 100% for both TOF-MRA and CE-MRA. Among ten aneurysms with a residual neck seen at DSA, both readers missed two residual necks in the same patient. This patient was treated for two unruptured aneurysms that were located very close to each other (one on the posterior communicating artery and one on the anterior choroidal artery).

**Detection of residual aneurysms**

The overall diagnostic performance of TOF-MRA and CE-MRA for the detection of residual aneurysms is summarized in Table 1.

According to both readers, there was a significant difference between the sensitivity of TOF-MRA (50% for reader 1 and 62.5% for reader 2) and CE-MRA (100% for both readers) in the detection of residual aneurysms. However, specificity was 100% for both readers with TOF-MRA and CE-MRA. The significant difference between TOF-MRA and CE-MRA sensitivity was related to the endovascular procedure that was used to treat patients. The major difference between the results of TOF-MRA and CE-MRA concerned patients treated with the stent-assisted technique (group 2). For this reason, diagnostic performance of TOF-MRA and CE-MRA for the detection of residual aneurysms was also calculated in group 2 alone (Table 2). In these ten patients, aneurysm occlusion at DSA consisted of five complete occlusions and five residual aneurysms. These latter five residual aneurysms were all identified by both readers on CE-MRA (sensitivity of 100%) whereas only two were identified by both readers on TOF-MRA (sensitivity of 40%). Both readers...
made these three false-negative evaluations in the same three cases (Fig. 2). Reader 1 identified two complete occlusions and one residual neck whereas reader 2 identified three complete occlusions.

**Patency of the parent artery**

In group 2, patency of the parent artery was demonstrated in all cases by both readers on TOF-MRA and CE-MRA. However, parent-artery intraluminal definition within the stent was judged better by both readers in all cases on CE-MRA (Fig. 2). Indeed, both readers identified parent-artery stenosis within the stent on TOF-MRA images in all cases.

**Discussion**

This study shows that TOF-MRA and CE-MRA have good-to-excellent intertechnical and interobserver reproducibility.
for the assessment of immediate aneurysm occlusion after selective EVT with detachable coils. Both MR techniques have high and comparable sensitivity and specificity except when the stent-assisted technique is used. Indeed, CE-MRA has higher sensitivity and specificity to evaluate the aneurysm occlusion in such cases as well as to assess parent-artery patency.

**Aneurysm occlusion after EVT**

To the best of our knowledge, no series has evaluated the correlation between TOF-MRA and CE-MRA with that of DSA immediately after selective EVT with coils. However, if MRA is to be replaced by DSA as the first-line imaging technique for the follow-up of coiled aneurysms, it is mandatory to know how MRA correlates with DSA findings immediately after treatment.

Therefore, we undertook this prospective study to compare the efficacy of TOF-MRA and CE-MRA with that of DSA to evaluate aneurysm occlusion immediately after treatment. We showed that both TOF-MRA and CE-MRA have high and comparable sensitivity and specificity to detect residual necks or aneurysms after EVT (Fig. 1). However, in aneurysms treated with the stent-assisted technique, we found that CE-MRA is more reliable than TOF-MRA for the assessment of aneurysm occlusion and parent-artery patency (Fig. 2). In cases of wide-necked or fusiform aneurysms [1,21], intracranial stents are sometimes needed to allow for subsequent coiling of the sac. In our series, ten aneurysms were treated by this endovascular approach, and DSA showed five complete occlusions and five residual aneurysms at the end of EVT. Among these latter five residual aneurysms, both readers could not detect three of them on TOF-MRA in the same three cases. In contrast, CE-MRA could detect and precisely depict residual aneurysms in all five cases.

To our knowledge, there is only one previous series [19] that has assessed the use of MRA for the evaluation of aneurysms treated with the help of intracranial stents. Lovblad et al. [19] showed that CE-MRA can improve parent-artery intraluminal definition. In our series, although TOF-
MRA and CE-MRA could both demonstrate parent-artery patency in all cases, both readers believed that CE-MRA was better for defining the parent artery lumen within the stent. Moreover, TOF-MRA showed a parent-artery stenosis within the stent in all cases; this was not seen on CE-MR images (Fig. 2).

Our study, although limited by its small patient population, thus confirms the findings of Lovblad et al. [19]. For this reason, we believe that, although both MRA techniques may be used to evaluate immediate occlusion of coiled aneurysms, CE-MRA would be needed in cases of aneurysms treated by intracranial stents.

TOF-MRA and CE-MRA

There is an ongoing debate in the literature as to whether or not the use of contrast material can improve the efficacy of MRA. Most authors have evaluated TOF-MRA [2,3,6,11,17,24,30-33] for the follow-up of coiled aneurysms. They have reported sensitivity for the detection and exclusion of a residual flow within the aneurysm as lying between 71% and 91%, and between 89% and 100%, respectively. However, the technique is limited by its sensitivity to both saturation and susceptibility artefacts [2,6,11,17]. These disadvantages may lead to false-positives or false-negatives, and it may also explain why some MR examinations are not analyzed [2,6]. Also, TOF sequences require a long acquisition time and may yet only result in a small acquisition volume. These limitations may be of importance in patients with multiple coiled aneurysms [2,3,6,11,17,24,30-33]. Nevertheless, these authors showed that TOF-MRA is useful for detecting residual necks or aneurysms, and they have suggested a partial replacement of DSA by MRA for the follow-up of coiled aneurysms.

CE-MRA is a more recent MR technique with several theoretical advantages [5,8-10,18,23,26]. It is less sensitive to flow turbulence and saturation effects than TOF sequences because of the high signal intensity within the arterial lumen caused by T1-shortening effects. In addition, contrast enhancement allows the imaging of low-flow signals that can lead to greater identification of a residual neck or aneurysm. CE-MRA is also less sensitive to coil-related artefacts (susceptibility artefacts) that can decrease image quality and prevent a precise visualization of a residual neck or aneurysm. The injection of contrast material allows better visualization because of the appropriate filling of the small arteries with gadolinium and because of the short acquisition time of the sequence, which reduces motion artefacts. Finally, the technique allows the assessment of a larger imaging volume than TOF-MRA, which is of particular interest in patients with multiple coiled aneurysms.

Nevertheless, CE-MRA does have disadvantages [5,8-10,18,23,26]. Venous enhancement occurs at the same time as arterial enhancement because of the short time-window between the phases, and this may degrade image quality, especially if aneurysms are located near the base of the skull or the middle cerebral artery [5,23,26]. Another disadvantage is the possibility of a false neck remnant, which may be explained by peripheral contrast enhancement of the organized thrombus or by the vasa vasonum within the aneurysm wall [9,10,18].

Despite many theoretical advantages, only a few authors have evaluated CE-MRA for the follow-up of coiled aneurysms [5,8-10,18,23,26]. Most of them have found no differences between TOF-MRA and CE-MRA. Only Leclerc et al. [18] showed a superiority of CE-MRA over TOF-MRA in a series of 20 patients. This outcome may be explained by the fact that all of those patients had aneurysms located on the anterior communicating artery. In fact, at this particular site, there is no venous opacification to cause degradation of image quality.

In the present study, there was no significant difference between TOF-MRA and CE-MRA in the evaluation of immediate aneurysm occlusion except when the stent-assisted technique was used. These findings thus confirm what most authors have recently found [5,8-10,26]. However, when a stent was used to treat complex aneurysms, CE-MRA was more sensitive than TOF-MRA in the detection of a residual aneurysm as well as to assess the patency of the parent artery.

Conclusions

This prospective series shows that both TOF-MRA and CE-MRA have good-to-excellent intertechnical and interobserver reproducibility for the assessment of immediate aneurysm occlusion after embolization with detachable coils. Both MR techniques have high and comparable sensitivity and specificity except for aneurysms treated with self-expandable stents. In these cases, CE-MRA is superior to TOF-MRA for detection of residual aneurysms as well as to assess parent-artery patency.

Références

Immediate intracranial aneurysm occlusion after embolization


