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Follow-Up of endovascular coil embolization applied for the treatment of intracranial aneurysms by magnetic resonance angiography

İntrakraniyal anevrizmaların tedavisi için uygulanan endovasküler koil embolizasyonunun manyetik rezonans anjiyografi ile takibi

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Abstract

Purpose: To assess the usefulness and reproducibility of magnetic resonance angiography (MRA) for the evaluation of intracranial aneurysms treated by endovascular coiling.

Materials and methods: 51 patients (18 men, 33 women; 21-86 year-old, mean age 50.2) with 54 aneurysms treated by detachable platinum coils were included in this study. The patients were scheduled for follow-up MRA imaging at three to six months after endovascular treatment. Two interventional neuroradiologists, evaluated the TOF-MRA images blindly. Source MR images and volume rendering techniques of 3D TOF images such as maximum intensity projection (MIP) and multiplanar reformation (MPR) were utilized for this purpose. Follow-up digital subtraction angiography (DSA) was performed as a reference test on a biplane angiographic unit on the sixth month and the first year depending on the patient's characteristics.

Results: DSA confirmed residual or recurrent aneurysmal flow in 5 patients out of 54 treated cerebral aneurysms; two with tip of basilary artery, one with left MCA bifurcation, one with anterior communicating artery and one with right supraclinoid internal carotid artery. Then the DSA images were compared with the MRA data. Total agreement was 0.94 for MRA. Kappa coefficient was 0.74 for indicating good concordance of the readers for MRA (95% CI was 0.44 to 1.04).

Conclusion: MRA is a reproducible technique for the follow-up of aneurysms after endovascular coil embolization. Conventional catheter angiography as a gold standard test could be used to solve uncertain cases.

Key words: Cerebral aneurysm, endovascular treatment, coil embolization, magnetic resonance angiography, digital subtraction angiography.

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Öz

Amaç: Manyetik rezonans anjiyografinin (MRA) endovasküler koil ile tedavi edilen intrakraniyal anevrizmaların takiplerinde kullanışlılığını ve tekrarlanabilirliğini değerlendirmek.

Gereç ve yöntem: Platin koil ile tedavi edilen 51 hasta (18 erkek, 33 kadın; yaş 21-86 yıl, ort. yaş 50,2 yıl) bu çalışmaya alındı. Hastalara, endovasküler tedaviden 3-6 ay sonra takip MRA planlandı. İki girişimsel nöroradyolog, TOF-MRA görüntülerini körleme değerlendirdi. Bu amaçla, maksimum yoğunluk projeksiyonu (MIP) ve multiplanar reformasyon (MPR) gibi 3D TOF görüntülerinin kaynak MR görüntüleri ve hacimsel işleme teknikleri kullanılmıştır. Altı ay ile birinci yılda hastanın özelliklerine bağlı olarak biplanar anjiografi ünitesinde bir referans testi olarak takip dijital subtraksiyon anjiyografi (DSA) yapılmıştır.

Bulgular: Tedavi edilen 54 serebral anevrizmalı hastadan, 5'inde rezidü veya rekürren anevrizma olduğu DSA ile doğrulandı; ikisi baziler tepe, biri sol MCA bifurkasyosu, biri anterior komünikan arter ve biri sağ supraklinoid internal karotid arterdi. Daha sonra DSA, MRA verileriyle karşılaştırıldı. MRA için toplam uzlaşma 0,94 idi. MRA için, okuyucuların iyi uyumunu göstermek için Kappa katsayısı 0,74 idi (%95 CI 0,44 ile 1,04 idi).

Sonuç: MRA, endovasküler koil embolizasyonundan sonra anevrizmaların takibi için tekrarlanabilir bir tekniktir. Altın standart bir test olarak konvansiyonel kateter anjiyografi şüpheli olguları göstermek için kullanılabilir.

Anahtar kelimeler: Serebral anevrizma, endovasküler tedavi, koil embolizasyon, manyetik rezonans anjiyografi, dijital subtraksiyon anjiyografi.

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Introduction

Although it has been increasingly used as a first-line treatment of intracranial aneurysms [1, 2], endovascular treatment carries a potential risk of aneurysm recanalization. The risk factors for recanalization is not well defined. Therefore, all patients should be followed up closely after endovascular treatment. Digital Subtraction Angiography (DSA) is still the reference imaging modality in follow-up; however, it is invasive and carries a risk of morbidity [2, 3]. Magnetic resonance angiography (MRA) is a non-invasive and radiation-free technique, and it can be used to reduce the need for follow-up DSA [4-7].

The purpose of our study was to assess the usefulness and reproducibility of MRA for the evaluation of intracranial aneurysms treated with coils endovascularly.

Material and methods

A total number of 51 patients (18 men, 33 women; 21-86 year-old, mean age 50.2) with 54 aneurysms treated by detachable platinum coils were retrospectively included in this study. The patients with stent-assisted coils were excluded from the study if the stents had interfered MRA evaluation. At the end of the embolization, the treatment was documented by DSA.

The patients who had no contraindications for MR were scheduled for the follow-up imaging three to six months after endovascular treatment. MRA was performed on 1.5 Tesla (Magnetom Avanto, Siemens AG, Erlangen, Germany) or 3 Tesla (Magnetom Skyra, Siemens AG, Erlangen, Germany) MR device using a 16 channel phased array head coil. Three-dimensional time-of-flight (3D-TOF) sequence was utilized in the axial plane, and a saturation band was placed above the acquisition volume to eliminate the venous signal. 3D-TOF parameters for 3T MR were as follows: TE 18 ms; TE 3.24 ms; flip angle 20°; section thickness 0.77 mm; field of view 210 mm; matrix 256x256, and for 1.5 Tesla MR as follows: TE 7 ms; TR 36 ms; flip angle 25°; field of view 210 mm; slab effective thickness 0.65-1.5; matrix 256x512.

Follow-up DSA was performed using a biplane angiographic unit (Axiom Artis, Siemens Medical Systems, Erlangen, Germany) at six months to one year, depending on the patient's characteristics. It consisted of multiple projections and 3D rotational angiography of the aneurysm parent artery. Through a 5F standard diagnostic catheter, iodinated contrast material was administrated with a power injector.

The study was approved by Anadolu Medical Center Ethical Committee and all the procedures were performed with the written informed consent.

Evaluation of images

Two interventional neuroradiologists (K.K and M.D), who did not perform the above embolization, evaluated the TOF-MRA images blindly. They were unaware of the DSA results before and after coil embolization.

The quality of TOF-MRA images was adequate in all patients. Minor artifacts were observed predominantly 3T MRA images that were related to the coils. However, they did not interfere with image interpretation. Visualization of the parent arteries was optimal in all cases. MRA data were evaluated on a dedicated workstation (Syngo, Siemens AG, Berlin, Germany). Source MR images and volume rendering techniques of 3D TOF images such as maximum intensity projection (MIP) and multiplanar reformation (MPR) were utilized for this purpose.

Based on the DSA, the observers assessed the occlusion status of the treated aneurysm according to the following Raymond classification [8]: Class 1, excluded aneurysm; Class 2, persistence of residual neck; and Class 3, persistence of residual aneurysm. Images were analyzed on a served workstation (Syngo, Siemens AG, Berlin, Germany) using InSpace 3D software. The maximum size of the residual lumen was also measured.

Results

The study included 54 treated cerebral aneurysms. DSA as a gold standard confirmed residual or recurrent aneurysmal flow in 5 patients out of 54 treated cerebral aneurysms; two with tip of basilar artery (one Class 2, one Class 3) (Figure 1), one with left MCA bifurcation (Class 2) (Figure 2), one with anterior communicating artery (Class 2) and one with right supraclinoid internal carotid artery (Class 2) classified according to Raymond et al [8]. 49 patients out of 56 were classified as Class 1 (excluded aneurysm). Incomplete aneurysm occlusions consisted of four recurrences (7.4%) and one residual aneurysm (1.8%), mean aneurysm diameter was 3.7 mm. Complete aneurysmal occlusion was seen at 49 aneurysms (90%). The patients' profile and aneurysm locations are shown in Table 1.

MRA images were evaluated with the presence and absence of an aneurysm only without any classification. All 5 aneurysms cases confirmed with DSA were identified with MRA by both readers. There were three false-positive cases on MRA compared to gold standard DSA.

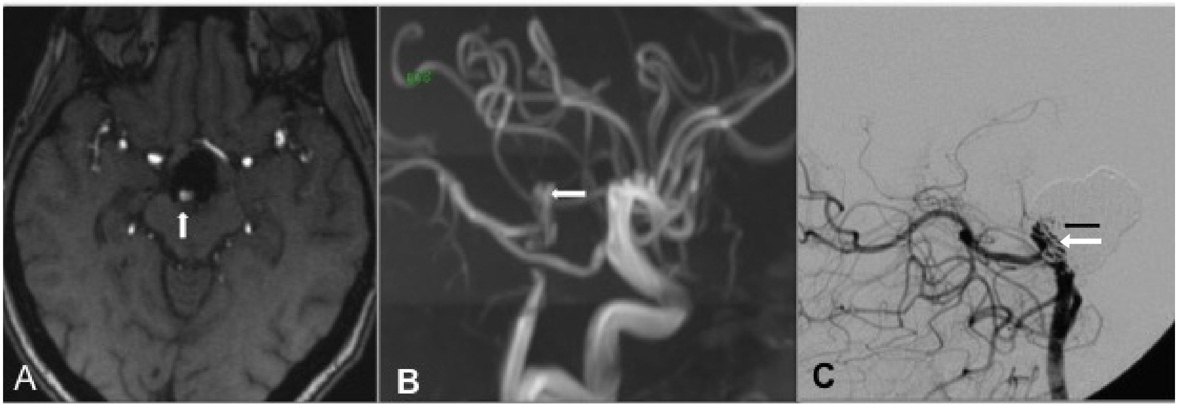

Figure 1. Follow-up at 3-6 months after basilar top aneurysm coil embolization.
A) TOF-MRA raw data showed recurrent filling of basilar top aneurysm sac posterior to the coils (white arrow). **B)** 3D TOF-MRA depicted aneurysmal sack filling of 6x3 mm. **C)** DSA confirmed the above findings (black arrow)

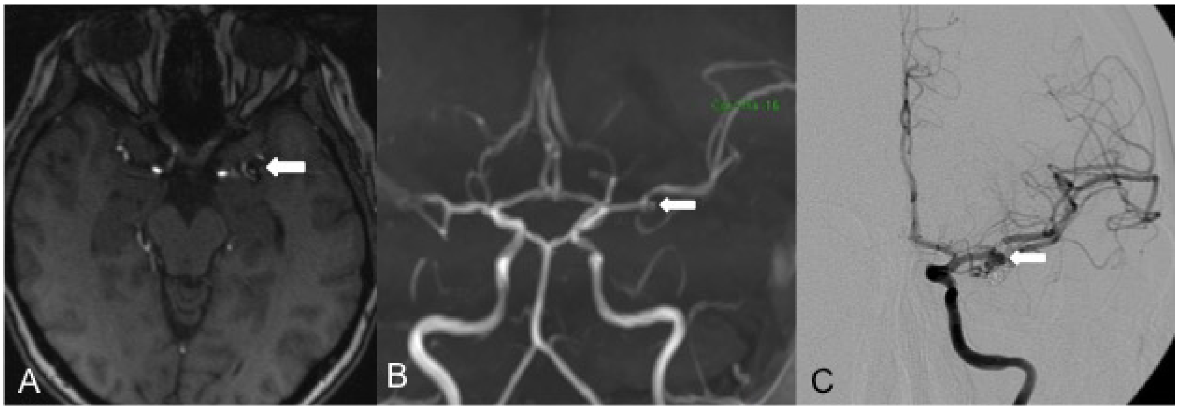

Figure 2. Follow-up 6 months after left MCA aneurysm coil embolization.
A) TOF-MRA raw data showed recurrent filling of left MCA aneurysm at neck (white arrow). **B)** 3D TOF-MRA depicted aneurysmal neck filling of 2 mm. **C)** DSA confirmed the above findings (white arrow)

Table 1. Patient profile and aneurysm location before coiling

Total number of patients	51
Age range	21-86 mean 50.2
Female	33 (65%)
Male	18 (35%)
Aneurysm numbers	54
ACA and ACoA	9
ICA and PCoA	27
MCA	12
BA and PCA	6
Subarachnoid hemorrhage	17 (33%)
Headache	28 (55%)
Incidental	6 (12%)

ACA: Anterior Cerebral Artery, AcoA: Anterior Communicating Artery,
ICA: Internal Carotid Artery, PcoA: Posterior Communicating Artery,
MCA: Middle Cerebral Artery; BA: Basilar Artery, PCA: Posterior Cerebral Artery

Statistical analysis

At the main step, the interobserver agreement for TOF-MRA is evaluated. For this purpose, *k* statistical test was calculated with corresponding 95% confidence intervals (CI). For the categorical data, *k* values 0.6-0.79 indicated substantial agreement [9]. Then the DSA is analyzed and compared with the MRA data.

Due to small number of selected patients during a short term follow-up, accuracy studies including negative and positive predictive values and sensitivity and specificity of MRA compared to DSA were not in this study's scope. Similarly, subgroup analyses were not performed for the test characteristics.

Interobserver agreement

Total agreement was 0.94 for MRA. Kappa coefficient was 0.74 for indicating good concordance of the readers for MRA (95% CI was 0.44 to 1.04). Interobserver agreement for DSA was not obtained, as it was regarded reference test. We did not observe any adverse event during or after the MR examination. Discrepancies between both examiners were noted in three cases. An additional peer reading was performed to have a consensus in these cases.

Discussion

Due to best efforts and technical advancements, coiled aneurysms may demonstrate persistent filling and re-growth of the aneurysm sac. Therefore, follow-up imaging is crucial for aneurysms treated with endovascular coiling. In our study, TOF MR angiography at both 1.5 T and 3.0 T showed comparable results to the gold standard DSA with a high interobserver agreement, as shown by others [10]. Hence, DSA did not always confirm a suspected incomplete occlusion at MRA due to low positive predictive value as implied in a multicenter study conducted by Schaafsma et al. [10]. We observed such cases, although there was an interval up to three months between two tests. It is not certain when in which risk groups to perform follow-up angiography to detect for reopening. The probability of reopening is minimal in aneurysms with complete or near-complete occlusion, as shown at 6-month follow-up [10-12]. Nevertheless, it might be reasonable to pursue it in the mid and long term, while the monitoring is adapted on a case-by-case basis [11].

Although the recurrence rates might be as high as 33.6%, retreatment is necessary in about 10% to 15% of cases with embolized aneurysms [8, 13]. There are 26 reports of late bleeding after coil embolization of previously unruptured aneurysms reported in the literature, while sixteen of them occurred in large and giant aneurysms [14]. Such aneurysms tend to have a high aspect ratio and should be meticulously observed. All delayed ruptures were observed in aneurysms with dome filling in the residual aneurysm (Raymond class 3).

DSA is still the gold standard to evaluate aneurysm occlusion, but it is invasive. However, a non-invasive image modality is required, such as MRA, to replace DSA. In MRA, the blood demonstrates high signal while coils have low signal. MRA can clearly show residual high signal aneurysm in a 3D fashion with reconstruction capabilities. There is no significant difference between DSA and MRA in the follow-up of coiled embolized brain aneurysms, as shown by many authors [4, 15, 16]. Besides, it might be of limited use because pulsation artifacts caused by the coils may interfere with images in three-dimensional rotational angiography. However, DSA may still be necessary, especially in aneurysms treated with stent remodeling. In one of our basilar tip aneurysm cases; remodeling stent did not interfere with interpretation of MRA due to residual filling of large aneurysm. However, the decision should be made depending on each case.

The sensitivity and specificity for detecting residual flow within the coil mass were reported between 90% and 100%, respectively, with different MRA techniques [4, 7, 16]. In an early study with 26 patients, there was a positive predictive value of 100% and a negative predictive value of 96% [17].Gonner et al. [18] compared different TOF MRA protocols with two different TE (6 ms vs 2.4 ms). These investigators concluded that coil related artifacts on MRA were reduced while visualization of the adjacent parent vessel was improved by 36% with the short TE sequences. As they demonstrated, the shortest possible TE was the key factor in improving perianeurysmal visualization [18]. Various types of coils are used for the occlusion of intracranial aneurysms. The Nexus coils were found to have inherently larger artifacts with MRA compared to other types of coils [19]. We observed minor artifacts related to the used new generation coils were observed on TOF-MRA images in two patients, which did not interfere with interpretation. There was a good correlation between DSA and MRA by the readers.

Since Majoie et al. [20], many others have demonstrated TOF-MRA might be utilized as a first-line exam for coiled aneurysm follow-up [21-23]. In a meta-analysis in the follow-up of embolized aneurysms with contrast-enhanced MRA and TOF-MRA, there were no significant statistical differences [24].

In our study, MRA was shown as a reproducible method for the assessment of intracranial aneurysms after coil embolization. Although TOF-MRA and DSA techniques showed similar results of aneurysm occlusion after embolization, catheter angiography remains the gold standard for evaluating treated aneurysms and should be used in cases of diagnostic uncertainty.

Conflict of interest: No conflicts of interest was declared by the authors.

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Contributions of the authors to the article

M.D. and K.K. designed the main idea and hypothesis of 'Follow-Up of Endovascular Coil Embolization for Intracranial Aneurysms Using Magnetic Resonance Angiography' study. M.D., K.K developed the hypothesis and arranged the materials and methods section. M.D., K.K., and S.G executed analysis and interpretation of data in the results section. M.D., K.K., and S.G. wrote the discussion section of the manuscript; M.D., K.K, and S.G. reviewed made necessary corrections, and approved. All authors also discussed and approved the final version.