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Methods and time schedule for follow-up of intracranial aneurysms treated with endovascular embolization: a systematic review

Metody i schemat okresowy kontroli obrazowej po przeznaczyniowym leczeniu tętniaków wewnątrzczaszkowych: systematyczny przegląd piśmiennictwa

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Abstract

Background and purpose: To review the diagnostic value of angiographic methods and the optimal timetable for follow-up imaging of patients after endovascular treatment of intracranial aneurysms.
Material and methods: A comprehensive computer-aided search for relevant primary papers was performed using the MEDLINE, PubMed, Embase, and Cochrane Collaboration database from January 1991 to March 2011. Original papers were included that reported either diagnostic value of angiographic modalities for follow-up vs. digital subtracted angiography (DSA) or comparison of aneurysm occlusion rate in delayed vs. early follow-up.
Results: The systematic review identified 35 relevant studies: 3 on the diagnostic value of three-dimensional (3D) DSA, 30 on the performance of magnetic resonance angiography (MRA), and 3 on time schedules for follow-up. 3D DSA had sensitivity of 100%, and specificity of 58.3-94.7%. Magnetic resonance angiography had sensitivity of 28.4-100%, and specificity of 50.0-100%. The proportion of aneurysms that recanalized between the early follow-up examination at 6 months and the delayed imaging at 1.5-6.0 years was 0-2.5%.
Conclusions: Magnetic resonance angiography seems to be the best imaging method for the follow-up. In selected cases, when invasive angiography is necessary, 3D DSA should be

Streszczenie

Wstęp i cel pracy: Celem pracy był przegląd opublikowanych prac oryginalnych na temat wartości diagnostycznej metod angiograficznych oraz schematów czasowych kontrolnych angiografii u chorych po przeznaczyniowym leczeniu tętniaków wewnątrzczaszkowych.
Materiał i metody: Przeprowadzono przegląd systematyczny piśmiennictwa indeksowanego w bazach MEDLINE, PubMed, Embase i Cochrane Collaboration w okresie od stycznia 1991 do marca 2011 r. Do analizy włączono badania oryginalne, w których określano wartość diagnostyczną metod angiograficznych w ocenie tętniaków po embolizacji w porównaniu z konwencjonalną arteriografią subtrakcyjną (DSA). Włączono również badania, w których porównywano wyniki embolizacji we wczesnej i późnej kontroli angiograficznej.
Wyniki: Kryteria włączenia do analizy spełniło 35 prac, w tym 3 oceniające wartość trójwymiarowej DSA (3D DSA), 30 oceniających angiografię rezonansu magnetycznego (MRA) i 3 dotyczące schematu czasowego kontroli angiograficznej. W analizowanych pracach 3D DSA miała czułość 100% i swoistość 58,3–94,7%, natomiast czułość i swoistość MRA wynosiły odpowiednio 28,4–100% i 50–100%. Odsetek tętniaków, które uległy rekanalizacji pomiędzy wczesnymi (po 6 miesiącach) i późnymi badaniami kontrolnymi (po 1,5–6 latach), wyniósł 0–2,5%.

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considered to improve the diagnostic accuracy. Most patients who present with stable and adequate aneurysm occlusion at 6 months after coiling may not require further follow-up.

Key words: intracranial aneurysm, embolization, coils, digital subtracted angiography, magnetic resonance, computed tomography.

Wnioski: Angiografia rezonansu magnetycznego wydaje się najlepszą metodą angiograficznej kontroli chorych po embolizacji tętniaków. W przypadkach, kiedy konieczne jest wykonanie angiografii inwazyjnej, 3D DSA może istotnie poprawić wartość diagnostyczną badania. Znaczna część chorych, u których stwierdza się prawidłowe wypełnienie tętniaka po 6 miesiącach od embolizacji, nie wymaga dalszej kontroli.

Słowa kluczowe: tętniaki wewnątrzczaszkowe, embolizacja, spirale, cyfrowa angiografia subtrakcyjna, rezonans magnetyczny, tomografia komputerowa.

Introduction

The prevalence of intracranial aneurysms (IAs) in the general population was estimated at 2.3%, with a tendency to increase with age [1]. The most serious complication of IA, i.e. an aneurysmal rupture and a subsequent subarachnoid haemorrhage (SAH), was reported to have a mortality rate of 32-67% and a 10-20% rate of permanent disability [2-4].

The majority of patients with IAs are treated with either surgical clipping or endovascular coiling. The most comprehensive prospective comparison of these methods, the ISAT study [5], presented a favourable outcome of embolization. Coiling resulted in a relative risk reduction in death or dependence of 22.6% and an absolute risk reduction of 6.9%, as compared to clipping [5]. However, the main drawbacks of endovascular treatment of intracranial saccular aneurysms are the possibility of reopening of an initially occluded aneurysm with time, and the risk of subsequent rebleeding [5-8]. In the recent meta-analysis by Ferns *et al.*, aneurysm recanalization was found in 20.8% of cases, and retreatment was performed in 10.3% [9].

The significant rate of aneurysm reopening and the possibility of rebleeding suggest mandatory patient monitoring after endovascular treatment of IAs. However, the preferred modality and the exact schedule of control imaging still remain a subject of debate. The purpose of this paper was to systematically review the diagnostic value of angiographic methods and the optimal timetable for follow-up imaging.

Material and methods

We sought to identify all original papers reporting the diagnostic value of digital subtracted angiography (DSA), magnetic resonance angiography (MRA), and computed tomography angiography (CTA) for the detection of residual or recurrent flow in the follow-up of IAs after endovascular coiling. Therefore, a comprehensive computer-aided search for relevant primary papers was performed using MEDLINE, PubMed, and Embase from January 1991 to March 2011. The following query was used: ((digital subtraction angiography) OR (digital subtracted angiography) OR (invasive angiography) OR (DSA) OR (magnetic resonance angiography) OR (MR angiography) OR (MRA) OR (TOF) OR (CEMRA) OR (CE MRA) OR (CE-MRA) OR (MR angiogram) OR (MR angiographic) OR (computed tomography angiography) OR (CT angiography) OR (CTA) OR (CT angiogram) OR (CT angiographic)) AND (aneurysm) AND ((cerebral) OR (brain) OR (cranial) OR (intracranial)) AND ((coil) OR (embolization) OR (coiling)). The Cochrane Collaboration database from 1991 to 2011 was also searched. Furthermore, the bibliographies of all papers selected for review were searched for potentially relevant articles that had not been identified by the original query. Then, titles and abstracts of the articles were reviewed independently by two researchers (Z.S. and P.S.). Subsequently, full copies of selected articles were retrieved and reviewed by the same two researchers. Only English-, German-, French- or Italian-language original papers were included that reported (i) diagnostic value of angiographic modalities for follow-up or (ii) comparison of aneurysm occlusion rate in delayed versus early follow-up.

Results

The primary query identified a total of 1064 papers. The abstract review restricted the number of potentially relevant papers to 120. We excluded articles on diagnostic performance which did not report at least sensitivity and specificity or kappa statistics, or did not provide sufficient data to calculate these parameters (7 papers). We also excluded meta-analyses (2 papers), in vitro stud-

Table 1. Studies reporting the diagnostic value of 3D digital subtracted angiography (DSA) and magnetic resonance angiography (MRA) in the follow-up of embolized aneurysms

Study	No. of patients/ aneurysms evaluated	MRA sensitivity/specificity (%)					3D DSA
		1.5 T TOF-MRA	1.5 T CE-MRA	3 T TOF-MRA	3 T CE-MRA	mixed / other MRA	sensitivity/ specificity (%)
Kiyosue *et al*., 2002 [10]	27/27						100/58.3
Zhou *et al*., 2010 [11]	109/121						100/75.0
Buhk *et al*., 2008 [12]	22/22	89.7/89.5					100/94.7
Schaafsma *et al*., 2010 [13]	310/381					82.0/89.0[1]	
Kaufmann *et al*., 2010 [14]	58/63	90.0/52.0	85.0/65.0	88.0/52.0	90.0/64.0		
Sprengers *et al*., 2009 [15]	66/72			75.0/98.0	75.0/97.0		
Kau *et al*., 2009 [16]	32/37	87.5/76.9	91.7/92.3				
Ferré *et al*., 2008 [17]	50/50			100/88.5			
Lubicz *et al*., 2008 [18]	55/67		93.0/95.5				
Ramgren *et al*., 2008 [19]	37 /41	50.0/100		57.7/100	61.5/80.0		
Wikström *et al*., 2008 [20]	38/47	95.0/72.0	82.0/76.0			95.0/68.0[2]	
Urbach *et al*., 2008 [21]	50/58			100/93.2			
Wong *et al*., 2007 [22]	37/42		100/81.8				
Lubicz *et al*., 2007 [3]	33/40	72.2/100	80.0/100				
Deutschmann *et al*., 2007 [24]	127/188					88.5/92.9[2]	
Gauvrit *et al*., 2007 [25]	106/107		97.5/98.4				
Saguchi *et al*., 2006 [26]	35/35	100/100					
Westerlaan *et al*., 2005 [27]	31/31	88.9/90.9					
Majoie *et al*., 2005 [28]	20/21			100/75.0	100/75.0		
Farb *et al*., 2005 [29]	28/36	28.4/80.0	76.5/73.7				
Yamada *et al*., 2004 [30]	39/51	100/50.0					
Okahara *et al*., 2004 [31]	33/33	80.0/100					
Cottier *et al*., 2003 [32]	58/71	83.3/100	83.3/100				
Leclerc *et al*., 2002 [33]	20/20	60.0/100	100/93.3				
Nome *et al*., 2002 [34]	51/79					93.2/94.3[3]	
Boulin *et al*., 2001 [35]	66/81		72.0/98.2				
Michardière *et al*., 2001 [36]	20/25	75.0/100					
Anzalone *et al*., 2000 [37]	49/64	100/97.4	100/92.6				
Kähärä *et al*., 1999 [38]	20/21	90.0/90.9					
Brunereau *et al*., 1999 [39]	26/27					100/100[3]	
Gönner *et al*., 1998 [40]	14/18	100/100					
Derdeyn *et al*., 1997 [41]	23/24					86.7/94.6[4]	

TOF – time-of-flight, CE – contrast-enhanced, 3D – three-dimensional
[1]mixed 1.5 T and 3 T TOF-MRA and CE-MRA
[2]1.5 T contrast-enhanced TOF-MRA
[3]1.0 T TOF-MRA
[4]mixed 1.5 T TOF-MRA and CE-MRA

Table 2. Studies comparing the proportion of completely occluded aneurysms in the early versus delayed follow-up after embolizations

Study	No. of patients/ aneurysms	Type of study	Early follow-up (years)	Early complete occlusion rate	Mean delayed follow-up (years)	Delayed complete occlusion rate
Ferns *et al.*, 2011 [42]	400/440	prospective	0.5	100%	6.0	97.5%
Tailor *et al.*, 2010 [43]	97/105	not reported	0.5	38.5%	2.0	36.9%
Sluzewski *et al.*, 2003 [44]	160/160	retrospective	0.5	59.5%	1.5	59.5%

ies (3), technical notes (6), case reports (2), comments or letters to the editor (4), duplicative reports (4), practice guidelines (2), and conference abstracts (6). Finally, a set of 35 original papers was selected for the review (Tables 1 and 2), consisting of 3 articles on three-dimensional (3D) DSA [10-12], 30 on MRA [12-41], and 3 on time schedules for follow-up [42-44]. There were no reports on CTA in the follow-up of embolized IAs which had met the inclusion criteria.

Of the studies included in the systematic review, 18 were prospective, 6 were retrospective, while 12 were not clear about the strategy of data collection.

Three papers dealing with the diagnostic accuracy of 3D DSA included a total of 158 patients with 170 aneurysms (Table 1). In all papers, 3D DSA detected more cases of aneurysm recanalization than 2D DSA.

Primary papers reporting the diagnostic performance of MRA included a total of 1554 patients with 1852 aneurysms (Table 1). 2D DSA was used as a gold standard in 23 studies, and 3D DSA in 3; in 4 studies, 3D DSA was used as an additional tool in selected cases. The value of non-contrast-enhanced time-of-flight MRA (TOF-MRA) was reported in 24 papers, while the performance of contrast-enhanced MRA (CE-MRA) was reported in 15 papers. Two studies reported the diagnostic accuracy of contrast-enhanced TOF-MRA [20,24].

Papers that compared the results of delayed versus early monitoring after embolizations included 657 patients with 705 aneurysms (Table 2). The early follow-up was scheduled at 6 months in all the cases, and the second examinations were performed at 1.5-6.0 years, on average.

Discussion

Digital subtracted angiography

Two-dimensional (2D) DSA is known as a gold standard for aneurysm evaluation after coiling [5,45-47], and is still commonly used in this regard in large prospective trials evaluating the efficiency of embolization [5,7,48]. However, DSA is an invasive procedure and was reported to result in transient neurological complications in 0-0.5% of examinations, and permanent deficits in 0-0.5% of them [49,50]. Although the risk of complications is low and seems to decrease, it remains cumulative, as repeated follow-up examinations are necessary [8]. Other disadvantages of DSA include exposure to ionizing radiation and to iodinated contrast media, as well as high cost of the procedure [51]. Finally, although 2D DSA is called a contemporary gold standard for the follow-up of aneurysms, it has a poorly defined margin of false findings [13,52,53].

Some improvement of the diagnostic performance of invasive angiography was achieved with the introduction of 3D DSA. Software postprocessing of 3D source images enables multi-planar reconstructions and volume rendering, as well as better differentiation between the contrast agent filling the arteries and vascular devices. However, 3D DSA is susceptible to pulsation artefacts, which may lead to either false-positive or false-negative results [13,54]. Therefore, reconstructed images always have to be compared with native 2D images.

The systematic review revealed only three papers directly comparing 2D and 3D DSA in the follow-up of embolized IAs, but reconstructed with three different methods. In the paper by Kiyosue *et al.*, 3D DSA presented as virtual endoscopy yielded sensitivity and specificity of 100% and 58.3%, respectively [10]. Buhk *et al.*, who tested 3D DSA reconstructed as CT-like multiplanar reformations, reported better diagnostic accuracy but considered this technique only as a supportive tool [12]. In a recent paper by Zhou *et al.*, 3D DSA had the highest power to detect the aneurysm remnant, while the difference between 2D and rotational DSA was not statistically significant [11]. Although the calculated specificity and sensitivity of 3D DSA vs. 2D DSA as a standard were moderate (Table 1), the authors considered the first modality as definitely more accurate and more reproducible.

In these three papers, 3D DSA revealed a higher ability to detect residual flow within the embolized aneurysms than 2D DSA. However, the use of the latter method as a gold standard results in low specificity of 3D angiography. In fact, finding a new method which would be more sensitive than the contemporary standard usually causes methodological and statistical problems. Therefore, the authors prefer to apply comparison statistics (weighted kappa, chi-square test, Pearson's correlation coefficient) rather than the common accuracy methods to compare imaging modalities [10-12]. Despite these controversies, 3D DSA was used as a gold standard instead of conventional angiography to evaluate other methods of aneurysm follow-up, such as MRA [14,16,18,22,26,30,31].

Magnetic resonance angiography

Magnetic resonance angiography is a non-invasive method, relatively inexpensive, and not requiring hospitalization. A common drawback of MRA is its sensitivity to susceptibility artefacts, which may be caused by remodelling stents [55]. These artefacts may result in a false diagnosis of lumen narrowing, which may suggest an in-stent thrombosis [55]. Like other MR examinations, MRA is contraindicated in patients with ferromagnetic implants or electronically operated active devices. The MRA examination may be performed as a non-contrast TOF-MRA or with the use of gadolinium-based contrast media (CE-MRA) (Fig. 1).

Time-of-flight MRA is easy to perform and does not require any contrast media, which is associated with lower costs. The main disadvantage of TOF-MRA is its low sensitivity to slow and turbulent blood flow, because of intravoxel dephasing and spin saturation [13,46]. Therefore, the slow residual flow within the coil mesh may not be detected due to a signal loss, resulting in false-negative results. This signal loss may occur especially in larger and tortuous remnants that create a kind of trap for the flowing blood [13,14,56]. False-positive results of TOF-MRA may be caused by a subacute thrombus, which has a high signal on T1-weighted images, and may simulate the residual flow [13,14,56].

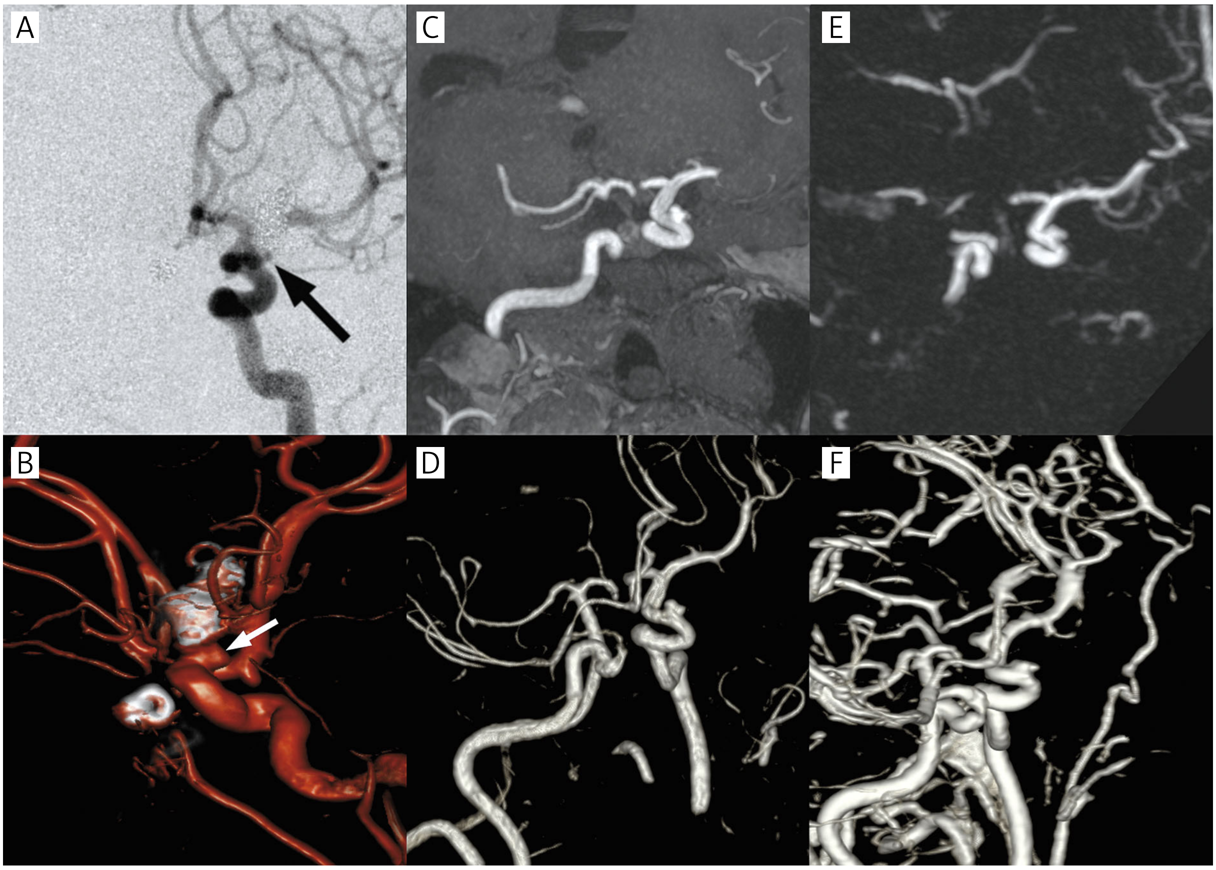

Fig. 1. Recanalization of the left cerebral artery aneurysm (arrows): a comparison of imaging with 2D DSA (A), 3D DSA (B), TOF-MRA MIP (Maximum Intensity Projection, C), TOF-MRA VR (Volume Rendering, D), CE-MRA MIP (E), and CE-MRA VR (F)

Contrast-enhanced MRA better depicts areas of slow and turbulent flow than TOF-MRA, and with fewer flow-related artefacts [13,14,56]. In the case of a stent-assisted embolization, CE-MRA may be superior to non-contrast MRA due to fewer susceptibility artefacts [23]. As a result, CE-MRA presents a slightly better diagnostic performance in detecting residual flow, as compared to TOF-MRA (Table 1), especially for larger remnants [14]. On the other hand, the use of contrast medium may cause an enhancement of the vasa vasorum and an organized thrombus, which is likely to produce false-positive results [25]. Moreover, a subacute thrombus may simulate the residual flow, as in the case of TOF-MRA. Finally, if a single long CE-MRA acquisition is performed without well-timed contrast triggering, venous enhancement can significantly reduce image quality [13,14].

The use of contrast agents for aneurysm follow-up increases the costs of imaging. Furthermore, their applicability has recently been restricted by numerous reports on nephrogenic systemic fibrosis (NSF) [57]. Nephrogenic systemic fibrosis is a not fully understood syndrome, related to the administration of gadolinium contrast media, that is expressed by fibrosis of the skin and internal organs, e.g. muscles, diaphragm, heart, liver, and lungs [58]. Consequently, NSF may lead to extensive contractures, cachexia, and death. Patients with chronic kidney disease (CKD) stage 4 and 5 (estimated glomerular filtration rate [eGFR] < 30 ml/min), patients on dialysis, and patients with a reduced renal function who had or are awaiting liver transplantation present a high risk of NSF development [58].

The overall sensitivity and specificity of MRA in the included papers was moderate and high (range 28.4-100%, and 50.0-100%, respectively), with significant differences between studies. Due to the high diagnostic accuracy of MRA in the most recent studies, several authors have proposed the use of this method as a primary method of follow-up of embolized aneurysms, instead of the contemporary gold standard, i.e. DSA [6,13,14,18]. The follow-up with MRA, as compared to DSA, results in a similar life expectancy (difference of 0.03 years), and quality-adjusted-life-years value (difference of 0.01), at lower costs [51]. However, some controversy exists regarding the clinical advantage of 3 T versus 1.5 T scanners and CE-MRA vs. TOF-MRA. Theoretically, the higher-field MR imaging provides better spatial and contrast resolution, and a higher signal-to-noise ratio [14]. On the other hand, the higher the magnetic field used, the more pronounced susceptibility artefacts may occur [14,59]. As shown in Table 1, MRA at 3 T generally results in a slightly improved diagnostic performance as compared to 1.5 T, but statistical significance was not reached in two out of three studies that addressed this problem [13,14]. Therefore, more prospective parallel studies comparing 3 T and lower field systems are necessary to establish the actual value of the new technology.

The advantage of CE-MRA over TOF-MRA in the follow-up of coiled IAs is equivocal as well. Some authors deny the necessity for the use of contrast media [15, 32]. On the other hand, Kaufmann *et al.* recommend performing both contrast-enhanced and non-enhanced MRA to increase the accuracy of the examination [14]. According to the meta-analysis by Kwee and Kwee, the pooled sensitivity and specificity of CE-MRA and TOF-MRA in the detection of residual flow were 86.6% and 91.9% vs. 83.3% and 90.6%, respectively, and were not statistically different. Similarly, in the largest recently published prospective study, by Schaafsma *et al.* (311 patients), the areas under receiver operating characteristic curves of the two methods were not statistically different [13]. Consequently, considering a similar diagnostic performance of both modalities, additional costs and potential adverse effects of contrast media administration, it seems reasonable to employ TOF-MRA as a method of choice for the follow-up, except for patients with implanted remodelling stents.

Computed tomography angiography

Computed tomography angiography has been recognized as a very efficient tool for detection and preoperative assessment of IAs [60]. However, since platinum coils were developed for optimal visibility during endovascular embolization under fluoroscopic control, high attenuation of the formed coil mesh has caused significant beam hardening and streak artefacts on CT. These artefacts strongly impede the evaluation of a coiled aneurysm, a parent vessel, and surrounding brain parenchyma [53,61,62]. Therefore, CTA is not recommended as a routine method for evaluation of the stability of aneurysm coiling. Recently, Kovács *et al.* proposed a promising modification of the CT technique, which was to reduce streak artefacts using gated acquisition and multi-segment image reconstruction [62]. Further reduction of artefacts may be achieved by the recently introduced single-source dual-energy CT [63]. The systematic review was not able to find any study evaluating the diagnostic accuracy of CTA in the detection of residual flow within embolized aneurysms, and thus CTA is not recommended for this application [64]. On the other hand, conventional CT remains a useful tool for an immediate postoperative assessment, especially in the case of intraoperative complications, such as intraprocedural aneurysm rupture [65].

Schedule for follow-up

There is no consensus regarding the optimal long-term monitoring strategy of coiled IAs [43]. Some authors advocate scheduling serial examinations for 2-3 years, while others state that obtaining a negative angiogram at 6 months after the embolization should stop the follow-up [42-45,53,66]. A significant part of these recommendations is based on authors' personal experiences and is not supported by scientific data. For instance, Wallace *et al.* proposed performing an immediate post-treatment MRA [53]. In patients in whom the correlation between DSA and MRA was satisfactory, further follow-up consisted of MRA at 3-6 months, 12-15 months, and 24-36 months [53].

The systematic review identified three studies that methodically compared the aneurysm occlusion rate in delayed versus early monitoring after embolizations, in order to determine the optimal time schedule for follow-up [42-44]. The proportion of aneurysms that recanalized between the early and the delayed examinations varied between 0% and 2.5% (Table 2). In the cohort of patients studied by Sluzewski *et al.*, aneurysm occlusion status changed in 38 out of 126 subjects (30%) between the initial DSA and the follow-up at 6 months [44]. However, no change was reported between control examinations at 6 and 18 months. Similar results were observed by Tailor *et al.*, who compared the occlusion rate at baseline, 6 months and 2 years after treatment [43]. Angiographic results changed in the period between the initial DSA and the first follow-up examination in 22 out of 79 patients (28%). In 59 patients who underwent angiography at 2 years, only one aneurysm (1.7%) completely occluded at 6 months developed a subsequent minor neck recurrence. The largest prospective study comparing the results of delayed versus early monitoring after embolizations was recently published by Ferns *et al.* [42]. They studied 400 patients with 440 aneurysms adequately occluded 6 months after coiling. In the mean follow-up period of 6.0 years, there were 11 late re-openings (2.5%), of which three (0.7%) required additional treatment. In a multivariate analysis, the only independent risk factors for late reopening were aneurysm size ≥ 10 mm (odds ratio [OR] 4.7) and the location on the basilar tip (OR 3.9).

Moreover, according to Sprengers *et al.*, the incidence of *de novo* aneurysms and the growth of untreated aneurysms in patients after embolization seems to be low [45]. In their study, MRA follow-up of 65 patients (carried out for 5.1 years, on average) resulted in the detection of one new IA (1.5%) with no indications for any treatment, 18 unchanged non-treated IAs (28%), and 4 lesions (6%) that could not be compared with baseline angiograms. This suggests that the delayed follow-up has a low yield in terms of detecting new lesions that may require treatment.

The results of the systematic review are in concordance with the opinion of van Rooij and Sluzewski [66]. According to them, patients with IAs that are adequately embolized at 6 months after coiling do not need further follow-up in the first 5-10 years after treatment since the recurrence rate is very low. Moreover, in these patients, the incidence of de novo IAs and the growth of untreated IAs are low, with an extremely low risk of SAH from these aneurysms [6,45,66]. Therefore, from a clinical point of view, IAs completely embolized at 6 months after the procedure may be considered cured [66]. However, although such patients constitute a majority of all patients treated endovascularly for IAs [42-44,66], some exceptions should be noted. Higher reopening rates were reported for partially thrombosed IAs, large and giant IAs, and lesions located within the posterior circulation [8,9,42,66,67]. In these cases, regular MRA follow-ups at every 1-3 years may be considered [66]. More frequent and prolonged monitoring might also be considered in patients at increased risk, such as patients with a positive family history, or patients with proven development of additional IAs [66]. Finally, the question whether patients might benefit from screening beyond a 10-year period cannot be answered yet [42,66].

Conclusions

1. Because of the possibility of recanalization and rebleeding, the follow-up of IAs treated with endovascular embolization is mandatory.
2. Magnetic resonance angiography seems to be the best imaging method for the follow-up, as it is non-invasive, relatively inexpensive, widely available, and presents a high diagnostic accuracy.
3. In selected cases, when invasive angiography is necessary, 3D DSA should be considered to improve the sensitivity and specificity of the examination.

4. Most patients who present with stable and adequate aneurysm occlusion at 6 months after coiling may not require further follow-ups.

Disclosure

The authors report no conflict of interest.

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