Cerebral Aneurysm Follow-Up: How Standards Have Changed and Why

A perspective on the optimal follow-up frequency and imaging modality type for treated cerebral aneurysms.

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Neurointerventional surgery has become the primary management strategy for both ruptured and unruptured cerebral aneurysms in most institutions. This approach was adopted after landmark studies demonstrated lower morbidity and mortality rates compared to conventional microsurgical clipping.[1,2] However, the long-term angiographic durability of coiling for both ruptured and unruptured aneurysms has been raised as a concern, with reports that one-fifth of patients demonstrate some form of occlusion status deterioration in early imaging follow-up. Of these recanalizations, approximately half may require retreatment.[3] Early recanalization is thought to be more likely when partial endosaccular occlusion is achieved without stabilizing the diseased parent vessel or the aneurysm neck. This phenomenon is particularly noted with the endovascular treatment of large or giant, wide-necked bifurcation aneurysms.[4] Despite this, long-term rebleed rates of ruptured aneurysms treated by endovascular means are very low at approximately ≤ 0.1%.[5-7]

Considering the potential for early or late retreatment and the propensity toward subtotal angiographic occlusion with standard coiling, it is reasonable to question the frequency and duration of imaging follow-up, despite the low rebleed rates. At present, no official guideline outlines the optimal evidence-based approach to follow-up frequency and imaging modality type. A review by Soize et al proposed an algorithm that likely approximates the method and timing of follow-up at many institutions.[8]

This article examines the available imaging modalities, rationale for lifelong follow-up, and issues that now present with an influx of novel devices used to treat more and more complex intracranial lesions.

TIMING AND DURATION OF ANEURYSM FOLLOW-UP

In general, there is no universally agreed upon timetable for imaging and clinical follow-up of treated aneurysms. Different centers will have subtly or significantly different regimens. Often, the time course of imaging evaluation is dictated by clinical suspicion for early recurrence, which may be based on aneurysm morphology and size, prior rupture status, digital subtraction angiography (DSA) results acquired during initial treatment, and the endovascular technique employed. The frequency of follow-up should be balanced against patient safety, related to both the aneurysm and the method of follow-up, and cost.

A typical follow-up regimen might involve an early imaging study at 3 to 6 months, followed by a second study at 12 to 24 months, and again at 3 to 5 years posttreatment. The majority of recurrences occur within the first year after treatment, necessitating an early posttreatment imaging study.[9] Because recurrences outside of the first year are less common, the time interval between subsequent follow-ups is lengthened. This protocol may be modified based on the clinician's suspicion for recurrence or the presence of significant risk factors for regrowth or recurrence (eg, giant aneurysm treated with coiling or stent assistance, wide-necked bifurcation/large aneurysm, aneurysms with initial suboptimal occlusion).

Historically, aneurysm follow-up was concluded at 5 years because data examining aneurysm recurrence beyond the 5-year mark were scant. A prospective cohort study by Lecler et al concluded that longer follow-up should be considered.[10] They identified a clinically significant percentage (12.4%) of patients who had secured aneurysms on MRA 3 to 5 years posttreatment that recanalized on MRA > 10 years posttreatment. Risk factors for progression included Raymond-Roy classification 2 lesions and retreatment within 5 years of initial coiling. In the same article, Lecler et al conducted a meta-analysis that identified a rebleed rate of 0.7% for patients who were followed up for > 10 years and a de novo aneurysm rate of 4.1% (or roughly 1 in 25 patients) at 10 years. Based on these findings, follow-up beyond 10 years is warranted.

IMAGING MODALITIES

DSA

DSA is the gold standard for identifying and characterizing intracranial vascular pathologies because of its high spatial and temporal resolution. Specifically, with respect to treated aneurysms, it can identify recurrent aneurysmal filling and abnormalities of the parent artery, and it is not susceptible to the same device-related artifacts as either MRA or CTA. However, DSA is prone to movement-related image degradation, which may increase procedural time, ionizing radiation dose, and cumulative contrast load through prolonged fluoroscopy and repeated acquisitions. Despite this and regardless of the endovascular device used (coils, intracranial stents, flow diversion [FD], flow disruption), DSA forms the basis for aneurysm follow-up within the first 12 months in most centers.

DSA is an invasive test with a small but not insignificant complication risk. The largest series to date evaluated all-comer complication rates in 19,826 patients.[11] In this study, neurologic complications occurred in 2.63%, with permanent deficits or disability in 0.14%. Other risks of DSA include access site hematoma, contrast reactions, and contrast-induced nephrotoxicity. The most commonly encountered procedural complication is access site hematoma, which may require further intervention with stenting, angioplasty, or percutaneous thrombin injection, depending on the underlying pathology.

MRA for Coiled Aneurysms

MRA is used extensively in neuroimaging and has become the primary method for screening and evaluating neurovascular disease. It has well-described benefits, including the lack of ionizing radiation and an acceptable safety profile of gadolinium-based contrast agents.[12] Drawbacks include contraindications for patients with certain pacemakers and other ferromagnetic implants. Also, comparatively long acquisition times render it prone to movement artifacts.

Two MRA techniques are used in aneurysm evaluation and follow-up: time-of-flight MRA (TOF-MRA) and contrast-enhanced MRA (CE-MRA). Each technique has benefits and drawbacks. TOF-MRA is sensitive to turbulent or slow flow, which may result in underestimation of Raymond-Roy classification in slow-filling aneurysms. Conversely, intrasaccular thrombus may mimic residual aneurysm due to the inherent T1 signal characteristics of subacute clot. CE-MRA is more costly and adds a small risk of allergic reaction to the contrast media. However, CE-MRA is significantly faster than TOF-MRA and avoids flow-related artifacts by using intravascular contrast.

Several meta-analyses have investigated the accuracy of MRA in coiled aneurysm follow-up. The most recent and extensive was published by van Amerongen et al.[13] Both TOF-MRA and CE-MRA techniques demonstrated high sensitivity and specificity for detecting aneurysm recurrence (86% and 84% for TOF-MRA vs 86% and 89% for CE-MRA, respectively). Although a small percentage of patients with residual or recanalized aneurysms would be missed using either technique, retreatment or changes in management would likely not be required.[12,13]

CTA for Coiled Aneurysms

CTA is a readily available modality with a lower cost than MRA and a short acquisition time. However, its value is limited in the follow-up of coiled aneurysms due to severe beam hardening artifacts from the aneurysmal coil mass, which can make evaluation of residual aneurysmal filling or compromise of the adjacent parent vessel less reliable. It is often reserved for the evaluation of aneurysms postclipping or in the follow-up of intracranial stenting, where artifacts are less likely compared to MRA. Novel approaches to intracranial vascular imaging using monoenergetic reconstruction of dual-energy CT (DECT) and spectral data show promise to further reduce artifacts from aneurysm clips, but the evaluation of coiled aneurysm remains a challenge.[14,15] In addition, the significant initial capital cost associated with DECT means that, as a technique, it is not broadly available or practical. Iterative metal artifact reduction (iMAR; Siemens Medical Solutions USA, Inc.) algorithms are available and employed with conventional CT. iMARs have been demonstrated to improve imaging quality after clipping or coiling on unenhanced CT scans; however, for CTA imaging, the issue of poor visualization of the adjacent vessels remains.[16]

NOVEL DEVICE DEVELOPMENT AND IMPLICATIONS FOR IMAGING FOLLOW-UP

Broadly, aneurysm recurrence after initially "adequate" endovascular treatment has been attributed to one of four mechanisms: (1) coil compaction secondary to a water-hammer effect from pulse pressure; (2) coil subsidence into the thrombus of a partially thrombosed aneurysm sac; (3) coil penetration through the wall of a previously intact aneurysm dome; and (4) growth of the aneurysm sac from an abnormal, inflammatory response to treatment.[17]

The last decade has seen a marked expansion in the development and availability of devices designed to overcome these challenges and improve the long-term angiographic outcomes associated with endovascular treatment. Many of these devices have been specifically designed to treat complex aneurysms, such as large lesions, giant lesions, wide-necked aneurysms, and/or bifurcation aneurysms, all of which are prone to recanalization. Stent-assisted coiling (SAC) with open, closed, or braided stents permits a denser coil mass and protects against parent vessel herniation, and bioactive/surface-coated coils or larger-caliber coils further increase packing density. More recently, FD, intrasaccular flow disrupters, and novel bifurcation devices have become available or have further evolved, each broadening the complexity of lesion that may be treated endovascularly. The type of device and its physical and ferromagnetic qualities dictate the most appropriate imaging modality to be used in follow-up.

FD and Intracranial Stents

For FD and intracranial stents, follow-up DSA is often required at least once, if not twice, after implantation, usually between 3 and 18 months. This is needed to determine aneurysm occlusion status and exclude in-stent stenosis or neointimal hyperplasia prior to considering a change in the patient's antiaggregation regimen. Beyond 18 months, imaging follow-up with noninvasive techniques is often more practical.

There is a relative paucity in data directly comparing MRA and its main techniques (TOF-MRA and CE-MRA) to the gold standard (DSA) for flow-diverted aneurysms. A recent study by Attali et al determined that at 3 T, CE-MRA outperformed TOF-MRA in the detection of aneurysm recurrence after FD (sensitivity and specificity, 83% and 100% for CE-MRA vs 50% and 100% for TOF-MRA, respectively).[18] However, both techniques have been shown to consistently overestimate in-stent stenosis, with high rates of false positives in both FD and routine SAC cases.[18-21] The presence or absence of in-stent stenosis on follow-up MRA often requires confirmation with a new DSA study.

Limited published data are available evaluating CTA and its role in the follow-up after FD. Novel applications such as metal artifact reduction software and DECT techniques may increase the role of CTA in imaging surveillance in the future, specifically for FD.[14,22]

Intrasaccular Flow Disrupters and Bifurcation Devices

The MR artifacts associated with FD and intracranial stents also apply to intrasaccular flow disrupters and novel bifurcation devices because their composition is similar to that of nitinol with platinum markers. Two recent studies compared DSA with TOF-MRA and CE-MRA for the follow-up of intracranial aneurysms treated with the WEB (Woven EndoBridge) embolization system (MicroVention Terumo). Specifically, the studies sought to identify residual/persistent aneurysm filling and evaluate interobserver agreement. In one study, CE-MRA failed to identify two out of five persistently filling aneurysms.[23] Another study reported a sensitivity of 25% for both TOF- and CE-MRA.[24]

No data are currently available on comparative follow-up imaging techniques for bifurcation devices, such as the PulseRider aneurysm neck reconstruction device (Cerenovus) or the Barrel vascular reconstruction device (Medtronic).

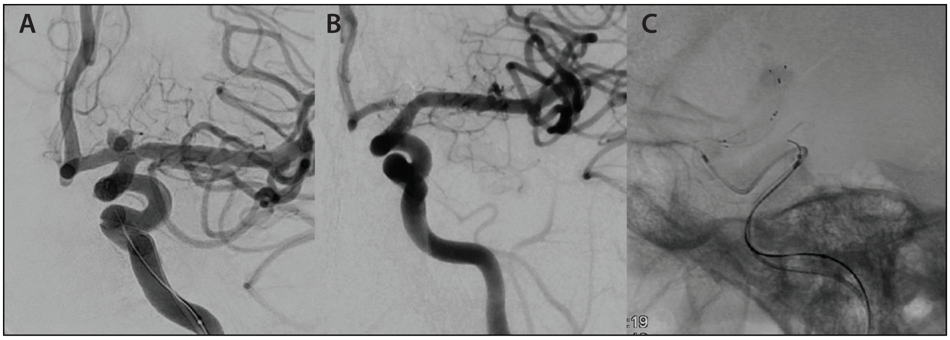

Figure 1. Subtracted pre- and postanterior oblique angiographic images (A, B) and oblique lateral single image (C) from PulseRider-assisted coil embolization of a left internal carotid artery terminus aneurysm showing Raymond-Roy classification 1 occlusion.

CONCLUSION

The timing and imaging modality used in the follow-up of endovascularly treated cerebral aneurysms will vary based on institutional preference and expertise

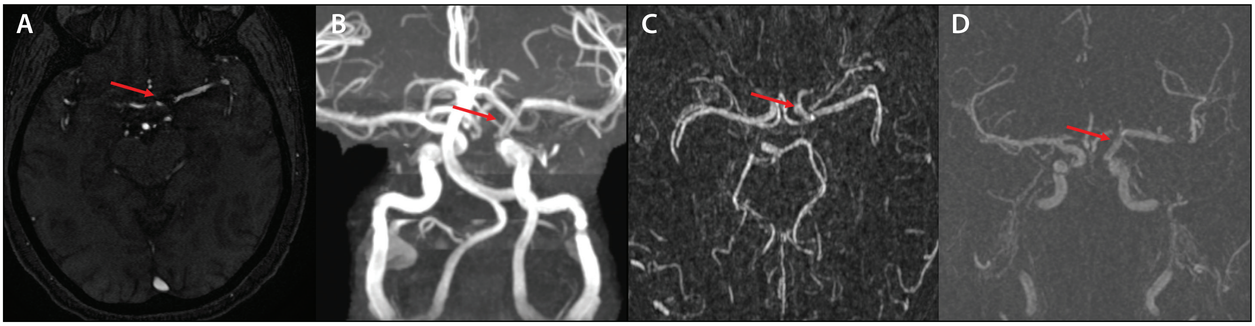

Figure 2. MRA evaluation for the aneurysm in Figure 1. Corresponding TOF-MRA axial source image and reformatted three-dimensional image at follow-up showing characteristic loss of signal associated with the PulseRider device (A, B). Ultrafast, high-spatial-resolution CE-MRA using differential subsampling with Cartesian ordering better depicts the parent vessel (C, D). Novel sequences can potentially help overcome some challenges faced by MRA for FD, SAC, and neck bridging devices.

(Figures 1 and 2). In general, early follow-up with DSA within the first 3 to 12 months is most common. For delayed follow-up using noninvasive techniques, MRA is preferred based on its high sensitivity and specificity for coiled aneurysms. However, DSA is recommended as the imaging modality of choice for novel devices, including intrasaccular flow disruption. Imaging follow-up beyond 10 years from treatment is recommended for all treated aneurysms based on the potential for delayed recanalization of certain types of high-risk aneurysms and the 1 in 25 likelihood of de novo aneurysm development in the all-comer treated population.[10] ■

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