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MR in the Evaluation of Aneurysms & Vascular Malformations

Specialty Area:

Multi-Disciplinary Neuroradiology
CNS Aneurysms & Vascular Malformations

Speaker Name:

Myriam Edjlali-Goujon, MD
Centre Hospitalier Sainte-Anne, University of Paris 5 – Paris, France
m.edjlali@ch-sainte-anne.fr

Highlights:

- **Identify MR methods to categorize the spectrum of aneurysms and vascular malformations in the brain;**
- **Explain the MR protocols used to evaluate treatment response of aneurysms and AVMs;**
- **Explain the features and artifacts of MR images used to diagnose and manage AVMs and aneurysms;**
- **Provide insights into the next generation of neurovascular MRI in order to identify potential rupture risk factors thanks to vessel wall imaging, via the visualisation of the inflammatory process and improved inflow based MRI techniques with alternative flow based metrics vessel wall health.**

Target Audience: Students, scientists, physicists, engineers, and clinicians interested current and prospective methods for the evaluation of intracranial vascular disease.

Objectives:
In this lecture, we explore the limits and potentials of current MR imaging techniques and research approaches to enhance MRI evaluation of intracranial vascular disease.

- Do's and don'ts of current MR angiography techniques applied to depiction and follow-up of brain vascular disorders and how these techniques compare to state-of-the-art angiographic techniques across modalities
- Discuss how new tools may change the imaging landscape:
    - Vessel wall imaging applied to aneurysmal clinical status (stable versus unstable)
    - 4D flow imaging applied to AVMs, aneurysms and dural arteriovenous fistulas

Purpose: This talk aims to summarize the actual MR use for depiction and follow-up of brain vascular disorders, to understand the features and pitfalls of such MR images and to provide insights into vessel wall imaging and 4D flow imaging to provide individual rupture risk factors of brain vascular disorders.

Current Imaging Landscape: Current clinical diagnosis of vascular lesions is largely based on "lumenographic". Based on these images and prior studies associating geometry and filling patterns with prognosis, treatment actions are considered. The required parameters depend on the disease in question. While CTA remains the first-line imaging technique in the acute setting for patients presenting with SAH, MR inflow based angiography is currently the most common technique for the assessment of intracranial vessels. While a variety of techniques have been proposed, time-of-flight (TOF) is typically used clinically. TOF is a simple T1-weighted sequence optimized to maximize an existing inflow based contrast. With the development of multi-slab excitation [1], use of magnetization transfer background suppression [2, 3], and 3T scanners, TOF has dramatically improved over the years. However, TOF is quite insensitive to slow flowing blood. It is therefore less well suited for giant aneurysms, stenosis, and AVMs with slow flowing components due to recirculation zones and venous drainage.

When Contrast Enhanced MRA (CE-MRA) was introduced, it made incredible inroads to almost every vascular territory. Its application in brain imaging allowed depiction and follow up of AVMs and dural arterio-venous fistulas. For the past decade, CE-MRA techniques have either ignored dynamic information entirely or relied on clever schemes to accelerate image acquisition (i.e. TRICKS [4],CAPR [5], TWIST, etc). Although they provide reliable information for Spetzler-Martin grading, their temporal resolution ~ 1 second remains insufficient to reliably identify all potential risk factors for rupture, such as deep venous drainage, venous ectasia and intranidal aneurysms [6]. The use of CE-MRA in the intracranial vasculature is still challenging due to the requirement for both high temporal and spatial resolution. New developments, exploiting known assumption about the underlying vascular structure, can help producing images of 0.5s temporal resolution and 0.7mm spatial resolution. This can be achieved using constrained technique, for example an approach that combines 2 radial acquisitions, a highly resolved 3D angiogram and a D-CE-MRA acquisition, resulting in a time series of 3D images (HYPR flow sequence [7]). Compared to routine protocols, such developments seems promising to better depict morphological rupture risk criteria.

Towards individual criteria of rupture risk:

The depiction and follow-up of morphological criteria of CNS vascular disorders are the first step of the MR analysis. However, emerging imaging techniques open new potentials by adding functional criteria that might predict the evolution and rupture risk of CNS vascular disorders. Two main orientations are suggested by recent studies: inflammation of the vessel wall [8] and analysis of physical constraints of blood flow thanks to both 4D Flow imaging (shear parietal) [9-11] and time resolved ASL [12]. Indeed, as exciting as acute treatment is in the stroke world, just as much energy should be focused on prevention. As with any disease, it is of great value to stratify the risk in order to prevent catastrophic events from ever happening, then the battle will have been won. Although much work has been done to risk stratify cerebral aneurysms based on size (International Study of Unruptured Intracranial Aneurysms), inflammation via vessel wall enhancement [13] and flow information related to 4D Flow MRI (ecg gated, 3D phase contrast) [14] are two main recent orientations towards individual criteria of rupture risk. 4D flow imaging can also be used to improve the characterization of brain AVMs by incorporating physiologic information into the imaging assessment [15].

It is now possible to extend the characterization to not only include important anatomic features such as size, location, and vascular components of arterial supply and drainage patterns, but also the flow conditions within each major arterial feeder, arteries near the AVM, and contra lateral arteries permitting a global assessment of flow across the entire cerebrovascular network [16].

The global flow network can be further defined by generating velocity- derived flow-tracking cartography, providing an overview of the dominant flow channels, with a chosen color code. Virtual MR flow-tracking cartography allows a precise assessment of AVMs, distinguishing the different arterial feeders, the venous drainage type, and may help in the AVM compartmentalization. When applied to dural arteriovenous fistula, virtual MR flow-tracking cartography has already shown its ability to classify this disorder, following the Cognard or Borden classification, in which the type of venous drainage is proportional to a rupture risk [17].

Conclusions: The assessment of intracranial malformations is still challenging. From a technical perspective, the flow is fast enough to be challenging for CE-MRA and yet slow enough to create artifacts in in-flow based techniques. Furthermore, pathologic structures are often small (aneurysms, stenosis) or rapidly filling (AVMs). However, emerging MRA techniques may substantially improve imaging performance. More importantly, it is likely that “lumenographic” techniques may become insufficient to grade vascular lesions depending on their risk of rupture. Here MRI holds potential to become a dominant and comprehensive technique, providing flow measurements and information on parietal wall inflammation.

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