**Specialty area: Sunrise Neuroimaging: Vascular Course**

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**Highlights**

- Neurovascular disease affect the lives of many young people. Treatment planning whether surgical or endovascular are informed by extensive imaging studies.
- With the development of turnkey MRI protocols that provide both non-invasive adjunct studies to current methods the overall radiation burden, and lifetime risk of cancers, can be dramatically reduced.
- MRI can provide detail physiologic data on neurovascular disease that is not readily available to physicians who must manage this disease.

**"CNS aneurysms & vascular malformations: what the neurosurgeon needs to know from imaging"**

**TARGET AUDIENCE :** MRI experts, clinicians and engineers, who desire or design pulse sequences and imaging protocols for the clinical evaluation of neurovascular disease.

**OUTCOME/OBJECTIVES:** The goal of this presentation is to improve the understanding of the clinical management of neurovascular disease and to review advanced imaging protocols that alter the clinical management of aneurysms and vascular malformation of the central nervous system(1). The advanced MR imaging discussed are those specific to inform management based on vascular topology, hemodynamic significance and functional eloquence of a lesion.

**PURPOSE:** This presentation will review the common clinic scenarios and treatment paradigms for AVM/aneurysms. We will highlight those questions that would benefit from imaging-based clarification.

Intracranail Aneurysms (IA): The management of intracranial aneurysms must the devastating risk of a rupture, which results in 24 mortality of roughly 50% against the risk of endovascular or surgical resection and their cure/recurrence rates. Open surgical clipping, coil and new flow diverting stent technologies evaluate the vascular topology, size and location of the targeted aneurysm on invasive catheter angiography.

Size is perhaps the most common metric of rupture risk used in clinical practice today. Typically, aneurysms larger than 10 mm are considered at a much higher rupture risk than smaller ones(2); however, many aneurysms smaller than 5mm are also known to rupture. Large patient-cohort studies (2, 3), have shown that other morphological parameters such as dome diameter, aspect ratio, and location are, to a degree, predictive of rupture risk but are by no means comprehensive. Clinical management based on these factors alone may fail to differentiate between IAs with similar morphologies but undergoing different natural histories. A multi-modal assessment of IAs that not only evaluates morphological parameters, but also luminal forces such as blood flow and wall shear stress (WSS), and biological and histological phenomena pertinent to the integrity of the vessel wall, could provide a clearer picture of IA natural history.

Intracranial Arterial Venous Malformations (iAVM): Estimates for bleeding from unruptured AVMs range from 1.3% to 4% per year (4, 5) with mortality of 10% to 30% from incident hemorrhage and neurological disability of 20% to 30%. The treatment of complex vascular malformation of the brain depends on the size, compactness of the nidus, the proximity of eloquent tissue and the vascular architecture. The risk of treatment can be quantified as the Spetzler-Martin grade(6). To further complicate evaluation, 17% of all AVMs have an associated flow related aneurysm that are prone to rupture from increase intra-arterial pressures resulting from embolism. In fact, deep AVMs with small compact nidus can be treat with focusses radiation (gamma knife surgery) without open surgery. Many of the properties of aneurysm/AVMs can be determined from high quality images. Since these abnormalities become symptomatic early in life (in 20 -50 year olds), the affect the lives of many young people and the need for periodic surveillance indicated the need for radiation free imaging to reduce the lifetime risk of cancer in these patients.

**METHODS:** We will discuss advanced imaging based on the clinical needs outlines above.

TOF MRA: Time of Flight MRA is the first line of defense for the detection of intracranial aneurysms. TOF uses flow related enhancement to create intravascular (intra aneurysmal) signal. Although many aneurysms are detected at TOF, slow flow in the dome of large aneurysm require follow up with CTA/DSA or Contrast angiography. TOF MRA is more susceptible to slow arterial flow that is characteristic of AVMs which lead to artifactual signal loss leading to gross underestimation of AVM size. Complex vascular topology with its slow and retrograde flow can be problematic for determining the vascular architecture.

Time Resolve CE-MRA: Compared to the frame rates (up to 24 frames/second) spatial resolution(~ 0.2 mm) MRI is exceedingly slow and coarse. MRA does off a non-invasive alternative to DSA and several investigators have applied advance image acquisition, parallel imaging and novel kspace and post-processing algorithms in an attempt to accelerate CE-MRA to the point where it can serve as a non-invasive alternative to catheter based DSA.

Aneurysm flow: Blood flow and WSS are commonly studied hemodynamic stressors in various cerebrovascular vessel wall disorders, including intracranial aneurysms, and are known to affect gene expression in luminal cells of the arterial wall. Computational Fluid Dynamic and Phase Contrast flow have been used to determine flow volumes and velocities in aneurysm and AVM. Several ongoing studies are

Vessel Selective ASL: Contrast Angiography can provide high resolution images for the vasculature but require a systemic venous injections. Much of the evaluation of vascular topology at angiography use selective injection with a microcatheter. Recent advancement in vessel selective labeling can provide a unique evaluation of the nidal compartment that an artery feeds (7).

Vascular Steal in AVM: The redistribution of blood flow near an AVM profoundly affects the local hemodynamics. In some cases chronic shunting of blood from a vascular territory can result in a loss of vasomotor reactivity that regulates local perfusion pressure. Post embolization or resection, normal perfusion pressure breakthrough (i.e. hemorrhage) can result. Vasomotor reactivity using ASL or DSC perfusion can provide critical information to physicians on the hemodynamic significance.

**RESULTS/DISCUSSION:** Clinical studies highlighted the success and remaining challenges in neurovascular MRI will be discussed.

Flow in Aneurysms: In animal models, prolonged high WSS has been shown to trigger nitric oxide release (NO) which can in turn induce smooth muscle cell apoptosis and arterial dilation. As a result, hemodynamic parameters such as blood flow and WSS have been proposed as useful markers for assessing rupture risk. However, as pointed out by Kallmes(8) definitive multi-center studies demonstrating causal or associative relationships between WSS and aneurysm remodeling and rupture remain elusive. Nevertheless, the significance of hemodynamic factors cannot be ignored in developing a unified model of IA disease.

CE-MRA: Both keyhole(9) and view-sharing techniques(10) showed CE-MRA is approaching the resolution and frame rates of Xray DSA. Multiple MRI studies have shown that size, location and drainage, key-components of the Spetzler-Martin grade is accessible with no-invasive MRI. There is some question whether the relatively coarse spatial resolution (> 1.0 mm) is sufficient for the detection of small, yet clinically significant feeders and flow related aneurysms.

Perfusion: MRI perfusion can reveal the underlying hemodynamic significance of an neurovascular abnormality. In AVM is t is well know that blood can be shunted away from adjacent vascular beds resulting in vascular steal which resulting in a reduction of perfusion despite maximal vasodilation.

## CONCLUSION:

There has been considerable effort devoted to the non-invasive imaging of neurovascular disease. Outside of the heart, neurovascular MRI remains one of the most challenge research areas. MRI-angiography may serve as a non-invasive adjunct to DSA for surveillance and pediatric patients where cumulative radiation dose should be minimized, but remains the standard of reference for angiographic imaging. However vessel labeled ASL, DSC perfusion, flow and CDF can provide additional non-invasive information to supplement angiographic assessment of IA and iAVM.

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