**Evaluation of the Cerebral Vessels**

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### Introduction

In the last decade there has been a dramatic shift to non-invasive imaging of the cerebral vessels. This is justified since selective catheter angiography (digital subtraction angiography, DSA) has a risk of neurological complications despite advances in techniques and safer contrast agents. Carotid Doppler is an excellent screening tool to study the carotid bifurcation in patients with transient ischemic attacks and stroke. Transcranial Doppler is useful to detect early vasospasm in patients with subarachnoid hemorrhage. Multi-slice computed tomography (CT) angiography (CTA) and magnetic resonance angiography (MRA) have become effective methods to image the cerebral arteries and veins. DSA is now employed selectively in treatment planning after non-invasive imaging has been used for diagnosis.

### CT Angiography

With the advent of multi-slice CT and improved post processing, CTA has played an increasingly important role in the evaluation of the cerebral vessels. CTA is excellent in evaluating patients with carotid stenosis. It can detect a hairline residual lumen, referred to as the “string sign”, in patients with near occlusion. Typically, the string sign, which was described on DSA, has been difficult to show by MRA.

CTA is a fast and reliable method to evaluate patients with intracranial hemorrhage, especially subarachnoid hemorrhage. CTA shows most cerebral aneurysms that are detected using DSA. CTA may also reveal thrombosis or calcification in the wall of a large or giant aneurysm. Post-processing allows assessment of the aneurysm with maximum intensity projections (MIP) and surface-rendered 3D projections in multiple planes. In many cases, CTA will be sufficient to allow treatment planning. If the aneurysm is unsuitable for endovascular treatment, the patient may be treated surgically without the need for DSA. CTA is able to demonstrate vasospasm after subarachnoid hemorrhage thus avoiding DSA in patients who are initially given a trial of medical therapy.

### MR Angiography

This technique plays a major role in cerebrovascular imaging. Gadolinium enhanced auto-triggered elliptic centric-ordered MRA (ATECO) has superior resolution compared to time-of-flight (TOF) MRA. This has been shown in the evaluation of carotid bifurcation, the intracranial arteries, and the intracranial veins. MRA to evaluate carotid stenosis has eliminated the need for DSA in the majority of patients. MRA of the extracranial and intracranial arteries is a standard part of the magnetic resonance imaging (MRI) evaluation of patients with stroke. Since ATECO is not dependent on the direction of flow, it yields excellent visualization of tortuous vessels and vessels with slow or turbulent flow. ATECO can determine whether there is an intracranial arterial occlusion in patients being evaluated for possible intra-arterial thrombolysis. At 3T, high-resolution imaging of the intracranial arteries with contrast has demonstrated vessel wall disease and has been helpful in differentiating atherosclerotic disease from vasculitis (Fig. 1). Wall disease is best seen on contrast-enhanced axial T1 images. T1 fluid-attenuated inversion recovery (FLAIR) is a black-blood acquisition that eliminates the signal from flowing blood, enabling specific visualization of the wall.

MRA is a good technique to screen high-risk individuals for aneurysms. Again, ATECO is superior to TOF MRA since the turbulent flow in an aneurysm may not be detected by the latter method. However, for screening purposes we prefer non-contrast TOF MRA due to its safety and ease of performance. At 3 T, non-contrast TOF MRA is similar to contrast-enhanced MRA at 1.5T. Remnants of the aneurysm neck in patients previously treated by coiling are best detected by gadolinium-enhanced MRA.

Time-resolved gadolinium-enhanced MRA is useful in the evaluation of arteriovenous fistula of the brain and spinal cord (Fig. 2). Confirmation of a fistula on the basis of the results from this non-invasive technique allows for appropriate treatment planning. Catheter angiography can be done at the same time as the endovascular treatment. ATECO magnetic resonance venography (MRV) is the imaging modality of choice to evaluate the cerebral veins.
and venous sinuses in sinovenous thrombosis. It is far superior to TOF and phase-contrast methods. In addition, the brain parenchyma can be assessed at the same time.

**Digital Subtraction Angiography**

Traditionally DSA has been the “gold standard” to evaluate the cerebral vessels. This remains true for the evaluation of the cerebral arteries, circulation time, and collateral flow but is no longer true for the evaluation of the venous system. ATECO MRV is superior to DSA. Since DSA uses selective arteriograms, there is “washout” of the cerebral veins and venous sinuses from unopacified blood. In ATECO MRV, all the veins are opacified equally.

DSA allows assessment of the circulation time. This is helpful in arterial occlusive disease, arteriovenous shunts, venous occlusive disease, and the venous congestion related to dural arteriovenous fistula with cortical venous reflux. In brain micro-arteriovenous malformations (AVMs), the only clue to the presence of shunt is the finding of an early draining vein. This would be difficult to detect using CTA or ATECO MRA.

Collateral flow develops in response to occlusive disease in the arteries and veins. Collateral flow and the direction of flow are best assessed using DSA. Non-invasive imaging with CTA or MRA may detect the presence of a vessel but not the direction of flow. Assessment of collateral flow and circulation time is important in arterial stenosis and chronic venous occlusive disease. When venous collaterals enlarge and become tortuous, they may be evident on non-invasive imaging. On DSA, this pattern is referred to as “pseudophelebitic”.

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**Fig. 1 a-c.** Vessel wall imaging at 3T in a patient with symptomatic atherosclerosis in the basilar artery. a Coronal contrast-enhanced T1 FLAIR shows the enhancing atherosclerotic plaque. Corresponding contrast enhanced MRA (b) and catheter angiograms (c).

**Fig. 2 a, b.** Time-resolved contrast enhanced MRA (“Tricks”) shows anterior cranial fossa dural arteriovenous fistula. a Lateral maximum intensity projection (MIP) from Tricks shows early venous filling of a dilated venous pouch above the crista galli. b Corresponding lateral view of the catheter angiogram in the right internal carotid artery.