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High Resolution MR of Arterial Vessel Walls

- A new high-resolution MR (HR-MR) black-blood imaging technique has been developed that enables examination of intra-cranial arterial vessel walls.
- HR-MR images can show arterial wall thickening (concentric or asymmetric), atherosclerotic plaque, intramural hemorrhage, and enhancement.
- HR-MR shows promise for the diagnosis of several cerebrovascular diseases:
  - Atherosclerosis
  - Arteritis
  - Reversible Cerebral Vasoconstriction Syndrome
  - Dissection

Cerebrovascular disease is a major cause of morbidity and mortality worldwide. Accurate diagnosis of diseases such as atherosclerosis, arteritis, dissection, and reversible vasoconstriction is essential for guiding appropriate therapy. Conventional angiography, whether by digital subtraction angiography, CT angiography, or MR angiography (MRA), are well established tools for examining patients with cerebrovascular disease. These tools are invaluable but limited because they only assess the lumen of blood vessels, not the vessel walls. Therefore, conventional angiography only provides an indirect indicator of vascular pathology, leaving more specific diagnostic questions unanswered due to multiple different pathologies that can result in luminal stenoses.

Imaging intracranial arteries is particularly challenging because the vessels are small (the largest are only 1–2 mm wide) and very tortuous. In the past few years, a new high-resolution MR (HR-MR) technique has been developed that creates images with a resolution of 0.4 x 0.4 x 0.4 mm by using a specialized imaging sequence, called black-blood imaging, on a 3T MR scanner with gadolinium contrast. In the resulting images, the lumen of the blood vessel appears black, and the arterial wall can be visualized (Figure 1). Several features can be discerned, such as arterial wall thickening (concentric or eccentric), vessel wall enhancement, atherosclerotic plaque, and intramural hemorrhage.

HR-MR shows promise as a means to differentiate among pathologies that cause vascular disease, including cerebrovascular atherosclerosis, arteritis, reversible cerebral vasoconstriction, and arterial dissection. As these pathologies require different treatments, the ability to accurately diagnose these conditions is vital.

Intracranial Atherosclerotic Disease

Although intracranial atherosclerotic disease (ICAD) causes 8-10% of strokes in North American patients, it causes about 30-50% of strokes in Asians and is commonly seen in Hispanic and African-American patients. Atherosclerosis results in heterogeneous thickening of the vessel wall due to plaque components, which include a lipid core, fibrous cap, intraplaque hemorrhage, calcification, and enhancement. While current HD-MR techniques cannot consistently characterize these features in intracranial arteries, vulnerable plaque features such as hemorrhage and enhancement can correlate with down-stream strokes. Moreover, HD-MR is advantageous in that it can detect small atherosclerotic plaques in vessels that, due to remodeling, do not have stenoses and cannot be visualized by conventional angiographic imaging. With HD-MR, plaques appear as eccentric and often irregular thickening of the vessel wall with variable enhancement thought to be due to inflammation or neovascularization. A more strongly enhancing plaque likely represents a culprit lesion for an ischemic event, suggesting that plaque enhancement may be a more precise marker of stroke risk than luminal stenosis.

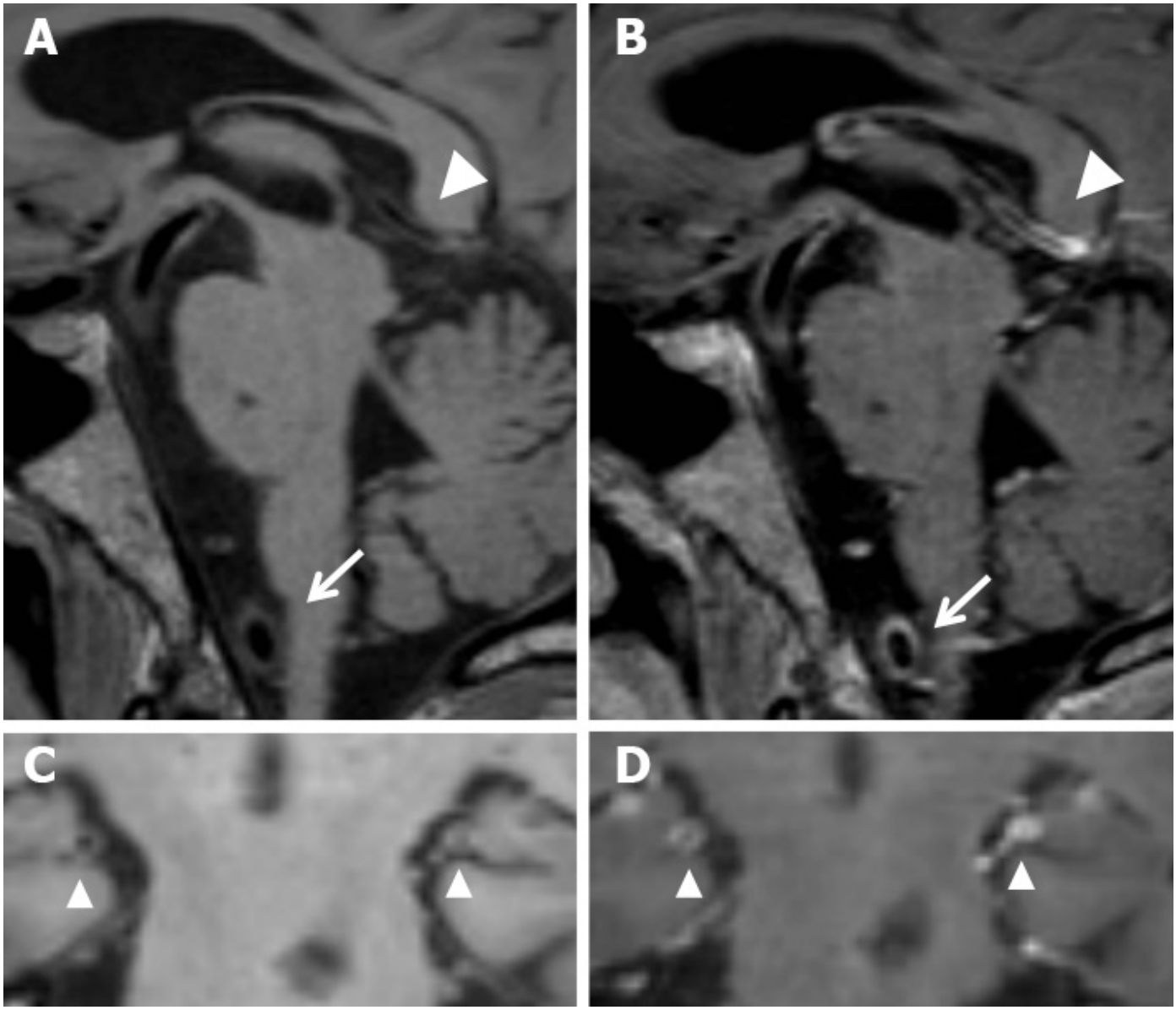

Figure 1. Pre-contrast **(A,C)** and post-contrast **(B,D)** high resolution MR imaging of intracranial vessel walls is shown in a patient with multiple intracranial infarcts. Sagittal **(B)** and coronal **(D)** post-contrast images show robust enhancement of the proximal basilar artery (arrow) and posterior cerebral artery (arrowhead). The posterior cerebral artery in cross-sectional view in the coronal plane **(C, D)** shows circumferential vessel wall thickening and enhancement of the vessel wall, findings of which are consistent with vessel wall inflammation.

Recanalization after intracranial thromboembolism may also induce changes in the arterial wall, especially after mechanical thrombectomy. These changes may include concentric wall thickening and enhancement that could be confused with vasculitis if the patient's history is unknown.

Arteritis

Inflammation of intracranial blood vessels is rare and is associated with a number of different diseases, including giant cell arteritis, Takayasu's arteritis, polyarteritis nodosa, granulomatosis with polyangiitis, and primary angitis of the CNS. Arteritis is associated with homogeneous and circumferential wall thickening. Enhancement may be eccentric, although an increased T2 signal is absent in vasculitis.

A brain biopsy is considered the gold standard for establishing a diagnosis of arteritis. However, sampling error has been reported as a diagnostic challenge, with one study reporting a non-diagnostic brain biopsy in 37% of 101 cases despite a positive angiogram. Moreover, given the significant morbidity related to brain biopsies, diagnosis is further limited by the inability to perform repeat biopsies.

Thus, diagnostic information from HD-MR, if vessel wall thickening and enhancement is visualized, may be complementary with brain biopsies by helping to guide the selection of tissue to individual vascular branches.

Reversible Cerebral Vasoconstriction Syndrome

Reversible Cerebral Vasoconstriction Syndrome (RCVS) is a disorder of arterial tone regulation which results in arterial vasospasms manifesting as multifocal narrowing of arteries. However, RCVS can spontaneously resolve within three months. Discriminating between RCVS and arteritis can be challenging due to overlapping patient demographics and the lack of imaging differences by conventional angiographic imaging. However, HD-MR imaging of arterial walls shows promise in distinguishing between these two entities during the acute phase. Both wall enhancement and thickening are observed in arteritis, whereas RCVS patients have diffuse uniform wall thickening along the length of the diseased vessel with little or no enhancement.

Dissection

Intracranial artery dissection can lead to cerebral ischemia and subsequent subarachnoid hemorrhage and is an important cause of strokes in young adults aged 20-50 years. The disorder is more common in Asian populations with some reports citing a prevalence of over 90%. The radiologic features associated with dissection, such as intimal flap, double lumen, and intramural hematoma, may be more easily visualized with HD-MR, helping to distinguish it from other etiologies of luminal narrowing, such as intracranial atherosclerotic disease. Vessel wall enhancement is sometimes observed in association with dissection and is thought to be due to inflammation, slow blood flow in the false lumen, or vasa vasorum enhancement. Moreover, the presence of an enhancing intimal flap, which has been reported in several recent reports using HD-MR, can be diagnostic of an arterial dissection and thereby can substantially improve patient outcomes by directing therapy.

Scheduling

HD-MR of arterial walls is performed on 3T MR scanners at the main campus of Massachusetts General Hospital in Boston. Appointments can be made through Epic (inside the Partners network) or Physician Gateway (outside the Partners network) or by calling 617-726-8396.

Further Information

For further information on HD-MR of arterial vessel walls, please contact Javier Romero, MD, Department of Radiology, Massachusetts General Hospital, at 617-726-8320.

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