MRI of Carotid Atherosclerosis

Clinical Implications of Plaque Morphology

Stroke is a leading cause of morbidity and mortality in the United States, and carotid artery atherosclerosis remains a common source. Interventions such as carotid endarterectomy are effective in preventing stroke, but should be done only in patients at sufficient risk of future events to outweigh the risk of surgery. Identification of individuals at risk of stroke from carotid artery atherosclerosis is generally based on degree of stenosis (as determined by angiography or carotid ultrasound) and the presence of symptoms, such as previous stroke or transient ischemic attack.

Many patients with symptoms of carotid disease do not actually have significant stenosis, and understanding the morphology and surface features of these plaques may provide insight into stroke risk. Studies of coronary arteries have revealed that plaque rupture occurs at low degrees of narrowing and the degree of stenosis poorly predicts events. In another study, subjects with atherosclerotic lesions treated with lipid-lowering therapies demonstrated a 75% reduction in adverse cardiovascular events despite only a minimal reduction in the severity of stenosis (less than 1% decrease in the degree of narrowing seen in only 12% of atheromas). This further emphasizes the importance of understanding atheroma morphology and not simply relying on its hemodynamic effect to assess risk.

Studies of atherosclerosis suggest that a large lipid core with a thin overlying fibrous cap are features of atheroma vulnerability. This pattern of vulnerability is supported by the association of hypoechoic atheroma seen by carotid ultrasound, likely representing the lipid core, with incident stroke. Rupture of the thin fibrous cap exposes the thrombogenic lipid core of the atheroma to flowing blood, with subsequent thrombus formation leading to the clinical event.

Characterization of Plaque Morphology by MR

In vitro studies have shown that MR can discriminate a variety of lipid mixtures typically found in human atheroma. In vitro MRI studies have revealed that atherosclerotic plaque components have unique signal characteristics that enable distinction from one another using this modality. Application of MRI for discriminating plaque components in vivo is supported by the strong agreement demonstrated between in vivo and ex vivo measurements of vessel wall thickness and T2 relaxation of atheroma components. The administration of gadolinium-based contrast enables even better discrimination between plaque components because of preferential uptake in fibrocellular tissue. Gadolinium administration has also been shown to identify sites of neovasculature and inflammation in plaque, which are important determinants of its likelihood of rupture.
Importance of Vessel Wall Imaging for Early Detection of Atherosclerosis

Early detection of carotid atheroma is crucial for early medical intervention to prevent atheroma progression and stroke. The importance of imaging the arterial wall and not relying on stenosis for early atheroma detection is highlighted by the vascular remodeling that occurs during atherogenesis. Atheroma initially forms eccentrically, and as it enlarges, the initial luminal area (taken as the area circumscribed by the internal elastic lamina [IEL]) is maintained and the arterial wall bulges outward. Thus, the lumen remains concave as the atheroma progresses (i.e., as the fibrous cap is formed). It has been shown in human coronary arteries that once the atheroma occupies roughly 40% of the IEL area, it begins to encroach on the lumen and stenosis is observed.

Early Detection by MR

There is strong evidence that the pathogenesis of atherosclerosis is based on an inflammatory process. Detection of inflammation within the vessel wall may provide insight into the earliest stage of atheroma development. Weiss et al. showed that MRI may be able to detect these inflammatory changes in the infra-renal aorta and common carotid artery of human subjects in vivo by showing associations between vessel wall abnormalities on MR with levels of serum markers of inflammation. The MRI scan was considered abnormal based on demonstrating elevated wall thickness, T2 relaxation, or contrast enhancement.

The notable limitation of these surrogate markers of atherogenesis is the uncertainty of their sensitivity and specificity. Circulating markers of inflammation are subject to systemic dilution and therefore these measures have limited sensitivity. Furthermore, such markers lack specificity, as abnormal levels may reflect nonvascular sources of inflammation. These markers cannot determine the stage of atheroma development and do not predict the immediacy of cardiovascular risk. Focused MR imaging of a vessel wall at risk for atherogenesis may provide a better measure of early atherogenesis, even before overt wall thickening can be detected.

Atherosclerotic plaque can go undetected even in more advanced disease because of compensatory vascular remodeling. Babiarz et al. showed that carotid stenosis measurements by black blood MRI were lower than those based on corresponding contrast-enhanced MRA images, with narrowing of 67% on the black blood images corresponding to no stenosis on the MRA. This difference is a result of MRIs ability to identify the outer wall and account for outward remodeling during plaque progression that preserves the lumen. The detection and characterization of atherosclerotic plaque that has little hemodynamic effect on the lumen enables the identification of lesions at risk for events that have eluded discovery by conventional angiography.

References:


