Contrast Enhanced High Resolution MRI for Atherosclerotic Carotid Artery Tissue Characterization

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Introduction
The goal of this study was to investigate whether contrast enhanced (CE) MRI can characterize atherosclerotic vessel wall tissue composition of human carotid arteries. In addition to lumen narrowing, atherosclerotic plaque tissue composition and plaque morphology may be important factors for differentiating "at risk" lesions that can cause thrombo/embolic events from stable lesions. Recent literature suggests that MR imaging with multiple contrast weighting may be able to identify certain plaque tissue types in the carotid artery in vivo [1]. Also contrast enhancement of the vessel outer wall boundary has been reported [2,3]. This study was designed to evaluate the effects of contrast enhancement within human carotid atherosclerotic plaque.

Methods
15 consecutive patients (all male, age range 48-87 years) scheduled to have carotid endarterectomy were recruited for an MRI scan prior to surgery. Informed consent was obtained from each subject. High-resolution cross-sectional MR images of bilateral carotid arteries were obtained using a custom-made phased array carotid coil on a 1.5T MR scanner (GE SIGNA Horizon EchoSpeed 5.8). The imaging protocol included 2D time-of-flight MR angiography (MRA) to determine the location of bifurcation and a double inversion recovery (DIR) T1-weighted (T1W) fast spin echo (FSE) sequence: TR/TE/TI = 800/10/650ms, ETL = 8, slice thickness = 2mm, FOV = 13x9cm, matrix = 256x256(with ZIP reconstruction). Pre-contrast T1W images and steady state post-contrast T1W images were acquired using the same imaging parameters at the same imaging location. A gadolinium based contrast agent (OmniScan, 20 ml) was used. Excised plaques were processed for histology examination. To date, H & E and Mallory's Trichrome stained histology sections from five patients' specimens are available for comparison.

Pre and post CE images from matched locations of both carotid arteries were analyzed. For each diseased artery, images from three locations (common, bifurcation, and internal carotid artery) 4 mm apart were selected for the review. Based on recent literature on plaque tissue contrast [4], regions of interest (ROIs) of atherosclerotic plaques visualized on MR images were identified as fibrotic (includes fibrous tissue and neovasculature) and non-fibrotic (includes necrotic core, calcium, and the acute intraplaque hemorrhage). Tissue identification was blinded with respect to the CE images. Signal intensities of these regions were measured and the percentage increase was calculated.

Results
Overall, visual comparison of pre- and post-CE T1W images showed improved plaque tissue contrast in post-CE images (Figure 1). Contrast enhancement of different levels was observed in many sub-regions of plaque tissues. Signal intensities and percentage changes from a total of 120 ROIs were obtained. For the non-fibrotic tissue group (NFTG), the mean signal increase (SI) was 24 ± 25% (N = 40) and for the fibrotic tissue group (FTG), the mean SI was 83 ± 38% (N = 80). The difference between the two mean SIs was statistically significant (p < 0.0001). A cutpoint of ≥50% SI to classify FTG yields a sensitivity of 80% and a specificity of 83%. Using a cutpoint of ≥100% SI can divide the FTG into "strong enhancement" of 28% of ROIs and "moderate enhancement" of 72% of ROIs. The strong enhancement ROIs were found to be from tissue regions with neovascularature (histology is available in 7 regions). The ROIs from the NFTG with minor enhancement were found to be primarily from lipid rich necrotic cores (histology is available in 10 regions).

Discussion
These preliminary results show that contrast enhanced T1W MRI may be useful for differentiating non fibrotic necrotic tissues and fibrotic tissues of atherosclerotic plaque. Furthermore, these results also show that neovascularization, a sign of plaque activities, may be identified as regions with strong contrast enhancement. Comparison of pre- and post-CE T1W images may provide valuable information on plaque tissue characteristics that is not available with existing techniques of T1-, T2, or proton density-weighting.

References