Characterization of Ex Vivo Carotid Plaque with 3T MRI: A Comparison with Histology

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Introduction: Atherosclerotic disease of the carotid artery is a significant cause of morbidity and mortality. Previous imaging techniques have focused on quantifying stenosis in the vessel, but recent research suggests that composition of plaque may be a more important prognostic factor. Ex vivo studies of carotid plaques have attempted to characterize plaque using 1.5 T MR and have shown that 2D PDW, T1W and T2W sequences on MRI may have some utility in demonstrating areas of fibrous matrix and necrotic core. [1,2] Here, we perform an intial evaluation of 3T MRI in the characterization of ex-vivo carotid plaque specimens.

Methods: 7 carotid plaque specimens were obtained after carotid endarterectomy surgeries. The specimens were fixed directly in 10% neutral buffered formalin and then scanned on 3T MRI, using carotid artery protocol, four channel carotid coils, and a custom phantom setup. Two dimensional T1, T2, and Proton Density weighted images were obtained. For T1, T2 and PD weightings the slice thickness was 2.0 mm. Inplane resolution 0.5x0.5 mm. 15 slices were acquired with an interslice gap of 0.2 mm. Spectral selective fat saturation was used. All sequences used a receiver bandwidth of 130Hz/Pixel. For the T1 TSE sequence TR=800 ms, TE 15ms with an Echo train of 3. Four signal averages were acquired with the scan separated into two acquisitions (concatenations). For the Proton Density weighted scan TR= 3000, TE 14, echo train length 3. Two signal averages were acquired. For the T2 weighted scan TR=8000, TE 83 with an echo train of 13 with 3 signal averages. After imaging, specimens were processed by a pathology facility, yielding standard H & E stained slides as well as Movat's Pentachrome stained slides for connective tissue analysis.
Images were processed using Image J and were coregistered using known distance from carotid bifurcation. Overall area of the plaque and vessel wall were calculated for both MR and histological images. A trained surgical pathologist reviewed the histological specimens to outline areas of fibrous matrix and lipid or necrotic core. Corresponding areas were depicted on stacked T1W, PDW and T2W images. These areas were then calculated as a percentage of the total specimen area and compared.

Results: 5 of the 7 specimens were determined to have areas of fibrous dense connective tissue matrix and all seven specimens were determined to have areas of necrotic core. Areas measured as percentage of total plaque showed good correlation between 2D and histological images with no statistically significant difference found between percent areas for lipid/necrotic core (Two-tailed t-test, p = 0.51). In comparison of fibrous matrix between histological and MR images, a statistically significant difference was shown (Two-tailed t-test, p = 0.01). (Fig 1, Fig 2) Areas corresponding to lipid core were found to be hypointense to isointense on T1W images, hypointense to isointense on PDW images and hyperintense to isointense on T2W images.

Discussion: This study shows promise for the capability of 2D 3T MRI to characterize plaque. Further study should focus on the ability of 3T to characterize other plaque components, including calcium, hemorrhage and thrombus.

References:
[1] Shinnar M et al. ATVB 1999; 19: 2756; [2] Clarke SE et al. MRM 2003; 50: 1199;

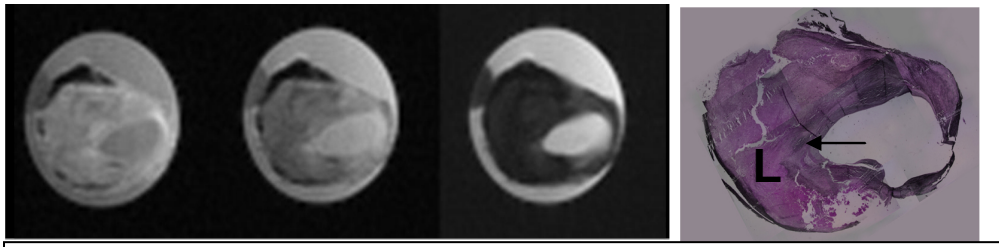

Fig 3. A) T1W image B) PDW image C) T2W image D) Histological specimen with Movat's pentachrome stain showing fibrous cap (arrow) and necrotic lipid core (L). **Note – calcium not present on histological specimen due to surface decalcification during processing.

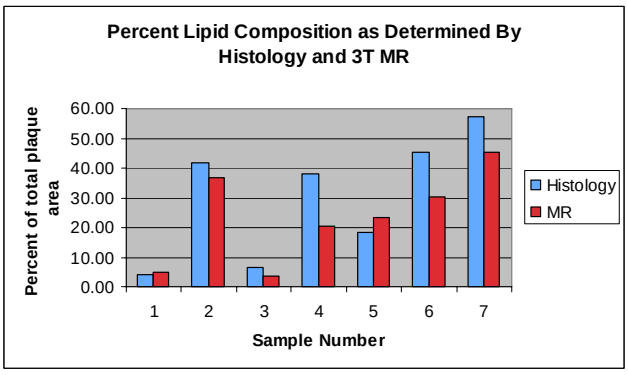

Fig 1. Comparison of Histology and MR for determining lipid core area as a percent. Values correlate closely, and there is no significant difference overall.

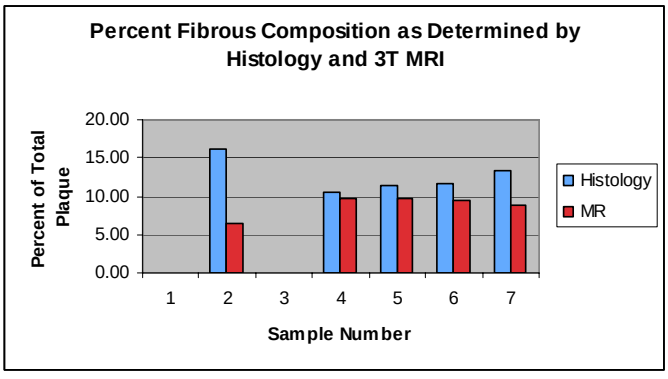

Fig 2. Comparison of Histology and MR for determining fibrous component area as a percent. ** Note – not all samples were determined to have a measurable fibrous component. Values correlate but there is a statistically significant difference.