Numerical simulations of carotid MRI: how accurately can we quantify atherosclerotic plaque components in vivo?

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BACKGROUND AND PURPOSE: Carotid atherosclerosis is a disease characterized by plaque formation in the carotid bifurcation. Vulnerable plaques, consisting of a large lipid-rich necrotic core (LRNC) separated by a thin fibrous cap (FC) from the lumen, are most prone to rupture and can be visualized *in vivo* by carotid MRI [1]. How accurately MRI can quantify plaque components such as thin FC's and LRNC's *in vivo*, remains unknown because of the lack of an accurate ground truth on the sub-millimeter scale. To circumvent this problem, we chose a novel approach by simulating carotid MRI using the open-source package JEMRIS [2].

METHODS: We simulated an *in vivo* T1W gadolinium contrast enhanced carotid MRI protocol, specifically designed to image FC's. We simulated identical timings, turbo-spin echo factor, acquired in-plane voxel dimensions and k-space filling. A set of 33 ground truth vulnerable plaque geometries derived from cross-sectional histological data from 12 patients were used as 2D sample models for the MRI simulations. Segmentation of carotid lumen, LRNC and outer wall on simulated images was performed by 3 expert MR readers and measurements derived from these segmentations were compared to the ground truth by correlation coefficient (R) and within readers by the intraclass correlation coefficient (ICC).

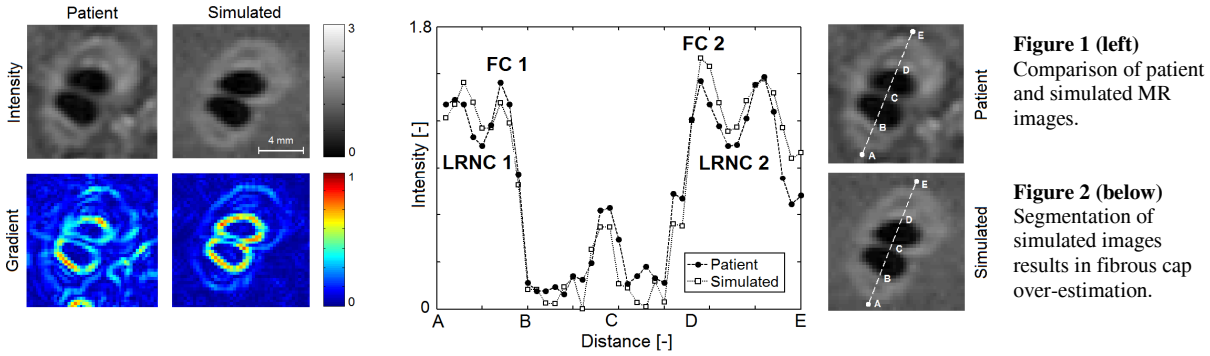
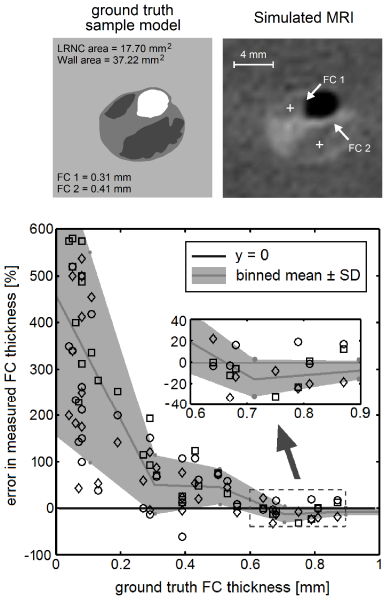


Figure 1 (left) Comparison of patient and simulated MR images.

Figure 2 (below) Segmentation of simulated images results in fibrous cap over-estimation.

RESULTS: MR readers segmented the lumen with high correlation and excellent agreement with the ground truth (R = 0.996, ICC = 0.99). Total measured vessel wall area correlated well (R = 0.96, ICC = 0.94), but was found to be overestimated by 15%. MR readers were found to systematically under predict LRNC area by -31%, but their measurements correlated well (R = 0.95, ICC = 0.94). Measured FC thickness showed a weak correlation (R = 0.71, ICC = 0.69). FC's smaller than 0.6 mm were on average severely overestimated in thickness by 201 ± 217%, where FC's between 0.6 and 0.9 mm were measured more accurate and slightly underestimated: -6 ± 15%.



CONCLUSION: We can conclude that *in vivo* MRI can accurately quantify plaques with regard to vessel wall area and LRNC, but that it has limitations for thin FC measurements. This might influence the reliability of *in vivo* MRI for assessing vulnerable plaque rupture risk by quantifying FC thickness.

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