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. 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.

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).

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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REFERENCES: