3D INVERSION RECOVERY FAST SPOILED GRADIENT RECALL (IR-FSPGR) AND TOF MRA WITH MORPHOLOGY ENHANCED PROBABILISTIC PLAQUE SEGMENTATION (MEPPS) PREDICTS THE SIZE OF LIPID-RICH NECROTIC CORE OF CAROTID PLAQUE

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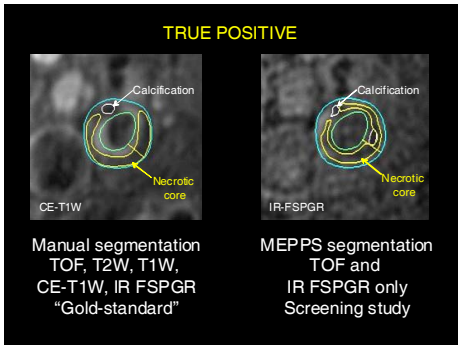
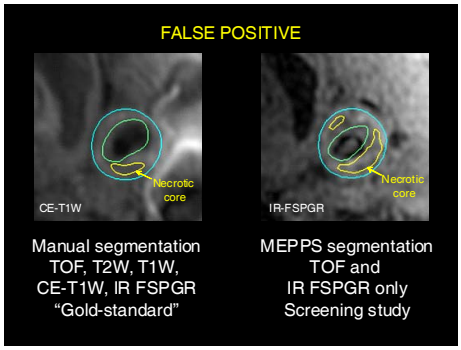
Target audience: Researchers, radiologists, and clinicians imaging/treating patients with carotid atherosclerotic disease.

Purpose: To evaluate the sensitivity, specificity, positive and negative predictive values of the automated segmentation of time-of-flight MR angiography (TOF) and inversion recovery fast spoiled gradient echo (IR-FSPGR) by morphology enhanced probabilistic plaque segmentation (MEPPS) to identify carotid bifurcation plaques harboring moderate to large (>20% area) lipid rich necrotic core (>20%maxLRNC) compared with the manual peer-reviewed segmentation of 5 non-contrast and contrast-enhanced MR carotid plaque sequences.

Materials and Methods: Twenty-six consecutive patients (50% men) with ≥50% asymptomatic stenosis of at least one carotid artery as measured by screening duplex ultrasound were included. All subjects underwent a bilateral carotid MR imaging using a GE 3T scanner with a dedicated four-channel carotid coil. Multi-contrast carotid MRI protocol included 5 different weightings: 3D TOF, pre-contrast T1-weighted (T1W), T2-weighted (T2W), 3D IR-FSPGR and gadobenate dimeglumine contrast-enhanced T1-weighted (CE-T1W) sequences. Images were acquired in the axial plane and centered to include bilateral carotid bifurcations. All the images were obtained with a field of view of 14 to 16 cm, matrix size of 256x256, slice thickness of 1 to 2 mm. Two experienced radiologists interpreted each carotid image through a consensus opinion process using published criteria previously validated by histology. The reviewers were blinded to subjects' clinical information and image review results of the contralateral carotid. An Image quality (IQ) score was rated per artery on a 4-point scale (1=poor, 4=excellent). Arteries with an average of IQ of <2, prior CEA or occluded arteries were excluded from image review. The extracranial carotid bifurcation level was used as a landmark for matching the five different weightings. For each artery, the presence of individual plaque characteristics: LRNC, fibrous cap rupture (FCR), intraplaque hemorrhage (IPH) and calcification (CA) were segmented manually by peer-review of the two experienced radiologists utilizing MRI-PlaqueView software for the analysis. By convention, LRNC can be non-hemorrhagic or contain IPH. Therefore the final area of LRNC per slice includes all regions of IPH and LRNC. During a second review, the manual segmentation results were removed and the carotid lumen and outer wall were outlined manually based on only the TOF and IR-FSPGR sequences. Automatic plaque segmentation using the MEPPS algorithm that had been previously developed from an initial 10 carotid plaque training dataset separate from this study group. The prevalence of carotid bifurcation plaques harboring >20% max%LRNC was compared between the manual segmentation of TOF, T2W, IR-FSPGR, T1W, CE-T1W and the MEPPS automated segmentation of TOF and IR-FSPGR after manual outlining of the carotid lumen and outer wall. The total volume of LRNC, IPH, CA, and wall as well as max%LRNC identified by MEPPS analysis of TOF and IR-FSPGR were compared with manual segmentation of all 5 carotid plaque sequences using paired T-test.

Results: Four (8%) of the total 52 arteries were excluded from image analysis due to poor quality (n=1), prior CEA (n=1) or occlusion (n=2). Accordingly, 48 arteries in 26 patients were included for the analysis. Sixteen arteries demonstrated >20% max%LRNC on both the gold-standard multi-contrast 3T MR carotid plaque images and the automated MEPPS analysis of TOF and IR-FSPGR. There were 6 false positive studies and no false negative studies. In the remaining 26 carotid arteries both techniques showed <20% max%LRNC. Based on the gold-standard multi-contrast 3T MR imaging, the sensitivity, specificity, positive predictive value, and negative predictive value from the automated MEPPS analysis of the 3D IR-FSPGR and TOF to detect >20% max%LRNC were 100%, 81%, 73%, and 100%. Outlining the lumen and outer wall based only on the TOF and IR-FSPGR lead to an overestimation of the wall volume compared with analysis including all 5 MR sequences (1162.2 mm^3 ± 305.2 vs.1116.2 mm^3 ± 296.2, p<0.01). MEPPS analysis demonstrated larger volume LRNC (74.1 mm^3 ± 79.0 vs 48.0 mm^3 ± 76.8, p<0.01), larger volume IPH (26.2 mm^3 ± 87.8 vs. 8.8 mm^3 ± 47.8, p<0.01), smaller volume CA (31.8 mm^3 ± 46.2 vs. 49.4 mm^3 ± 62.5, p<0.01), as well as larger max%LRNC (21.9% ± 14.5 vs. 15.2% ± 16.0, p<0.01).





Discussion: Patients harboring moderate/large LRNC have been proposed as the phenotype of atherosclerotic disease at increased risk to develop new stroke.[1] A recently proposed carotid atherosclerotic score noted that patients with >20%maxLRNC were at medium-high to high risk of demonstrating other complex carotid plaque features such as IPH or FCR.[2] This study demonstrates that one-third of patients under treatment of vascular surgeons for asymptomatic moderate carotid stenosis demonstrated this carotid plaque phenotype that might benefit from more aggressive lipid-lowering therapy. It would therefore be valuable to develop a rapid non-contrast carotid plaque protocol to screen for patients with >20%maxLRNC. This study demonstrates the potential of automated MEPPS segmentation of TOF/IR-FSPGR to rapidly identify patients potentially harboring moderate/large LRNC as confirmed by multi-contrast carotid plaque protocol. Good performance of MEPPS using 3D MERGE in addition to TOF and IR-FSPGR has also been reported[3], but requires additional imaging time and is less suitable for screening.

Conclusions: Approximately one-third of patients under treatment by subspecialists for asymptomatic carotid stenosis demonstrate moderate/large LRNC that has been associated with future stroke. This study demonstrates the ability of the MEPPS segmentation of two non-contrast carotid plaque sequences to screen for >20%maxLRNC with 100% sensitivity and 73% specificity. This rapid automated analysis of TOF and IR-FSPGR can potentially help guide risk assessment and suggest a subgroup of patients with asymptomatic moderate carotid stenosis who might benefit from additional plaque imaging and more aggressive lipid-lowering medical therapy.

References: 1. *Stroke* 2006;37:818-23. 2. *AJNR* 2010;31:1068--75. 3. *JMRI* 2012;35:812-9