Is automatic analysis of multicontrast MRI ready for clinical studies on plaque tissue composition?

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TARGET AUDIENCE: Physicians, researchers and co-medical staffs addressing carotid atherosclerotic disease

PURPOSE: Although the utility of multi-contrast MRI for in vivo assessment of atherosclerotic plaque composition is well established, quantitative image interpretation can be time-consuming and requires systematic training on both MR plaque imaging and vascular pathology. As a viable solution, automated plaque segmentation algorithms such as Morphology-Enhanced Probabilistic Plaque Segmentation (MEPPS) have been proposed, which may be particularly helpful for large-scale and/or multicenter studies. However, application of automatic classifiers in prospective clinical studies has been scarce, and few data are available on the performance of automatic plaque segmentation in the real world. In this study, by using a prospective cohort study with baseline and follow-up imaging, we sought to compare automatic review using MEPPS and expert human review in analyzing plaque tissue composition.

METHODS: Patients: 59 asymptomatic patients (46 males; 64.9±7.7 years) with 16-79% carotid stenosis by ultrasound and lipid-rich/necrotic core (NC) by screening MRI were recruited under a multicenter cohort study to examine the natural history of NC.[1] **MRI imaging protocol:** Patients were scanned using 3-T imaging units and phased-array surface coils at baseline and six months later (mean interval: 6.9±1.0 months). A standardized multi-contrast MRI protocol was used for plaque characterization (three-dimensional time-of-flight, T1-weighted, and T2-weighted). The contrast–enhanced T1-weighted images were also acquired. All images were obtained with a field-of-view of 16 × 16 cm, matrix size of 256 × 256, and section thickness of 2 mm with no section gap (spatial resolution before zero-fill interpolation, 0.625 × 0.625 × 2 mm). Imaging coverage was 32 mm. **Image analysis/Manual review:** We utilized a custom-designed image analysis software (CASCADE; University of Washington).[2] Calcification (CA) and NC were measured on both time point scans based on established criteria for multiple-contrast MRI of carotid atherosclerosis by two expert reviewers who were blinded to time sequence and MEPPS review.[3] Volumes of CA and NC were calculated with areas outlined on all matched slices. CA and NC progression was calculated as annualized changes in common coverage of the two time points. **Automatic classifier:** The MEPPS algorithm automatically segments areas of CA, NC (including intraplaque hemorrhage) based on a probability model of morphological and MRI signal characteristics as described by Liu et al.[4] All cases were re-analyzed by the MEPPS algorithm using manually-defined lumen and outer wall boundaries. Volumes of CA and NC were calculated in the same manner as manual review. **Statistical analysis:** Pearson's correlation coefficient (R) and the intra-class correlation coefficient (ICC) (two-way random, absolute agreement) were used. Bias was assessed by a paired Wilcoxon test with $P<0.05$ considered a significant level of bias.

RESULTS: Assessing compositional volumes: The correlations between manual and MEPPS reviews were excellent for both CA and NC at baseline (Table 1), with similar results at follow-up scan. Notably, mean volumes of CA and NC as measured by MEPPS review were significantly smaller than those by manual review. **Assessing changes in compositional volumes:** The correlations between manual and MEPPS in detecting compositional changes were good for CA, and moderate for NC (Table 1 and Figure 1). Mean changes in compositional volumes between scans showed no significant difference between manual and MEPPS results.

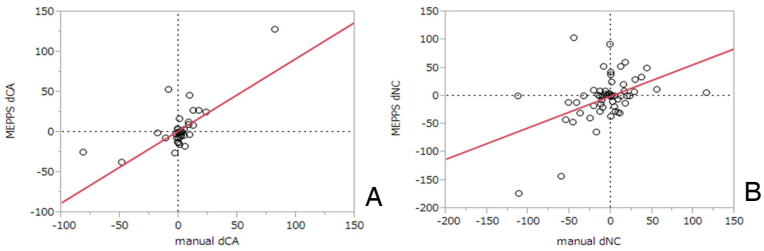

Figure 1. Correlation plots of change in volume between manual and MEPPS reviews. A: for Calcification (CA); B: for Lipid-rich/necrotic core (NC)

Table 1. Comparison of manual and MEPPS reviews

	Mean ± SD		*P****	R	ICC (95%CI)
	Manual	MEPPS			
Volume*					
CA (mm^3)	28.02 ± 53.40	20.85 ± 44.83	<0.01	0.97 ($P < 0.01$)	0.95 (0.89-0.97)
NC (mm^3)	62.89 ± 63.95	53.90 ± 76.99	0.03	0.84 ($P < 0.01$)	0.82 (0.72-0.89)
Change in volume**					
CA (mm^3)	0.63 ± 17.49	2.84 ± 21.81	0.95	0.72 ($P < 0.01$)	0.70 (0.55-0.81)
NC (mm^3)	-5.20 ± 34.28	-2.74 ± 42.43	0.83	0.45 ($P < 0.01$)	0.45 (0.22-0.63)

*At baseline; **Annualized; ***A paired Wilcoxon test

DISCUSSION: This represents one of the first head-to-head comparisons of the MEPPS algorithm against manual review in analyzing multi-contrast MRI for plaque tissue composition in the setting of clinical cohort studies. The correlation of MEPPS review with human review was excellent at each time point, which is consistent with previous reports and supports the use of automatic plaque analysis in cross-sectional studies.[2] The performance of MEPPS relies on training images which are from patients with end-stage plaques and apparently different from the asymptomatic subjects in this study. It remains to be studied whether the lower component volumes measured by MEPPS are due to training or other issues such as misregistration between contrast weightings. There was also a moderate correlation between MEPPS and human review in detecting compositional changes. The weaker correlation in detecting compositional changes may reflect the different approaches utilized by MEPPS and human review of serial images: while human readers review images of multiple time points side-by-side for differences, MEPPS currently handles multiple time point scans separately. However, it is beyond the scope of this study to determine which approach is better and there may be a trade-off between sensitivity and noise. Another reason underlying the weaker correlation in detecting compositional changes may have been the short time interval between scans in this study. Compositional changes were generally small, which may have affected the agreement between MEPPS and human review.

CONCLUSION: Applying MEPPS to a real world cohort study for automatic plaque segmentation showed excellent correlation between MEPPS and expert human review in obtaining cross-sectional data on plaque tissue composition, yet only moderate to good correlation in analyzing compositional changes. Automatic plaque segmentation using algorithms such as MEPPS may be helpful for large-scale multicenter studies to reduce image analysis time and avoid bias between readers of various levels of experience, particularly for cross-sectional designs.

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