In vivo Carotid Plaque Tissue Segmentation using Probability Distribution Function and Coupled Active Contours

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Introduction:

MRI is a promising tool for analysis of plaque vulnerability, through quantitative assessment of carotid plaque composition [1]. Although manual segmentation methods based on multi-contrast weighted MR images accurately assess plaque composition, automatic segmentation methods are more efficient and provide more reproducible results.

Purpose:

We propose an efficient, consistent, and flexible framework for automatic plaque composition segmentation in vivo based on multi-contrast weighted MR images, that segments 3 types of tissue – calcification, necrotic core and loose matrix.

Methods:

Twelve patients scheduled for carotid endarterectomy (CEA) were imaged on a 1.5T MR scanner to obtain images with T1 (TR=800, TE=11), T2 (TR=3150, TE=66), PD (TR=2770, TE=9.3), TOF (TR=23, TE=2.8) and contrast-enhanced (CE) T1 (TR=800, TE=11) weightings. These images were registered, and the lumen and outer wall contours were drawn manually before applying our algorithm.

The first step is to establish baseline intensity. The vessel region is compensated by a coil correction algorithm and normalized to a consistent intensity range. Then, using an active region algorithm [2] each MR image is pre-segmented into bright, medium and dark intensity regions. We use the medium intensity as the baseline, which is subtracted to produce a normalized image. Next, a probability map for calcification, necrotic core and loose matrix tissue is generated based on a tissue probability density function (PDF). The PDF is estimated using a Gaussian kernel function with the Parzen window method on pixels of each tissue extracted from histologically confirmed regions in a training set.

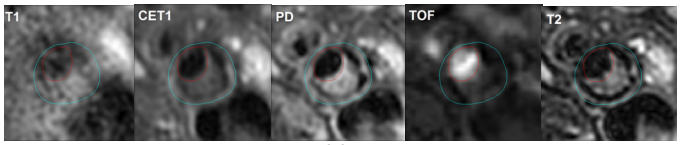
Based on the probability map for each tissue, the active region method is again used to seek each tissue with one active contour. Each contour moves under a smoothness constraint to maximize the total probability for the corresponding tissue within it.

An adaptive online training method is adopted to further refine the PDF and allow the segmentation results to be tailored to specific data sets. The PDF is automatically adjusted based on manual input of missed or improperly included regions.

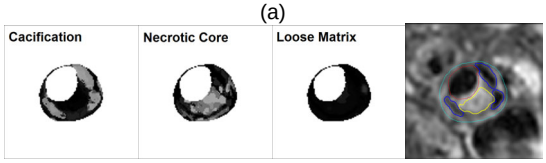
For validation, surgical specimens from CEA were sectioned and stained and measurements of plaque composition were extracted from MRI-matched sections, as in [3].

Results:

Typical examples of the relevant steps are illustrated in Fig. 1. Results comparing MR and histological segmentation are presented in Table 1. The first row shows the correlation of the total area for each tissue using PDF based automatic MR segmentation and the second for manual MR segmentation.



(a)



(b)

Fig1. (a) MR images (b) probability map and final segmentation (1 necrotic core and 3 calcifications are displayed in a PD image)

Table 1. Correlation between MR and histology segmentation

	Calcification	Necrotic Core	Loose Matrix
Automatic	R=0.954	R=0.696	R=0.729
Manual	R=0.922	R=0.524	R=0.632

Conclusion:

These results demonstrate that reliable, automated, in vivo segmentation of carotid plaque components is possible and quantitatively comparable to manual results. This technique could thus be used to reduce manual labor and bias in the assessment of plaque vulnerability or the time course of plaque evolution. The success of the technique is likely due to the pre-segmentation providing consistent intensity normalization across individuals and the probability map being generated without any assumptions on the pattern of tissue intensity distribution. Although not validated, the online training method provides a flexible way for radiology experts to incorporate further experience in the analysis of multi-contrast weighted MR plaque images.

References

1. Yuan C et. al. *JMRI* 2004; 19:710-719.
2. Paragios N et. al. *ECCV* 2000; 224-240.
3. Saam T et. al. *JCMR* 2004.