# In vivo Automated Quantification of Fibrous Tissue Content in Atherosclerosis Plaque MRI with T2-Mapping and Contrast Enhanced (TMCE) Technique

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## Introduction

Atherosclerosis plaque rupture is highly correlated with thromboembolic complications [1, 2]. The presence and distribution of fibrous tissues, based on its physical appearance and location within the plaque, has long been identified as an indicative marker of the stability of the atherosclerosis plaque [3]. However, *in vivo* identification and quantification of fibrous tissue content in atherosclerosis plaque are envisaged as either controversial or complicated. To simplify the complicated methods, an automatic technique based on T2 Mapping and Contrast Enhanced (TMCE) MRI is developed. This technique will take the advantage of low T2 value and high contrast enhancement properties [4] of fibrous tissue, generating, based on in vivo MR atherosclerotic plaque images, highly reliable and reproducible fibrous tissue maps in an automated fashion.

## Materials and Methods

Patient preparation Thirteen locations were selected from three subjects that were scheduled for carotid endarterectomy and had underwent multi-contrast weighting MR scans. All subjects were recruited after informed consent was obtained. Consent forms and MRI protocols were approved by the institutional review board.

MRI protocol High resolution MR images were obtained using phased-array carotid coil on a 1.5T MR scanner (GE Signa). The imaging sequence and parameters were: dual-echo PD/T2 weighted fast spin echo (FSE) sequence TR/TE1/TE2= 3RR/18/67ms, ETL = 8, slice thickness = 2 mm, FOV = 16cm*16cm, matrix size: 256*256; pre-/post- contrast weighted DIR-T1W FSE sequences: TR/TE/TI= 800/10/320ms, other parameters are the same with dual-echo sequence. The post-CE images were obtained approximately 10 minutes after injection of a gadolinium-based contrast agent (OmniScan, 20 mL).

Generation of fibrous map Based on the PD/T2 weighted images, the T2 map was calculated as previous described [5]. The contrast enhanced (CE) map was generated by subtracting pre-contrast T1 image from post-contrast T1 image, on a pixel-by-pixel fashion. After normalization, fibrous map was generated by subtracting CE map from T2 map (TMCE). The content of fibrous tissue was then automatically identified by comparing with a threshold value.

Histological specimens The atherosclerotic carotid plaques were excised, fixed, sectioned and stained as previously described [2]. Registration between histology and MRI series were also conducted, with common carotid bifurcation used as a marker [2].

Manual contours on MR images Manual contours were based on agreement between an image reviewer and a peer reviewer, both of whom are blind to the histology data. This process is highly accurate and reproducible [6].

Statistical analysis After the fibrous maps were generated, identification of fibrous regions was confirmed by histology. However, due to the inevitable surgical loss in histology specimen (which are primarily fibrous tissue), it is biased to correlate the MRI fibrous contents with histology quantitatively. As an alternative, Pearson's correlation coefficient was used to estimate the agreement between TMCE technique with the manual segmentation.

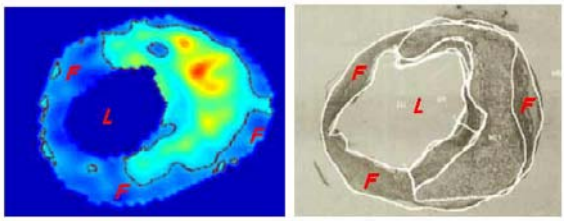


Fig. 1 Comparison of fibrous tissue identification result between TMCE technique and histology data. *Left*: TMCE technique, *Right*: Histology result. Legend: ***F***-fibrous tissue, ***L***-lumen

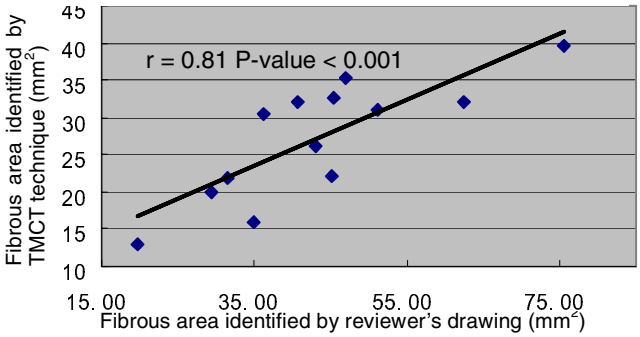


Fig. 2 Correlation between TMCE technique and Reviewer's contour (r=0.81, P-value < 0.001).

## Results

Comparison with histology As figure 1 shows, the left panel is the fibrous tissue identified by TMCE technique, which shows close agreement with the area identified from histology data from the right panel.

Correlation with manual segmentation data High correlation (r=0.81, P-value<0.001) was observed between the TMCE technique and data obtained from manual contours (Fig. 2).

## Conclusions

TMCE technique has been shown to have promising potential to be highly sensitive and reproducible and thus can be used to identify and quantify fibrous tissue contents *in vivo*. This technique will greatly expedite the computer-assisted tissue characterization process in carotid plaque MRI imaging.

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