Validation of Automatic Fibrous Cap Measurement with In Vivo MRI and FCPL Lesion Index Evalution

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Introduction

Atherosclerotic disease is one of the leading causes of death and major disability in the United States. Growing evidence has shown that plaque composition is the decisive factor determining plaque vulnerability. High resolution magnetic resonance imaging (MRI) has become a valuable non invasive imaging modality for assessing atherosclerotic components such as the lipid-rich, necrotic core (LR-NC) and fibrous cap (FC) status. Cai et al[1] using gadolinium-based contrast enhanced MRI showed that post contrast T1-weighted MR images can provide accurate quantitative measurements of the intact FC in advanced carotid atherosclerotic plaques in vivo. Based on this observation, an automatic FC detection method was developed. The goals of this study were: (i) validate this FC segmentation algorithm by comparing measurements in histology data. (ii) design and explore a new lesion index, fibrous cap projected length (FCPL), which we propose will capture the contribution of the LR-NC to the risk of plaque rupture better than measurements of LR-NC size.

Methods

Eighteen patients scheduled for carotid endarterectomy were scanned on a 1.5T GE Signa MR Scanner one week prior to their surgery. The imaging parameters were (TR/TE, ms): T1W(800/10), T2W(2400/20), PDW (2400/40) and TOF (23/3.8), FOV=13x13cm, matrix=256x256. Scan coverage was 24mm with 2mm slice thickness. Post contrast T1W images were captured 6-10 minutes after injection of a gadolinium-based contrast, 0.1mmo/kg body weight.

The MRI images were reviewed by radiologists with CASCADE [2], blinded from histology. Lumen, wall and plaque compositions, such as LR-NC, calcification and loose matrix were identified with contours. In this study, FC is defined as the area between lumen and LR-NC. An automatic FC segmentation method was implemented by using a level set based active contour algorithm [3] to search curves that outline all LR-NC regions. The regions between the found curves and lumen were labeled as FC. For validating the performance of MRI based FC segmentation method, subject's histological sections with intact FC and underlying LR-NC were selected and analyzed by a histological reviewer. Fig. 1 illustrates the method at one matched location. For quantification, we use the FC's projected length (length along the lumen circumference) and compared MRI and histology.

Performance Validation

MRI and histology data was aligned by using carotid artery bifurcation as landmark. Quantitative measurement of luminal projection length was collected at matched locations on both MRI and histological slices. The agreement between MRI and histology measurements was assessed with Pearson correlation coefficient. As shown in Figure 2, it demonstrated a very good correlation ($r = 0.77$, $P<0.001$).

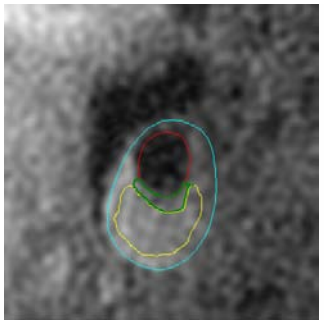

Fig 1. Analysis in MRI and histology. LR-NC (yellow) was outlined. FC (green) is the region between LR-NC and lumen.

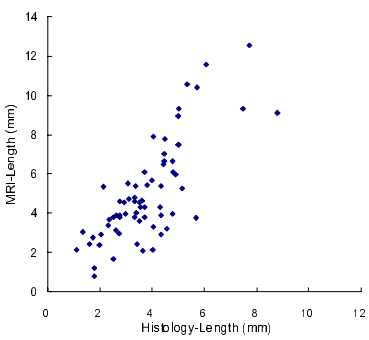

Fig 2. Correlation between MRI and histology measurements.

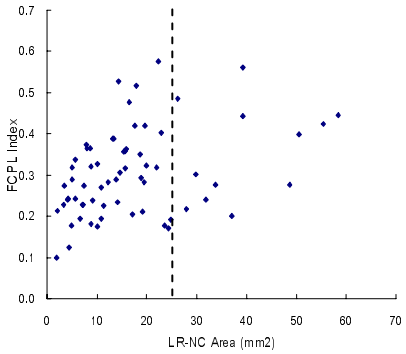

Fig 3. The relationship of LR-NC area and FCPL index.

Discussion: FCPL Index

Previous study has shown that increasing size and proximity to the lumen of the LR-NC [3] correlates to a higher incident of plaque rupture. However, if LR-NC's progression does not change its distance to lumen, then the size increase may be less critical. In other words, plaque rupture is more likely to happen when LR-NC is closer to lumen and/or surrounds the lumen to a greater extent. The proposed index FCPL captures this concept because the FCPL increases in both of these scenarios. The similarity and difference of FCPL compared to LR-NC size is illustrated in Fig. 3. It shows that some correlation exists between LR-NC size and FCPL. However, the remaining range of variation in FCPL suggests that the FCPL captures other factors affecting the impact of the LR-NC on the lumen surface. The FCPL index was also compared with the patient's symptom status in the above data set. Interestingly, 75% of patients showed symptoms when the maximum FCPL was over 33%; and only one third of the patients displayed symptoms when the FCPL was below 33%. This may indicate some predictive power of FCPL index. More patients' data should be analyzed to explore this relationship.

Summary

This study proposes an MRI based automated FC measurement method. Its performance is validated by the strong correlation between FC measurements in both MRI and histology. Based on this method, a new index, FCPL, is proposed to represent LR-NC's contribution to the risk of plaque rupture. Preliminary results show that it may be a more reliable indicator of plaque rupture than LR-NC size. It can potentially be very significant to carotid artery disease evaluation and patient's symptom prediction.

Reference:

1. Cai et al. Circulation 2005; 112: 3437–3444.
2. Malladi R. et. al., IEEE TPAMI, 1995; 17(2):158-175.
3. Xu et al, ISMRM 2004; 1195.
4. Takaya, et al, Stroke. 2006; 37: 818–823.