MR Imaging of Adventitial Vasa Vasorum in Carotid Atherosclerotic Plaque

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Introduction

The adventitia is the outer layer of the artery wall, which plays a significant role in the atherosclerotic process. Neovessels arise from the adventitial vasa vasorum and serve as a portal of entry for inflammatory cells into the plaque [1]. Furthermore, inflammation of the adventitia itself has been observed surrounding the vasa vasorum in ruptured plaques [2]. Neovasculature and inflammation within the plaque has previously been shown to alter contrast agent kinetics in dynamic contrast-enhanced (DCE) MRI of carotid atherosclerosis [3,4]. This study sought to determine whether the same DCE-MRI techniques applied only to the adventitia of the carotid artery have potential for detecting inflamed, rupture-prone plaques. The rationale for targeting the adventitia alone is that it is a consistent, well-defined structure that lends itself to robust and reproducible identification. Thus, a sub-aim of this study was to develop and evaluate a rigorous procedure for measuring adventitial contrast agent kinetics.

Methods

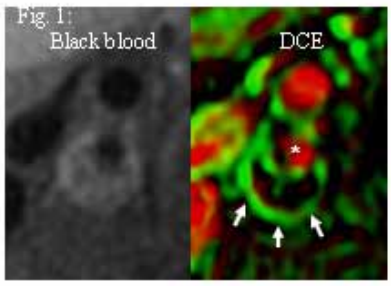
Twenty asymptomatic subjects with >50% carotid stenosis were recruited with informed consent to participate in a dynamic contrast-enhanced (DCE) MRI study. Images from 6 contiguous axial locations were obtained at 15 second intervals on a 1.5T MR scanner (GE Signa) using an SPGR protocol (TR=100, TE=3.4 , flip=60, FOV=16x12, matrix=256x144, thickness =3mm). A bolus of 0.1mmol/kg of contrast agent (Omniscan) was injected coincident with the second of 12 time frames. To analyze the images, a region of interest around each carotid artery was first registered [5] and then pixels representing the arterial input function (AIF) were extracted using a clustering algorithm. The AIF was used to perform kinetic modeling to determine the partial plasma volume (v_p) and transfer constant (K^{trans}) of the agent into the extravascular extracellular space of each pixel. These results were then displayed in a colorized parametric image with v_p in red and K^{trans} in green. Finally, lumen and outer wall boundaries drawn on a corresponding black-blood image (which has better boundary delineation) were mapped to the parametric image and the average K^{trans} along the outer boundary was computed. These measurements were repeated by two reviewers to assess inter-rater agreement and compared to serum levels of C-reactive protein (hsCRP), an indicator of inflammation. Agreement was assessed by computing the intraclass correlation coefficient. The association with hsCRP was assessed by computing Pearson's correlation coefficient for K^{trans} versus log hsCRP (because CRP is approximately log normal).

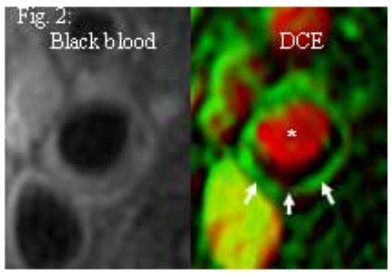
Results

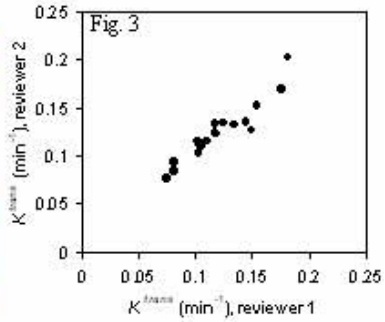
Interpretable results were obtained in 19/20 subjects. In the remaining subject, substantial patient motion caused the registration algorithm to fail. The time required by either reviewer to measure adventitial K^{trans} averaged less than 1 minute per location, including interactive placement of the vessel wall boundaries on the corresponding black-blood image and all automated processing steps. The parametric images provided a clear indication of the plaque, with the lumen appearing red (asterisks in Figs. 1,2) and the adventita appearing as a bright green rim of high K^{trans} (arrows). Independent measurements by two reviewers were highly consistent (Fig. 3) with an intra-class correlation of 0.94. Finally, the measurements were significantly correlated (R = 0.57; p=0.01) with log hsCRP (Fig. 4).

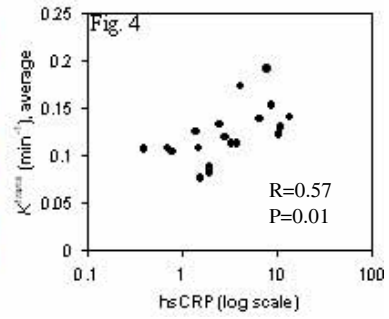
Conclusions

This study provides further evidence that DCE-MRI combined with kinetic modeling of contrast agent uptake gives insight into the inflammatory state of carotid atherosclerotic plaque. Adventitial K^{trans} was found to be positively correlated with CRP, a serum marker of inflammation and independent risk factor for cardiovascular events. Limiting the analysis to the adventitia helped to establish the technique as a highly automated, rapid and reproducible procedure. Furthermore, display of the kinetic parameters as a colorized image allowed them to be integrated with standard images as an additional "contrast weighting" for review.









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