Localized Measurement of Atherosclerotic Plaque Inflammatory Burden with Dynamic Contrast-Enhanced MRI

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Introduction:

Inflammation is important in both the pathogenesis and outcome of atherosclerosis [1]. Recently, dynamic contrast-enhanced (DCE-MRI) has been shown to be sensitive to inflammatory content within plaque [2]. Similar to ^{18}F-Fluorodeoxyglucose Positron Emission Tomography (FDG-PET), which shows increased glucose metabolism associated with macrophages [3], DCE-MRI is thought to highlight the increased vascular supply and permeability that supports macrophage metabolism. Unlike PET, however, DCE-MRI provides relatively high spatial resolution, which may allow DCE-MRI to generate measurements of inflammatory burden localized to key regions within the plaque. In this study, we sought to demonstrate the ability of DCE-MRI to provide localized measurements by comparing the transfer constant (K^{trans}) of contrast agent uptake across plaque regions with different composition. We hypothesized that different plaque components would be associated with different values of K^{trans}, reflecting the varying vascularities and permeabilities of each region.

Methods and Materials

Population Forty patients (age range: 30-90 years, mean age: 65.3 years) with carotid atherosclerosis of >50% stenosis were evaluated using DCE-MRI.

MR Imaging All images were acquired on a 3T scanner (Signa, GE Healthcare). The exam included application of a gadolinium based contrast agent (Omniscan, GE Healthcare, Milwaukee, USA) at a dose of 0.1mmol/kg. Coincident with injections, sequences of 2D spoiled gradient recalled echo (SPGR) images were obtained with TR=100ms, TE=6.2ms, thickness=2mm, and FOV=14cm, with interleaving. Data were acquired at six locations, centered on the carotid bifurcation, and at 12 time points separated by a repetition interval of 19s. Other contrast weightings acquired with a standard protocol [4] included time-of-flight (TOF), T1, contrast-enhanced T1 (CET1), T2 and proton density (PD).

Image analysis For each acquired DCE-MRI slice, the corresponding TOF, T1, CET1, T2 and PD weighted slices were reviewed using CASCADE analysis software [5] to identify the lumen and outer wall boundaries of the carotid artery and necrotic core (NC), calcification (CA), hemorrhage (Hem), and loose matrix (LM) regions within the plaque. Regions within the wall not classified were considered to be fibrous tissue (FIB). Each DCE-MRI slice was then automatically processed to produce a vasa vasorum (V-V) image [6] that shows the fractional plasma volume (V_p) and K^{trans} as a color-coded parametric image (Fig. 1). Next, the boundaries of lumen, outer wall and plaque components were mapped to the V-V image by an automatic registration algorithm [6]. The average K^{trans} values within each component were then reported.

Data analysis For each cross sectional location, average K^{trans} of each component was recorded. Then the mean values and confidence intervals of K^{trans} for each component were compared. The Mann-Whitney U test (nonparametric test) was used to compare the significance of differences between components, with P-values below 0.05 considered significant.

Results

Nine subjects were excluded, either because the standard image weightings were uninterpretable or because the V-V image algorithm failed. In the remaining 31 arteries, the mean K^{trans} values for each component are illustrated in Fig. 2. The statistical comparison between any two of the components is summarized in Table 1. The K^{trans} values for any pair of components were significantly different.

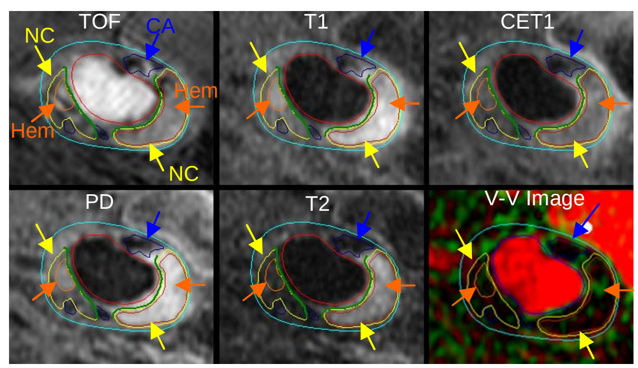

Fig. 1. TOF, T1, CET1, PD, T2 weighted MR images and Vasa Vasorum Image with contours of plaque components (arrows).

Conclusion

The results of this analysis indicate that DCE-MRI is able to detect differences in K^{trans} within plaque regions with different composition. LM is a loosely organized region of fibrous tissue with high water content and permeability that leads to the highest measured K^{trans}. In contrast, NC, Hem, and CA are poorly perfused regions with substantially lowered values of K^{trans}. These results suggest that K^{trans} could be helpful in determining plaque composition. More significantly, localized K^{trans} measurements could also be used to assess inflammatory burden in specific regions, such as the plaque shoulders, where inflammation is most likely to lead to plaque disruption.

Table 1. Statistical comparison (Mann-Whitney U test) of K^{trans} between any two of the plaque components (P-Value).

P-Value	NC	Hem	LM	CA	FIB
NC	1.000	*<0.001*	*<0.001*	*0.006*	*<0.001*
Hem	*<0.001*	1.000	*<0.001*	*0.045*	*<0.001*
LM	*<0.001*	*<0.001*	1.000	*<0.001*	*<0.001*
CA	*0.006*	*0.045*	*<0.001*	1.000	*<0.001*
FIB	*<0.001*	*<0.001*	*<0.001*	*<0.001*	1.000

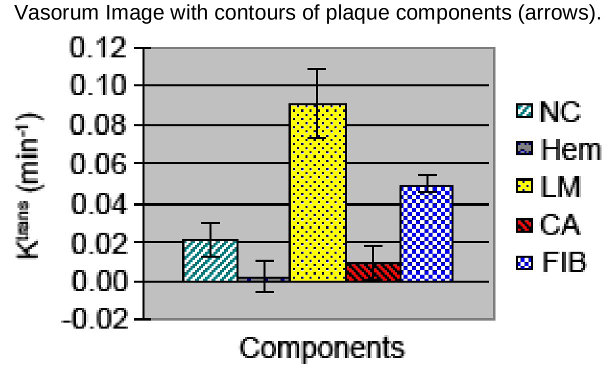

Fig. 2. Comparison of mean K^{trans} (columns) and its confidence interval (bars) across different components.

Reference:

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