In-vivo MRSI detection of Lipid in Carotid Atherosclerotic Plaque

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Introduction

Typical features of vulnerable plaque include a large lipid core subscribed by a thin collagen cap. Proton spectroscopic imaging has previously shown great potential for the identification of lipid content [1], but to date only ex-vivo results have been presented. Cholesterol can be distinguished spectroscopically from triglyceride fat by comparing the ratio of methyl ($-CH_3$) to methylene ($-CH_2-$). In this investigation, a newly introduced spectroscopic imaging technique, Linear Response Equilibrium (LRE) [2] is applied to measure the fatty acid and cholesterol content in-vivo. The technique is demonstrated on five healthy volunteers and three patients with advanced carotid atherosclerosis (>50% stenosis documented by clinical MRI or ultrasound examination).

Methods

All imaging was carried out on a Philips 1.5T Intera system (Philips Medical Systems, Best, The Netherlands).The body coil was used for signal transmission and a 10 cm surface coil for reception. The receive coil was placed on the neck overlying the region of the bifurcation of the common carotid artery.

Anatomical images were obtained with a fat-saturated multi-slice, multi-echo spin-echo sequence, with TR=757ms, TE=25ms, FOV=140x140mm^2 with continuous slices of 4 mm thickness, a 256x256 matrix, reconstructed to a 512x512 matrix, flip angle α=90° and echo train length 8. Scan duration was 4:54min including 6 averages.

A LRE sequence was used to acquire the SI data. Using fully refocused gradients this sequence has the unique ability to resolve only part of the spectrum with high resolution. LRE excites a frequency interval into a steady-state and only a reduced spectral field-of-view needs to be read out. Thereby the temporal dimension can be sampled sparsely allowing the acquisition of a large spatial matrix. The sequence was set up to excite the resonances of methylene (1.28 ppm) and methyl (0.86 ppm). Caution was exercised that no resonances of relevant strength were within the aliasing bands shifted by the frequency 1/TR relative to the main excitation band. The LRE scan acquired 25 spectral points and a spatial matrix of 96x96x15, FOV 100x100x30mm^3, TR=6.4ms and TE=3.2ms. The 25 peaks were each excited with a strength of 1.75°/TR and read out with a LRE reduction factor of 2 in 4:15min.

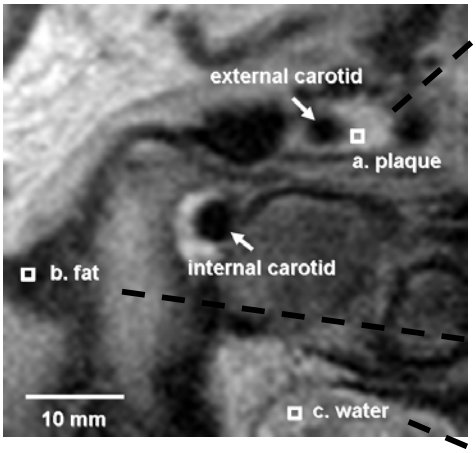

Fig. 1: Spin-echo images (TR=757ms, TE=25ms) above carotid artery bifurcation of a patient with severe stenosis of the right carotid artery. Boxes mark voxels of spectra in fig. 2.

Results

Figure 1 shows the spin-echo image of the neck of a patient with atherosclerosis of the right carotid artery. The spectra of the marked areas in Figure 1 are shown in Figure 2. The voxel placed in a highly stenotic region of the carotid artery exhibits a high methyl to methylene ratio characteristic of cholesterol (Fig. 2a). Figure 2b displays a spectrum from a voxel containing triglyceride fat. Figure 2c displays the spectrum of a voxel chosen to contain only tissue water.

Discussion

The differentiation between a highly stenosed but stable plaque and a vulnerable plaque containing a lipid core is important, since vulnerable plaques are more susceptible to rupture and lead to disease. Metabolites in the spectral regions of the aliasing sidebands may fold into the spectrum, distorting the spectra. However, this was not observed in any spectra. Despite sufficient SNR in the data, automatic processing of spectra is complicated by the low resolution and signals from macromolecules. Future work will be dedicated to display the spectral information in greyscale maps.

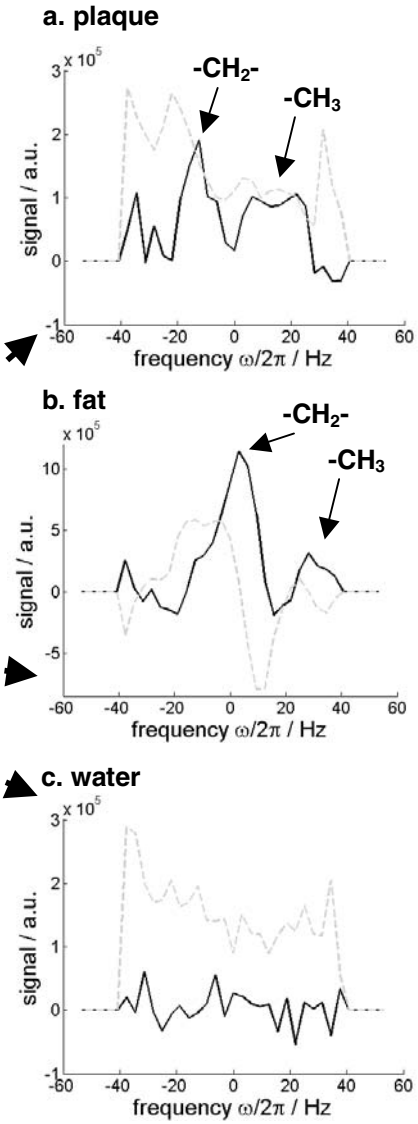

Fig. 2: Spectra of marked regions (voxel size *2.2mm^3*) from fig. 1 with the absorption spectrum (black solid line) and the dispersion signal (grey dotted line). Frequencies are relative to the excitation frequency. (a) shows a spectrum from a carotid plaque while (b) displays a typical triglyceride fat spectrum with a large methylene and small methyl resonance, (c) spectrum from a water voxel. The offset of the dispersion signal is an effect of the water from the voxel. Due to the short TE of 3.2ms the spectra can show contributions from macromolecules.

Conclusion

For the first time, in-vivo measurements of lipid content and composition of atherosclerotic plaques have been presented. This method may provide a potential means to assess the effects of cholesterol-lowering drugs on atherosclerotic plaque.

References

[1] CH Maynor, et al., Invest Radiol 1989;**24**(1):52-60. [2] KW Eberhardt, et al., JMR 2006; (in press)