Quantification of Myocardial Lipid using a Breath Hold Multiecho Technique at 3.0 Tesla

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Introduction

There is increasing interest in the role of myocardial lipotoxicity as a mechanism for cardiac dysfunction in obesity and diabetes. In an animal model over-accumulation of ectopic lipid within the myocardial cells of obese rats leads to apoptosis and subsequent impairment of systolic function which is reversed by antisteatotic therapy[1]. The pathogenesis of myocardial dysfunction in diabetics is poorly understood, however the development of cardiomyopathy in diabetic mice is associated with marked myocardial lipid accumulation[2]. Non-invasive measurement of myocardial lipid has been attempted using proton spectroscopy and is associated with increased left ventricular mass and reduced septal wall thickening[3]. However, cardio-respiratory gated proton spectroscopy presents a number of technical challenges for routine clinical use.

Purpose

Our aim was to develop a spatially-resolved breath hold sequence to quantify myocardial lipid content.

Method

We designed a multiecho cardiac-triggered gradient echo sequence on a Philips Intera 3.0 tesla MRI system using a 6-element phased array cardiac coil (Flip angle 15º, slice thickness 10mm, matrix 128 x 256, field of view 320mm, TR 11ms, TEs 1.15, 2.3, 3.45, 4.6 and 5.75ms). The echo times (TE) were chosen so that the signals from fat and water were either in-phase or out-of-phase with respect to each other yielding 5 images per breath hold. A dual inversion black blood prepulse was used to suppress flow artefacts. Phantom studies using a lipid emulsion were performed with electrocardiogram simulation to test the sensitivity of the technique to low fat fractions. In vivo imaging was performed in 5 normal volunteers and in 3 patients with hyperlipidaemia or diabetes. A 10mm mid-ventricular short axis slice at end diastole was acquired. Signal intensities were measured within regions of interest drawn over the myocardial septum and liver parenchyma using ImageJ software. A curve fitting model run on Matlab derived the fat fraction and global T2* decay at a fat/water precessional frequency difference of 3.45ppm.

Results

Phantom studies using concentrations of 10 and 20% lipid emulsified in water demonstrated an oscillating signal intensity with respect to the chosen in- and out-of-phase echo times. Proton spectroscopy was performed on the samples at 11.7T and the estimated fat fraction was in good agreement with the multiecho technique. No oscillation in signal was observed with samples of pure water. The clinical imaging protocol was well-tolerated and a complete cardiac study could be performed within an hour. In vivo studies demonstrated satisfactory image quality for TEs of up to 5.75ms and breath holds did not exceed 20 seconds. Flow artefacts were adequately suppressed by the black blood prepulse and only minor susceptibility artefact was apparent adjacent to the left ventricle posterior wall. Preliminary in vivo imaging amongst diabetic and hyperlipidaemic patients demonstrated an oscillating signal decay in myocardial tissue corresponding to fat fractions of up to 5% (figure 1). Liver parenchyma typically contained greater levels of lipid with fat fractions of up to 21%. Normal volunteers demonstrated no significant fat within the myocardium.

Discussion

The use of a multiecho technique allows for accurate registration of clinical images which is especially important for quantitative cardiac MR. This sequence design also controls for global or noise-adaptive image scaling that may compromise single echo sequences. Imaging at 3.0 tesla has an advantage for opposed-phase imaging as it yields twice the number of data points for a given range of TEs compared to 1.5 tesla and offers a higher signal-to-noise ratio. Measuring fat fractions within the myocardium may be of use in screening individuals at risk of developing diabetic cardiomyopathy and in monitoring response to treatment. Further work needs to be performed to validate the technique with myocardial or liver biopsy specimens. The short acquisition time means that this sequence can be readily incorporated into a complete cardiac MR examination in order to assess any associated impairment of systolic and diastolic function. A related sequence has been used to assess myocardial iron concentration by measuring T2* at 1.5 tesla[4]. Our technique therefore offers a method of measuring both fat and iron content within tissues.

Conclusion

Our preliminary phantom and patient data shows - as a proof of concept - that breath hold in-phase and opposed-phased imaging is a promising technique for assessing myocardial fat content. Further work is required to validate the technique and explore its clinical value.

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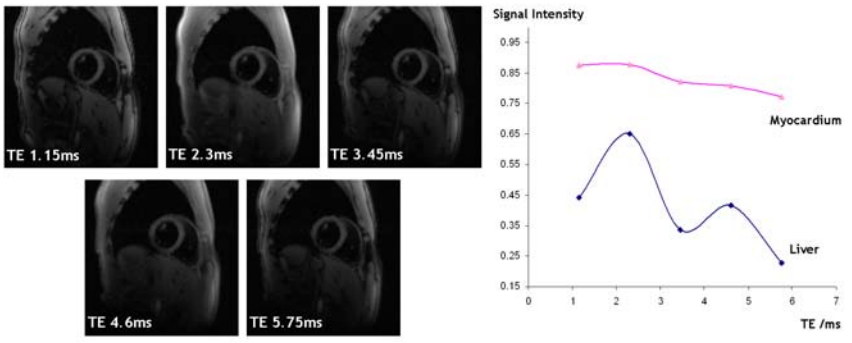

Figure 1 – Triggered gradient echo images of the left ventricle short axis using in and out-of-phase echo times in a non-obese hyperlipidaemic patient. Regions of interest are placed over the myocardial septum and liver parenchyma. The amplitude of the signal oscillation reflects the fat fraction (myocardium 4%, liver 21%).

References

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